PROCEEDINGS

Looking Back, Moving Forward:
Advances in Conservation

Terra 2022: Proceedings of the 13th World Congress on Earthen Architectural Heritage, Santa Fe, New Mexico, USA, June 7–10, 2022

Edited by Leslie Rainer,
Luis Fernando Guerrero Baca,
Frank Matero, and Lauren Meyer



Getty Conservation Institute

Terra 2022

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Actas del XIII Congreso Mundial del Patrimonio Arquitectónico de Tierra, Santa Fe, Nuevo México, EE.UU., del 7 al 10 de junio de 2022

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Una mirada al pasado para seguir adelante: Avances en conservación

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Getty Conservation Institute
Los Angeles

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Timothy P. Whalen, *John E. and Louise Bryson Director*

The Getty Conservation Institute (GCI) works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, field projects, and the dissemination of information. In all its endeavors, the GCI creates and delivers knowledge that contributes to the conservation of the world's cultural heritage.

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Front cover: The remains of the eighteenth-century Misión La Nuestra Señora de los Ángeles de Porciúncula at Pecos National Historical Park, New Mexico, USA. The adobe church is built on the site of an earlier Spanish colonial period church that was destroyed during the Pueblo Revolt of 1680 and sits within a large Ancestral Pueblo village that was occupied from the early 1300s to 1838. The Pueblo of Jemez and the modern town of Pecos have active cultural connections to the site and share an enduring bond through oral history, traditions, and ceremonies. Photo: Eric Vondy.

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Foreword

It is my great pleasure to present the proceedings of Terra 2022, the 13th World Congress on Earthen Architectural Heritage, on behalf of the Getty Conservation Institute (GCI) and our partners, the Vanishing Treasures Program of the US National Park Service (NPS) and the University of Pennsylvania Stuart Weitzman School of Design. These proceedings represent our joint efforts and the excellent work of all contributors to this volume, who collectively present a wide range of topics, diverse voices, and different perspectives on the care and conservation of earthen architectural heritage.

Terra 2022 marked several significant events that were celebrated at the conference. It was the fiftieth anniversary of convening specialists in the field of earthen architecture under the aegis of the International Council on Monuments and Sites (ICOMOS), the first experts' meeting having been held in Yazd, Iran, in 1972. It was also the first time in just over thirty years, since Adobe 90, that the conference was held in the southwestern US. Perhaps just as importantly, it marked the first time after two years of COVID-19 that many of us were able to come together to exchange information, present new research, and strengthen networks to advance the field of earthen architectural conservation. In addition, Terra 2022 was the first hybrid Terra congress, which allowed more participation by those who could not attend in person. It was also the first time that workshops were organized as a lead-up to the congress, allowing attendees to participate in hands-on exercises and gain knowledge on the properties of earth as a material, earthen construction techniques, and conservation practice.

Terra 2022 brought together over 350 professionals and practitioners from fifty-two countries in person and remotely. Thirteen participants from the Middle East and Africa were provided funding from ICCROM's Architectural and Archaeological Tangible Heritage in the Arab Region program (ICCROM-ATHAR), and forty-three participants from the southwestern US and northern Mexico tribes and pueblos were able to attend thanks to generous grants from the Chamiza and Getty Foundations. The attendance of these participants enriched the program and the activities of Terra 2022, added diversity to both speakers and participants, and expanded the conversation about the care and conservation of earthen architectural heritage with a wider range of viewpoints, experience, and expertise.

The decision to hold Terra 2022 in Santa Fe, New Mexico, was influenced by the region's rich earthen heritage, including significant archaeological sites, historical buildings, urban areas, cultural landscapes, and the rich living cultures of New Mexico in the Native American, Hispanic, and Anglo contexts. These factors and facets made it the perfect place to convene this international group of professionals and practitioners to present regional projects and to share the experiences of colleagues working on earthen heritage around the world with local participants. Themes addressed at the conference included care by and for communities; advances in research; conservation of archaeological sites, decorated surfaces, historic and modern buildings, and cultural landscapes and routes; the history of conservation; risk and vulnerability; and conservation education.

A natural focus of Terra 2022 was the section titled "Care by and for Communities," a topic specific to the region but one that also resonated with colleagues around the world who are woking with earthen sites where community is closely engaged in their care. The diversity of speakers

brought out a wide range of perspectives not only on the material conservation of earthen architectural heritage but also on the earth as a living culture and the social and cultural values associated with it.

Terra 2022 brought together a diverse community of professional colleagues, strengthening established networks and creating new collaborations sparked by conversations and thoughtful exchanges of information before, during, and after the conference. It is our hope that these proceedings will be a lasting legacy of the knowledge and experiences exchanged at the event and will benefit professionals and organizations responsible for the conservation of the world's earthen cultural heritage.

The GCI has been engaged in the conservation of earthen architectural heritage since its earliest days, working with a great number of partners on field projects in China, Morocco, Israel, Benin, Mexico, El Salvador, Peru, and the southwestern US; carrying out training on these sites and through courses in the Middle East, Latin America, and the US to build capacity for those practicing in this area of conservation; conducting scientific research on materials and methods for conserving this heritage using appropriate materials and technologies; convening colloquia, including the Decorated Surfaces on Earthen Architecture Colloquium (DSEAC) and congresses like Terra 2022 and Adobe 90 in the US and Terra 2008 in Mali; and widely disseminating project and research results, guidelines, and proceedings from conferences.

The GCI is privileged and honored to have organized this conference with our partners under the aegis of ICOMOS's International Scientific Committee on Earthen Architectural Heritage (ICOMOS-ISCEAH). We are grateful for the support from local organizations and individuals, including Cornerstones Community Partnerships, the New Mexico History Museum, the New Mexico Department of Cultural Affairs, the Center for New Mexico Archaeology, TOURISM Santa Fe, the University of New Mexico School of Architecture and Planning, our colleagues Michael Taylor and Brian Vallo, and many others who formed the local organizing and outreach committees. I would like to acknowledge the steering committee, who contributed to the development of the conference program, themes, and content; and the scientific committee, who worked with the partners to review abstracts and papers. Thanks to their combined expertise and commitment, the conference offered a robust and varied program covering a wide range of topics.

I would also like to recognize the organizations that provided funding and support for scholarship recipients' attendance, including the Chamiza Foundation, Cornerstones Community Partnerships, the Getty Foundation, and ICCROM-ATHAR. Their generous contributions allowed professionals and practitioners from across the southwestern US, northern Mexico, the Middle East, and Africa to attend the conference, present their research, and engage in the growing network of professionals working in this specialized field of study.

Particular thanks go to the editors of these proceedings, Leslie Rainer, Luis Fernando Guerrero Baca, Frank Matero, and Lauren Meyer; translators Luis Villacorta Santamato, Elena Macchioni, and Cesar Bargues Ballester; project editor Laura diZerega; GCI publications manager Martin Coleman; and manuscript editor Katrina Posner for their outstanding work compiling this volume; and to Anna Duer and Cameron Trowbridge for their invaluable support on the bibliographic materials. Thanks also to Getty Publications and their excellent editing, design, and production teams, and to Elizabeth Levine for coordinating these proceedings.

With this volume we continue our commitment to the conservation of earthen architectural heritage worldwide. Through our own research and work, and that of our partners and colleagues, we hope to strengthen and encourage new collaboration and to expand the growing network of professionals and practitioners dedicated to preserving and caring for this vulnerable heritage as a legacy and living culture for future generations.

Timothy P. Whalen
John E. and Louise Bryson Director
Getty Conservation Institute

Prólogo

Es un placer para mí presentar las actas de Terra 2022, el XIII Congreso Mundial del Patrimonio Arquitectónico de Tierra, en nombre del Getty Conservation Institute (GCI) y nuestros socios, el Programa Tesoros que Desaparecen, del Servicio de Parques Nacionales de Estados Unidos (NPS), y la Escuela de Diseño Stuart Weitzman de la Universidad de Pensilvania. Estas actas representan nuestros esfuerzos conjuntos y el excelente trabajo de todos los colaboradores de este volumen que, de forma colectiva, presentan una amplia variedad de temas, opiniones diversas y perspectivas diferentes sobre el cuidado y la conservación del patrimonio arquitectónico de tierra.

Terra 2022 marcó una serie de eventos importantes que se celebraron en la conferencia. Fue el quincuagésimo aniversario de esta reunión de especialistas en el sector de la arquitectura de tierra, con el patrocinio del Consejo Internacional de Monumentos y Sitios (ICOMOS); la primera reunión de expertos tuvo lugar en Yazd, Irán, en 1972. También fue la primera vez en más de treinta años, desde Adobe 90, que la conferencia se llevó a cabo en el suroeste de Estados Unidos. Es igualmente importante destacar que es la primera vez, dos años después de la COVID-19, que muchos de nosotros pudimos reunirnos para intercambiar información, presentar nuevas investigaciones y fortalecer las redes para avanzar en el sector de la conservación de la arquitectura de tierra. Además, Terra 2022 fue el primer congreso Terra híbrido, lo que posibilitó una mayor participación de aquellos que no pudieron asistir en persona. Asimismo, fue la primera vez que los talleres se organizaron previamente al congreso, lo que permitió que los asistentes pudieran participar en actividades prácticas y adquirieran conocimiento sobre las propiedades de la tierra como material, las técnicas de construcción con tierra y las prácticas de conservación.

Terra 2022 reunió a más de 350 profesionales de cincuenta y dos países en persona y de forma remota. Trece participantes provenientes de Medio Oriente y África recibieron fondos del Patrimonio Arquitectónico y Arqueológico Tangible en la Región Árabe programa del ICCROM (ICCROM-ATHAR), así mismo, cuarenta y tres participantes provenientes de tribus y pueblos del suroeste de Estados Unidos y del norte de México pudieron asistir gracias a las generosas subvenciones que realizaron las fundaciones Chamiza y Getty. La asistencia de estos participantes enriqueció el programa y las actividades de Terra 2022, agregó diversidad tanto de ponentes como de participantes, y expandió la conversación respecto al cuidado y la conservación del patrimonio arquitectónico de tierra con una variedad mayor de puntos de vista, experiencias y especialidades.

La decisión de realizar Terra 2022 en Santa Fe, Nuevo México, se vio influenciada por el rico patrimonio de tierra de la región, incluidos los importantes sitios arqueológicos, las edificaciones históricas, las áreas urbanas, los paisajes culturales y la amplia cultura viva de Nuevo México en el contexto de las culturas hispana, anglosajona e indígena estadounidenses. Todos estos factores y facetas hicieron que éste fuera el lugar perfecto para convocar a este grupo internacional de profesionales y practicantes, para que presentaran proyectos regionales y compartieran experiencias de colegas que trabajan en patrimonio de tierra en el mundo con participantes locales. Los temas que se abordaron en la conferencia fueron el cuidado por y para las comunidades; los avances en la investigación; la conservación de sitios arqueológicos,

superficies decoradas, edificaciones históricas y modernas, y paisajes y rutas culturales; la historia de la conservación; los riesgos y la vulnerabilidad; y la educación en conservación.

El enfoque natural del Terra 2022 era "Cuidado por y para las Comunidades," un tema específico de la región pero, a la vez, uno que resonaba entre los colegas internacionales que trabajan en sitios de tierra en los que la comunidad está muy involucrada con su cuidado. La diversidad de ponentes generó una amplia variedad de perspectivas no solo respecto a la conservación de materiales del patrimonio arquitectónico de tierra, sino también a la tierra como cultura viva y los valores sociales y culturales asociados a ella.

Terra 2022 reunió a una comunidad diversa de colegas profesionales, fortaleciendo las redes establecidas y creando nuevas colaboraciones que nacieron de conversaciones e intercambios profundos de información antes, durante y después de la conferencia. Esperamos que estas actas sean un legado duradero del conocimiento y de las experiencias intercambiadas en el evento, y que beneficien a los profesionales y a las organizaciones responsables de la conservación del patrimonio cultural internacional de tierra.

El GCI ha participado en la conservación del patrimonio arquitectónico de tierra desde el principio y trabaja con un gran número de socios en proyectos del sector en China, Marruecos, Israel, Benín, México, El Salvador, Perú y el suroeste de Estados Unidos. Lleva adelante capacitaciones en esos sitios y dicta cursos en Medio Oriente, América Latina y Estados Unidos para desarrollar las capacidades de las personas que trabajan en las áreas de conservación e investigaciones científicas sobre los materiales y métodos para la conservación del patrimonio con materiales y tecnologías apropiados; organiza coloquios y congresos como Terra 2022 y Adobe 90 en Estados Unidos y Terra 2008 en Malí; además, divulga los resultados de proyectos e investigaciones, lineamientos y actas de las conferencias.

El GCI tiene el privilegio y el honor de organizar esta conferencia con nuestros socios con el patrocinio del Comité Científico Internacional del Patrimonio Arquitectónico de Tierra del ICOMOS (ICOMOS-ISCEAH). Estamos agradecidos por el apoyo de las organizaciones locales y las personas, entre ellas, Cornerstones Community Partnerships, el Museo de Historia de Nuevo México, el Departamento de Asuntos Culturales de Nuevo México, el Centro de Arqueología de Nuevo México, la Oficina de Turismo de Santa Fe, la Facultad de Arquitectura y Planificación de la Universidad de Nuevo México, nuestros colegas Michael Taylor y Brian Vallo, y muchos otros que son parte de los comités de organización y divulgación. Quiero expresar mi reconocimiento no sólo al comité directivo, que contribuyó al desarrollo del programa de la conferencia, los temas y el contenido, sino también al comité científico, que trabajó con los socios para revisar los resúmenes y proyectos. Gracias a la conjunción de experiencia y compromiso, la conferencia ofreció un programa sólido y variado con temas de todo tipo.

Además, quiero agradecer a las organizaciones que proveyeron fondos y apoyo para la asistencia de los beneficiarios de las becas: Chamiza Foundation, Cornerstones Community Partnerships, Getty Foundation e ICCROM-ATHAR. Sus generosas contribuciones permitieron a profesionales de todo el suroeste de Estados Unidos, el norte de México, el Medio Oriente y África asistir a la conferencia, presentar sus investigaciones y participar de esta red creciente de profesionales que trabajan en esta área especializada de estudio.

Un agradecimiento especial para los editores de estas actas, Leslie Rainer, Luis Fernando Guerrero Baca, Frank Matero y Lauren Meyer; los traductores Luis Villacorta Santamato, Elena Macchioni y Cesar Bargues Ballester; la editora Laura diZerega; el gerente de publicaciones de GCI Martin Coleman; y la editora del manuscrito Katrina Posner, por su excelente trabajo en la compilación de este volumen; y a Anna Duer y Cameron Trowbridge por su inestimable apoyo en el material bibliográfico. Un agradecimiento para Getty Publications y sus excelentes equipos de edición, diseño y producción, y a Elizabeth Levine por la coordinación de estas actas.

Con este volumen, continuamos con nuestro compromiso con la conservación del patrimonio arquitectónico de tierra a nivel mundial. A través de nuestra investigación y trabajo, y el de nuestros socios y colegas, esperamos fortalecer y fomentar nuevas colaboraciones, así como expandir la red creciente de profesionales y practicantes dedicados a la preservación y el cuidado de este patrimonio vulnerable como legado y cultura viva para las generaciones futuras.

Timothy P. Whalen
Director John E. y Louise Bryson
Getty Conservation Institute

Opening Remarks

Michael T. Reynolds, Deputy Director, External Affairs, National Park Service, Washington, DC, USA

Good morning.[1] *Buenos dias.* How is everyone today? I hope well. I bring a warm welcome from the 20,000 women and men of the National Park Service. We are honored and humbled to be working shoulder to shoulder with you in the conservation of our critical earthen cultural heritage. In particular, I would like to welcome our tribal partners, local community members, and those of you from around the world. The Secretary of the Interior and our first Native American cabinet secretary in the history of the United States, Deb Haaland, and the first director of the National Park Service from tribal lands, Charles "Chuck" Sams III, both regret that they cannot be here. Secretary Haaland, who is from Laguna Pueblo in New Mexico, and Director Sams send greetings and sincere appreciation for the work that you do and for the blended academic and traditional approaches to conservation that you all represent.

Speaking to many of you from around the world, and those of you who may not be familiar, there is a very large mosaic of public land managers in the United States—the National Park Service, the Bureau of Land Management, the US Forest Service, the US Fish and Wildlife Service—all with a stewardship mission. Within these government organizations, the National Park Service serves as a leader in resource management and heritage conservation, with a particular emphasis on caring for and interpreting for the public the vast array of cultural heritage across the nation. Of course, here in the American Southwest, this heritage is inclusive of earthen buildings in varying states of preservation, archaeological sites, cultural landscapes and their component features, engineering and industrial sites, museum collections, and other places and objects significant to traditionally associated Native American tribes, communities, and the public at large.

You are all stewards, whether you are a scientist, an architect, or an Indigenous traditional practitioner. One thing that has kept me around the National Park Service for a long time is the stewardship mission as stated in our Organic Act of 1916, which created the NPS. One of my favorite lines in that document is that our mission, under law, is to preserve, protect, leave things unimpaired for future generations, and provide for the enjoyment of the public. I mention this to you because it is something that I hope you are thinking about this week in addition to the technical and collaborative work that you need to do together. Remember to help all the citizens of the world enjoy, absorb, and understand what you do, what these places are, and their importance.

I think that our current selfie culture attracts many visitors to your places. I bet some of the things that you steward, the things that you care about, are kept rather secret as a part of preservation and conservation. But in this very troubled world right now, people are flocking to understand traditional culture. They are flocking to places that connect them to the earth. Visitation numbers are through the roof in many of our national parks. Some of that is just pure recreation but much of it, when I talk to the American people and visitors from around the world, is driven by a desire to better understand deeply traditional values and to make connections to people and places.

Many of these places, particularly in the southwestern part of the country—and here, where you sit, in Santa Fe—have a long tradition of building with earth, and many preserve the resources that demonstrate those traditions. To me, this says that the traditional practices, materials, and cultures represented by earthen heritage across the American landscape and globally, as well as the continuation and conservation

of these places, their building materials, and practices that are perceived to be undervalued, are, in fact, highly valued. They have advocates within communities, throughout American culture and government, and, I would add, throughout the world. These traditions go back millennia, especially in northern New Mexico. I hope that you have a chance to really experience and enjoy this rich and diverse place and to reach out to, and learn from, the people of the tribes and pueblos in the region who have deep ties to this place and are really the teachers for all of us.

We are all trying to make sure that these sites persist, adapt, and evolve. Those of us in the NPS are simply a blip in the stewarding of this heritage compared to Indigenous communities over time. We have been stewarding these places for about a century, and we have so much more to learn and so much to do. We are very proud of sites like Casa Grande, Chaco Canyon, Bandelier, and Mesa Verde. Under the leadership of Secretary Haaland and Director Sams, we are now reaching out and seriously discussing the idea of co-management with Indigenous and Native people and stewarding these places together.

One thing I wanted to say to you all today is that when I read your bios, I recognized that you are the kind of professionals, the kind of people that care, that can help bridge gaps. There is the technical side of your work, this deep knowledge that you bring. There is also the sharing of your work and passion with each other and with the next generation of practitioners and stewards. That is so inspirational. I hope that just being together will spark robust conversation, and I hope that you will find connectivity across and between the very complicated academic and technical work that you do and the traditional and Indigenous practices and perspectives.

I want to talk to you a little bit about the future. I am going to try not to be a downer, but I think we have some shared challenges in park and resource management. Climate change. We recently had some of the largest wildfires experienced in North America burning just a few miles from Santa Fe, threatening resources, people, homes, and lands. We are seeing crazy weather—intense and destructive desert rainstorms that have had devastating effects on earthen heritage. At the Casa Grande Ruins in southern Arizona, for example, we have a major project to figure out how to maintain a shelter that offers protection to the fragile archaeological site below. Is that the right thing to do? We are consulting with Native American tribes to better understand all site values and improve our stewardship of them in light of changing environmental conditions. We are also working every day to better predict impacts, use scientific approaches to determine site and material sensitivities, and adapt our management approaches. So, climate change is really on our minds and I hope very much on your agenda.

We are focused on being proactive and, by utilizing existing efforts like our Vanishing Treasures Program and the knowledge and experience of our expert partners, we are building our understanding of the existing challenges and working toward the protection of our most fragile resources. How can we better engage all of you toward addressing our common needs? A second area of focus, one that I find really interesting, is workforce. In some ways we are not attracting everyone we used to attract. It is getting harder to hire, harder to find people who retain traditional skill sets. We have historic preservation centers, but they are thin right now. Budgets are hurting. I think the more we do together and the more we focus on workforce and handing off to the next generation, the better. And we all have a stake here, in this education component. Like all of you, we are building programs that allow for mentoring and development opportunities for people interested in learning more about careers in the preservation trades. Additionally, ensuring engagement of Indigenous and culturally associated communities in the preservation of these places is vital, and we are working to expand and improve relationships with traditional communities, Indigenous people, and others.

We have a new Indian Youth Service Corps program within the NPS that is focused on preservation trades and is developing alongside the Ancestral Lands Conservation Corps at Acoma, Zuni, Hopi, and the Diné Nation. I am hopeful that funding for programs such as this one will increase, but we need people like you to support these types of efforts. We will have to turn to this community, your community, all of you. And I don't mean in only a contractual way, but in a heart and soul way. And that is another reason that we are shoulder to shoulder with you in this constant battle, if you will, for the preservation of these important resources.

I mentioned education and inspiration. I mentioned the skill sets that you have, but what I also really wanted to say was to remind you, if you don't already know, that you are heroes in the world. You may not feel it. You may meet somebody occasionally at a business conference or on an airplane and they really have no idea what you do, right? But know this: You are deeply needed in a troubled world right now. You are heroes to us. We turn to you for knowledge, but also for inspiration.

Folks like me—and I'm sure each of you knows someone just like me—we are decision-makers or political leaders. We are the people who have to decide where the money goes and which resources to prioritize. I turn to my team and they look to you. We may have never met, but our connection in the preservation and long-term stewardship of these places is a bond.

So, I want to remind you how inspiring you are to people like me, how inspiring you are to the world. And I don't think it was said earlier, but there is no better time for your work, for this idea of protecting, adapting, and evolving. I am so excited about the idea of traditional practices combining with modern science in order to really start achieving a new vision of stewardship. We need it in the world right now—between some of the things I just mentioned with climate change, changing demographics, and the loss of connection to the earth that people feel when they live in urban areas. We see this hunger and, even more, we see the need. I just want for you to relax this week, enjoy each other's company, have some of the best conversations you have ever had, and get super refreshed to go back and be the professionals and the heroes in the world that you are.

It is an honor to be with you. I want to give a special thanks and recognition to the folks from the Getty Conservation Institute and the University of Pennsylvania Stuart Weitzman School of Design who opened this conference, and a special acknowledgment to my colleague Lauren Meyer and her entire team, led by Amy Cole. Thank you again for everything that you have done to get us here.

Note

1 This text is a transcript of Michael T. Reynolds's remarks delivered on June 7, 2022, at the opening of Terra 2022: 13th World Congress on Earthen Architectural Heritage, Santa Fe, New Mexico.

Comentarios inaugurales

Michael T. Reynolds, Director adjunto de Asuntos Exteriores del Servicio de Parques Nacionales, Washington, DC, EE.UU.

Buenos días.[1] ¿Cómo están hoy? Espero que bien. Les doy una cálida bienvenida en nombre de los 20 000 mujeres y hombres del Servicio de Parques Nacionales (NPS). Tenemos el honor de trabajar codo a codo con ustedes en la conservación de nuestro crítico patrimonio cultural de tierra. En especial, me gustaría dar la bienvenida a nuestros socios de tribus, a los miembros de la comunidad local y a todos aquellos de ustedes que proceden de distintas partes del mundo. La representante de la Secretaría del Interior y primera secretaria indígena estadounidense del gabinete en la historia de los Estados Unidos, Deb Haaland, y el primer director del Servicio de Parques Nacionales de tierras tribales, Charles (Chuck) Sams III, se disculpan por no poder estar aquí. La secretaria Haaland, que es oriunda de Laguna Pueblo en Nuevo México, y el director Sams, envían saludos y su más sincero aprecio por el trabajo que hacen y por los enfoques conjuntos tanto académicos como tradicionales para la conservación que todos ustedes representan.

Para los participantes internacionales y aquellos que no estén familiarizados con estos asuntos, existen equipos directivos diversos a cargo de los territorios públicos en Estados Unidos, todos con una misión administrativa: el Servicio de Parques Nacionales, la Oficina de Administración de Tierras, el Servicio Forestal de los Estados Unidos, el Servicio de Pesca y Vida Silvestre de los Estados Unidos. Dentro de estas organizaciones gubernamentales, el Servicio de Parques Nacionales es el líder en gestión de recursos y conservación del patrimonio, con un especial énfasis en el cuidado y la interpretación para la sociedad de la amplia gama de patrimonio cultural existente en el país. Por supuesto, aquí en el suroeste de los Estados Unidos, este patrimonio incluye las construcciones con tierra en distintos estados de conservación, sitios arqueológicos, paisajes culturales y las características de sus componentes, sitios de ingeniería e industria, colecciones en museos y otros lugares, así como objetos importantes para las tribus indígenas estadounidenses, las comunidades y la sociedad en general.

Todos somos guardianes, ya sea como científicos, arquitectos o miembros de una comunidad indígena. Lo que me mantuvo dentro del Servicio de Parques Nacionales por tanto tiempo es la misión de gestión, tal como se indica en la Ley Orgánica de 1916, que dio origen al NPS. Una de mis líneas favoritas de ese texto dice que nuestra misión, en virtud de la ley, es preservar, proteger, dejar los elementos intactos para generaciones futuras y propiciar su disfrute por la sociedad. Les menciono esto porque es algo en lo que espero que piensen esta semana, además del trabajo técnico y colaborativo que deben hacer juntos. Recuerden ayudar a todos los ciudadanos del mundo a disfrutar, absorber y comprender qué hacen ustedes, qué son estos lugares y cuál es su importancia.

Creo que nuestra actual cultura de la *selfie* atrae a muchos visitantes a nuestros lugares. Apuesto a que algunas de las cosas que ustedes gestionan, las cosas que les importan, se mantienen bastante en secreto como parte de la preservación y la conservación. Sin embargo, en este mundo actual tan problemático, las personas acuden cada vez más para comprender la cultura tradicional. Acuden cada vez más a lugares que los conecten con la Tierra. La cantidad de visitas se ha incrementado notablemente en muchos de nuestros parques nacionales. Si bien en gran parte son visitas de carácter meramente recreativo, cuando hablo con estadounidenses y visitantes internacionales, muchos de ellos lo hacen por el deseo de comprender mejor los valores tradicionales y conectarse con las personas y los lugares.

La mayoría de estos lugares, particularmente en el suroeste del país (y aquí, donde estamos reunidos, en Santa Fe), tienen una larga tradición de construcción con tierra y preservan los recursos que evidencian esas tradiciones. Para mí, esto refleja que las prácticas, los materiales y las culturas tradicionales representadas por el patrimonio de tierra en todos los paisajes estadounidenses y en el mundo, así como la continuación y preservación de estos lugares, sus materiales de construcción y las prácticas que se perciben como desvalorizadas, de hecho, son muy valiosas. Existen defensores dentro de las comunidades, en toda la cultura y el Gobierno estadounidense y, agregaría, en todo el mundo. Estas tradiciones se remontan a milenios atrás, especialmente, en el norte de Nuevo México. Espero que tengan la posibilidad de experimentar y disfrutar realmente de este lugar rico y diverso. Que puedan relacionarse y aprender de las personas de las tribus y los pueblos de la región, que tienen profundas raíces en este lugar y son verdaderos maestros para todos nosotros.

Todos estamos tratando de asegurarnos de que estos sitios perduren, se adapten y evolucionen. Quienes formamos parte del NPS somos un simple eslabón en la gestión de este patrimonio si nos comparamos en el tiempo con las comunidades indígenas. Hemos gestionado estos lugares por casi un siglo, pero tenemos mucho por aprender y por hacer. Estamos orgullosos de lugares como Casa Grande, Chaco Canyon, Bandelier y Mesa Verde. Bajo el liderazgo de la secretaria Haaland y el director Sams, ahora estamos acercándonos y debatiendo a conciencia la idea de una cogestión con las comunidades indígenas y originarias para administrar juntos estos lugares.

Algo que quiero decirles a todos hoy es que, cuando leo sus biografías, reconozco que son el tipo de profesionales, el tipo de personas que se preocupan y que pueden ayudar a acortar las brechas. Su trabajo tiene una parte técnica, ese vasto conocimiento que aportan. También está el compartir ese trabajo y esa pasión con los demás y con las generaciones venideras de profesionales y administradores; lo cual es realmente inspirador. Espero que este encuentro genere conversaciones profundas y que descubran las relaciones entre las complejas áreas del trabajo académico y técnico que realizan, y las prácticas y perspectivas tradicionales e indígenas.

Quisiera hablarles un poco sobre el futuro. Intentaré no ser pesimista, pero creo que tenemos algunos desafíos comunes en la gestión de parques y recursos: el cambio climático. Hace poco, experimentamos uno de los incendios más grandes de América del Norte que acabó con algunas millas de Santa Fe, poniendo en peligro los recursos, personas, casas y tierras. Estamos viendo un clima cambiante: temporales intensos y destructivos en el desierto han tenido efectos devastadores para el patrimonio de tierra. Por ejemplo, en las Ruinas de Casa Grande, al sur de Arizona, tenemos un gran proyecto para descubrir cómo mantener una cobertura que protege un sitio arqueológico frágil. ¿Es eso lo que hay que hacer? Consultamos a las tribus indígenas estadounidenses para entender mejor todo el valor del sitio y mejorar nuestra gestión, a la luz de las cambiantes condiciones climáticas. También estamos trabajando todos los días para mejorar la predicción de los impactos, aplicar el uso de enfoques científicos para determinar los aspectos delicados de los materiales y sitios, y adaptar nuestros enfoques de gestión. Entonces, realmente tenemos en mente al cambio climático, y yo espero verlo en su agenda.

Nos enfocamos en ser proactivos y, haciendo uso de los esfuerzos existentes, como nuestro Programa Tesoros que Desaparecen, y del conocimiento y la experiencia de nuestros socios expertos, estamos construyendo nuestro entendimiento sobre los desafíos existentes y trabajando por la protección de nuestros recursos más frágiles. ¿Cómo podemos involucrar mejor a todos ustedes en esta aproximación a nuestras necesidades comunes? Una segunda área de trabajo, que particularmente encuentro muy interesante, es la fuerza laboral. De alguna manera, no estamos atrayendo a todas las personas que solíamos convocar. Se nos hace cada vez más difícil contratar, cada vez más difícil encontrar personas que tengan habilidades tradicionales. Tenemos centros de preservación histórica, pero actualmente son pequeños. Los presupuestos son limitados. Creo que, mientras más hagamos juntos y más nos enfoquemos en la fuerza laboral y la transferencia a la generación futura, mejor será. Y todos tenemos algo por aportar aquí, en este componente educativo. Como todos ustedes, estamos generando programas que permiten mentorías y oportunidades de desarrollo para personas interesadas en aprender más sobre carreras en el sector de la preservación. Adicionalmente, es vital asegurar la participación de los grupos indígenas y las comunidades culturalmente asociadas en la preservación de estos lugares. Por ello, estamos trabajando para ampliar y mejorar las relaciones con las comunidades tradicionales, las personas indígenas y otros.

Tenemos un nuevo programa de Grupo de Servicio Juvenil Indio (Indian Youth Service Corps, IYSC) en el NPS, que se enfoca en el sector de la preservación y se desarrolla en conjunto con el Grupo de Conservación de Tierras Ancestrales en los pueblos Acoma, Zuni, Hopi y la Nación Diné.

Espero que los fondos para programas como estos aumenten, pero necesitamos el apoyo de personas como ustedes para este tipo de esfuerzos. Tendremos que recurrir a esta comunidad, su comunidad, a todos ustedes. Y no me refiero meramente a lo contractual, sino en cuerpo y alma. Esa es otra de las razones por las que trabajamos codo a codo en esta batalla constante, si se le puede llamar así, por la preservación de estos importantes recursos.

Mencioné la educación y la inspiración. Me referí a las habilidades que tienen, pero lo que realmente quería era recordarles, por si no lo sabían, que son héroes y heroínas en este mundo. Es posible que no lo sientan así. Es posible que se encuentren con alguien en una conferencia de negocios o en un avión, y que no sepa qué hacen ustedes, ¿verdad? Pero tengan en cuenta esto: son vitales en el problemático mundo actual. Son héroes y heroínas para nosotros. Acudimos a ustedes en búsqueda de conocimiento, pero también de inspiración.

Las personas como yo (y estoy seguro de que todos ustedes conocen a alguien como yo) somos tomadores de decisiones o líderes políticos. Somos quienes tienen que decidir a qué se asigna el dinero y qué recursos se priorizan. Acudo a mi equipo, y ellos los buscan a ustedes. Es posible que no nos conozcamos, pero nuestra conexión con la preservación y la gestión a largo plazo de estos lugares es lo que nos une.

Por eso, quiero recordarles cómo nos inspiran a personas como yo y cómo inspiran al mundo. Creo que no lo dije antes, pero no hay mejor momento que éste para su trabajo, para esta idea de protección, adaptación y evolución. Me entusiasma poner en marcha la idea de las prácticas tradicionales combinadas con la ciencia moderna para poder realmente alcanzar una nueva visión de la gestión. Es lo que necesitamos ahora. Entre las cosas que mencioné respecto al cambio climático, el cambio demográfico y la pérdida de conexión con la Tierra que sienten las personas que viven en zonas urbanas, vemos el hambre y, cada vez más, la necesidad. Quiero que esta semana se relajen, disfruten de la compañía de los demás, tengan las mejores conversaciones y se renueven para volver a trabajar y ser los profesionales, héroes y heroínas del mundo que habitan.

Es un honor para mí estar con ustedes. Quiero agradecer especialmente y reconocer a los miembros del Getty Conservation Institute y de la Escuela de Diseño Stuart Weitzman de la Universidad de Pensilvania, que inauguraron esta conferencia, y brindar un reconocimiento especial a mi colega Lauren Meyer y a todo su grupo, liderado por Amy Cole. Gracias nuevamente por todo lo que han hecho para que llegásemos aquí.

Nota

1 Este texto es una traducción de los comentarios de Michael T. Reynolds el 7 de junio de 2022 en la inauguración del Terra 2022: XIII Congreso Mundial del Patrimonio Arquitectónico de Tierra, Santa Fe, Nuevo México, Estados Unidos.

PART 1

Keynote Addresses / Discursos de apertura

Tradition, Vision, Partnership: Building an International Community of Practice for the Conservation of Earthen Architecture

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Abstract: *Over the last fifty years, the conservation of earthen architecture has developed as a defined area of conservation practice. This evolution involved the convergence of centuries of building tradition with visionary leadership and the individual and collective work of a number of international organizations, including ICOMOS, ICCROM, CRAterre, and the Getty Conservation Institute (GCI). In this paper, the author reflects on this history through the lens of personal experience, highlighting important events and initiatives that led to lasting change. The paper concludes with some thoughts on current challenges and aspirations for the future.*

Resumen: *En los últimos cincuenta años, la conservación de la arquitectura de tierra se ha desarrollado como un área definida de práctica de conservación. Esta evolución implicó la convergencia de siglos de tradición de construcción con el liderazgo visionario y el trabajo individual y colectivo de una serie de organizaciones internacionales, incluidas ICOMOS, ICCROM, CRAterre y el Instituto de Conservación Getty. En el artículo, la autora reflexiona sobre esta historia a través de la mirada de la experiencia personal, destacando eventos e iniciativas importantes que condujeron al cambio duradero. El documento concluye con algunas reflexiones sobre los desafíos actuales y las aspiraciones para el futuro.*

Keywords: conservation, earthen architecture, Terra Project

Introduction and Early History

Though my paper has a rather lofty title, this will be a somewhat personal reflection on my own journey with the conservation of earthen heritage and how that intersected with some of the early pioneers and subsequent developments in the field. I will not be comprehensive, nor do I pretend to speak for everyone. We all have our own experiences and cannot help but see the world through that lens. But I would like to offer my thoughts on the last forty or so years of work in this field and the people who were so instrumental in leading us to where we are today.

As we are all aware, earth is one of the oldest forms of construction and the tradition of building with earth is evidenced in all parts of the world. And yet, I managed to graduate from a two-year program in historic preservation at a well-known university on the east coast of the United States without anyone ever mentioning earth buildings. And this omission occurred even though there is actually quite a lot of earthen architecture in this country, as is evidenced by our surroundings here in Santa Fe. To be fair, it was early in the preservation movement and the focus was on managing the preservation infrastructure of the United States, but the lack of a more international outlook was a bit disappointing, even to a young person like me.

So, upon graduation, I decided that I needed to broaden my horizons and, in a first rare twist of fate, was accepted to the ICCROM Architectural Conservation Course (ARC) in Rome in 1982. Needless to say, the experience burst my rather provincial world wide open, both through the extraordinary array of professionals who taught on the course (including Cevat Erder, Paul Philippot, Giorgio Torraca, Giacomo Chiari, Laura Mora, and many others) and through the relationships formed with my fellow participants, who hailed from all parts of the world. Alejandro Alva, a Peruvian architect with a passion for, and deep knowledge of, earthen architecture, was then the ARC assistant course coordinator and responsible for the week on earthen architecture. And so began an association that changed my life.

Long before it was commonplace, Alejandro recognized the critical connection between conservation and what was then often called "sustainable development"—the need to preserve both the earthen architectural heritage and the building traditions that created it and ensured its continued use and stewardship. It was this vision that led him to seek out people and events that heritage professionals would not usually encounter or attend. One such event was a conference on Earth Construction Technologies that was held in Brussels in December of 1984. I—recently employed at ICCROM as a lab assistant for the ARC course and newly interested in earthen architecture—went with Alejandro to the conference. And there, another extraordinary thing happened. Alejandro Alva met Hugo Houben, one of the cofounders of CRAterre, an organization that was then only a few years old. I distinctly remember the first conversation between them that went something like: Alejandro "You're doing very interesting work but should really know more about heritage conservation." To which Hugo responded "You're right, let's figure out how to collaborate." My first lesson in how visionary leaders begin to imagine the future.

That fateful meeting eventually led to the Fifth International Meeting of Experts on the Conservation of Earthen Architecture, which was held in Rome in 1987 and organized by ICCROM and CRAterre in collaboration with the ICOMOS specialized committee on earthen architecture. This was a small meeting—attended by only a little over twenty participants—but two important things (among many) emerged from the gathering. The first was a decision to hold the next international meeting in Las Cruces, New Mexico, in the United States. This became Adobe 90 (fig. 1), at which the test walls at Fort Selden, the site of a collaborative project between the Getty Conservation Institute (GCI) and New Mexico State Monuments, were discussed and visited.

The second important result of the 1987 experts meeting was an eventual collaborative agreement between ICCROM and CRAterre in 1989 to work together on training regarding the conservation of earthen heritage. This led to a series of courses held in Grenoble between 1989 and 1994 that, it is fair to say, radically changed education in this realm. In the words of Alejandro Alva: "To preserve the cultural tradition of earth construction, a dialogue was required between conservation-oriented disciplines and disciplines focused on new construction and planning. It was necessary to emphasize the relationship between tradition and modernity as a way to preserve earthen architecture as a resource and a constructive culture" (Alva Balderrama 2001, 6). Pedagogically, these courses (known as the PAT courses) were also formative in that they focused not just on earth as material but also on earth as building and building *culture*, and on larger issues of conservation planning and management. The courses were characterized by strong team teaching, a fundamental connection between theory and practice, and an emphasis on critical thinking.

My own connections with colleagues at CRAterre—and with the many people from all over the world who participated in the PAT courses as both instructors and students



(a) (b)

FIGURE 1 (a) Alejandro Alva speaking at Adobe 90 and (b) Fort Selden test walls viewed by participants at Adobe 90. Photos: Neville Agnew, GCI.



FIGURE 2 Jeanne Marie Teutonico (second from left) teaching a laboratory exercise at PAT 89 in Grenoble, France. Photo: Alejandro Alva.

(fig. 2)—really stem from this intense period of teaching and learning. The beginnings of a thriving community of practice were born in this moment.

Other interesting collaborations also emerged, such as one with Mike Taylor (who had done the ICCROM ARC course in 1987 and was then working for New Mexico State Monuments) on both a regional course held in Santa Fe and a series of didactic videos on the characterization of earthen building materials. I was very pleased to hear that ICCROM has recently digitized those videos and will make these early examples of virtual teaching available through its archive.

Earthen Architecture in the United Kingdom

I left ICCROM in 1992 to take up residence in England. Of course, I brought my interest in earthen architecture with me and sought out like-minded colleagues. I found allies in the many practitioners like John Hurd and Dirk Bouwens who were part of numerous regional earth building groups in the UK (among them the Devon Earth Buildings Association and EARTHA in East Anglia), as well as an architect named Linda Watson who taught at the University of Plymouth in Devon and wanted to bring more training in this realm to her architecture students. With the support of English Heritage, by whom I was then employed, these regional efforts eventually coalesced into a number of national initiatives regarding earthen architecture, including the formation of an ICOMOS-UK Earth Structures Committee, the establishment of a National Centre for Earthen Architecture at the Plymouth School of Architecture, and a first national conference on earth building in the UK called *Out of Earth* that brought together both heritage professionals and those interested more broadly in exploring the material's potential for contemporary architecture.

These events greatly increased awareness of the important earthen heritage in the UK, which ranges from domestic buildings of various types to more ancient and monumental sites like Silbury Hill and Maiden Castle dating from 2400 to 100 BCE (fig. 3). They also set the stage for these three organizations (English Heritage, the University of Plymouth, and the ICOMOS-UK Earth Structures Committee) to host the



(a)



(b)

FIGURE 3 (a) A domestic earth building in East Anglia, England. Photo: Dirk Bouwens; used by kind permission of EARTHA, and (b) Silbury Hill, Wiltshire, England. A Neolithic chalk-and-earth mound, part of the Stonehenge / Avebury UNESCO World Heritage Site, 2400–2300 BCE. Photo: Greg O'Beirne, © GFDL-Creative Commons.

8th International Conference on the Study and Conservation of Earthen Architecture in Torquay, Devon, in May 2000, for which English Heritage also sponsored a publication titled *Terra Britannica* that showcased the great breadth and diversity of earthen architecture in the UK.

What I most remember from Terra 2000 was our initial inability to get any press even remotely interested in the conference. Every journalist asked the same predictable question: "Why should we care about earthen architecture and what does it have to do with the UK?" On about the twentieth interview, John Fidler, then head of the Building Conservation and Research Team at English Heritage, responded in frustration with: "Well, the Teletubbies live in an earth building!"—and that was it. Press coverage was off the charts after that. It really is all about how you tell the story.



FIGURE 4 Participants in the PAT 96 earthen architecture course at the site of Chan Chan, Trujillo, Peru. Photo: Jeanne Marie Teutonico.

The Terra Project

These more regional and national activities intersected with what was happening on an international level. Perhaps most importantly, ICCROM and CRAterre had joined forces with the Getty Conservation Institute in 1996 to bring the PAT course model to Latin America through a regional training course in Peru (fig. 4). This course led to the formation of a broader partnership between the three organizations in 1998 called the Terra Project, which included not just educational programs but also research and field activities. This integrated approach to the conservation of earthen heritage would have a profound influence on the development of the discipline.

My life again intersected with these international developments when I accepted a job in the fall of 1999 as associate director at the Getty Conservation Institute. GCI efforts in the Terra Project were then led by Erica Avrami, who had worked closely with Alejandro Alva and Hugo Houben in establishing the strategic aims of the initiative, and we began to build on those ideas.

In the years to come, outcomes of the Terra Project included another regional PAT course in Peru in late 1999, where aspects related to site management were further refined; the development of a conservation and management plan for the site of Chan Chan in collaboration with the Instituto

Nacional de Cultura of Peru; and a number of research activities, including the development of a research index that attempted to articulate priorities for the field of earthen architecture conservation. In fact, a special meeting to discuss current and potential avenues of research as well as opportunities for collaboration was held in conjunction with the Terra 2000 conference in Torquay. Though a relatively low-key affair, that research meeting was incredibly important both in developing the conservation of earthen heritage as a science and in setting the stage for many future research projects and collaborations.

In this period the Terra Project also organized, in collaboration with others, a number of smaller colloquia dealing with specific issues related to earthen architecture conservation. These included the Shelters Symposium held in Tumacácori, Arizona, in 2001 in collaboration with the US National Park Service, New Mexico State Monuments, and the US/ICOMOS Specialized Committee on Earthen Architecture, as well as a Colloquium on the Conservation of Decorated Surfaces on Earthen Architecture held at Mesa Verde National Park in Colorado in 2004 (fig. 5), again in collaboration with the US National Park Service, the US/ICOMOS Specialized Committee, and the Colorado Historical Society. These more intimate gatherings allowed a smaller group of heritage professionals to come together to debate and to develop recommendations regarding more specific concerns in the conservation of earthen heritage. The resulting publications remain important references today and have contributed to the growing body of literature in the discipline.



FIGURE 5 Mesa Verde National Park, Colorado, where the Colloquium on the Conservation of Decorated Surfaces on Earthen Architecture was held in 2004 as part of the Terra Project. Photo: Claudia Cancino, GCI.

Earthen Architecture Initiative at the Getty Conservation Institute

The Terra Project concluded in 2006, but its long-term goals have continued under the programs of the individual partner institutions. At the GCI, what is now called the Earthen Architecture Initiative has been advanced over time by a number of my colleagues, including Claudia Cancino, Ben Marcus, Elena Macchioni, and Leslie Rainer, all of whom were involved in the planning of Terra 2022.

Our goal has been to continue to advance the field of earthen architecture conservation through field projects that create models of best practice, research that addresses unanswered questions, capacity building, and the dissemination of information in a variety of forms. In all these endeavors, we have worked with partners in various parts of the world who bring their knowledge, experience, diverse ideas, and rich cultural traditions to the collaboration.

In the last fifteen years the GCI's efforts regarding earthen architecture have included:

- working with the Mali Ministry of Culture to bring the Terra conference to Africa for the first time in 2008;
- a major project at the Kasbah of Taourirt in collaboration with the Centre de Conservation et de Réhabilitation du Patrimoine Architectural des Zones Atlasiques et Subatlasiques (CERKAS) in Morocco that sought to rehabilitate and create vital new uses for the kasbah while preserving and expanding both constructive and conservation knowledge and skills;
- an ongoing project with the School of Science and Engineering at the Catholic University in Lima and the Peruvian Ministry of Culture that seeks to develop and implement seismic retrofit techniques that are cost-effective and locally sustainable on a number of earth buildings that represent typical building typologies in Latin America. The first project has been completed at the Church of Santiago Apóstol in the village of Kuñotambo in the Andes (fig. 6) and a second is about to begin at Ica Cathedral;
- a regional course on the conservation of earthen architecture (based on the PAT model) held in Abu Dhabi and Oman in 2018 in collaboration with Abu Dhabi's Department of Culture and Tourism, with a second iteration planned for later this year.



(a) (b)

FIGURE 6 (a) The Church of Santiago Apóstol in the village of Kuñotambo, Peru, before conservation. Photo: Wilfredo Carazas, 2010, © J. Paul Getty Trust, and (b) the Church of Santiago Apóstol in the village of Kuñotambo, Peru, after conservation. Photo: GCI.

Reflections on the Past and Future

Many advances have been made since those early heady days in the 1980s when I arrived in Rome and first learned about earth and one of the most important constructive cultures in the world.

Of course, many challenges—some specific to earthen heritage, some more general—remain. Like all heritage, earthen architecture is increasingly threatened by global warming and climate change, which has produced more extreme weather conditions such as hurricanes, floods, and fire. These phenomena endanger our heritage and require us to plan for such emergencies, but also challenge us to think more broadly about how we use energy and manage our environment.

There is conflict in many parts of the world that can have catastrophic consequences for heritage, especially when objects or sites are targeted for ideological reasons. There is development pressure, especially on our historic cities, as societies become more mobile and work is increasingly located in urban centers. And, of course, there are issues of social justice that have been front of mind in recent times. Obviously, there is still much to do.

But to return to the points I've been trying to make throughout this talk . . .

Perhaps most importantly, real and lasting change occurs when creative, like-minded people—and the institutions that they represent and influence—come together to envision a compelling future. And that is because heritage conservation, including the conservation of earthen heritage, is by its nature a profoundly human endeavor. Objects and places gain significance from the people who make, value, and care for them. The work we do is, therefore, a collective undertaking that demands collaboration with, and learning from, a variety of other people to ensure that we understand what we are safeguarding and pass it on to future generations in a way that will allow them to make their own decisions about what is important and why. Considered in this way, our work is indeed about valuing and understanding the past but also very much about the future we want to create together.

The visionary leaders who pioneered the field of earthen architecture conservation (and I have only mentioned some of them) understood this. Generous, humble, and respectful of the ideas and values of others, they built meaningful connections between the many communities involved in the construction, care, and conservation of earthen buildings, and inspired generations of students, colleagues, and practitioners with their knowledge, passion, and belief in the power of collective action.

On a wall plaque above the tombstone of the architect Sir Christopher Wren in St. Paul's Cathedral in London (fig. 7), there is a Latin inscription that ends with the words "si monumentum requiris, circumspice," loosely translated as: "If you would seek his monument, look around you." Looking around this room (and the larger, virtual one), I think



FIGURE 7 Wall plaque above the tombstone of Sir Christopher Wren in St. Paul's Cathedral, London, England. Photo: John Fidler.

the same could be said of those who were so instrumental in creating the community of practice we see today. I was fortunate to learn from, and be mentored by, many of those early pioneers—serendipity that I have tried to honor by doing my part to continue their legacy. As is fitting, the future rests with the next generation.

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ICOMOS-ISCEAH and the Future of Earthen Architectural Heritage Conservation

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Abstract: *The ICOMOS (International Council on Monuments and Sites) International Scientific Committee on Earthen Architectural Heritage (ISCEAH) was created in 2005. Since then, ISCEAH has been an active committee contributing to the awareness, knowledge, and preservation of earthen architectural heritage. A new Bureau was elected in 2018 for a mandate of three years to head and coordinate ISCEAH. In 2021, ISCEAH has 142 expert members, associate members, and emerging professionals and is one of the largest ICOMOS International Scientific Committees (ISCs). ISCEAH has reactivated its membership network, reenergized its five research themes (In-Use, Archaeology, Landscape, Technology, and Seismic), created the new Emerging Professional Working Group, prepared the launch of the international call to organize the Terra 2022 and 2025 congresses, developed collaborations with other ISCs, contributed to the new Climate Change Working Group, responded to various requests regarding earthen World Heritage Sites, revised its bylaws, and planned a road map for an Earthen Architecture Charter. This paper addresses the creation of the earthen committees within ICOMOS and the importance of Terra congresses. It assesses where ISCEAH stands today, its alignment with the ICOMOS Work Program, and where ISCEAH can go from here. This paper allows us to examine the different challenges and opportunities that have been faced so far and how such an examination can contribute to a more strategic and inclusive approach to earthen architectural heritage conservation.*

Resumen: *El Comité Científico Internacional de Patrimonio Arquitectónico de Tierra (ISCEAH) del Consejo Internacional de Monumentos y Sitios (ICOMOS) se creó en 2005. Desde ese momento, el ISCEAH es un comité activo que contribuye a la concienciación, el conocimiento y la preservación del patrimonio arquitectónico de tierra. En 2018 se eligió una nueva junta por un mandato de tres años para dirigir y coordinar el ISCEAH. En 2021, tiene 142 integrantes expertos, participantes asociados y profesionales emergentes, y es uno de los comités científicos internacionales (ISC) más grandes de ICOMOS. El ISCEAH reactivó su red de integrantes, dinamizó sus cinco temas de investigación (en uso, arqueología, paisajes, tecnología y sísmica), creó el nuevo grupo de trabajo de profesionales emergentes, implementó varias actividades en diferentes países, preparó el lanzamiento de la organización de TERRA 2022 y TERRA 2025, desarrolló colaboraciones con otros ISC, contribuyó al nuevo grupo de trabajo sobre el cambio climático, respondió a distintas peticiones relacionadas con los sitios de tierra declarados Patrimonio de la Humanidad, revisó sus estatutos y empezó a planificar una hoja de ruta para la Carta sobre la arquitectura de tierra. En este artículo, se desarrolla la creación de los comités de ICOMOS que se dedican a la arquitectura de tierra y la importancia de los congresos TERRA. Se analiza la posición actual del ISCEAH y su alineación con el programa de trabajo de ICOMOS; además, se aborda el rumbo futuro del ISCEAH y la manera de avanzar. Esto nos permite analizar los desafíos y las oportunidades que enfrentamos hasta ahora, y la manera en la que este análisis puede contribuir con un enfoque más estratégico e integrador de la conservación del patrimonio arquitectónico de tierra.*

Keywords: ICOMOS, ISCEAH, earthen architectural heritage, conservation, preservation

Introduction

For a long time, it was believed that a third of the housing around the world was built of earth, a statistic that Doat et al. discussed in their 1985 publication, *Construir con tierra, Tomo I & II*. Additionally, in 1989, Houben and Guillaud stated that "at least 20% of urban and suburban populations live in earth homes" (1989, 6). In a constantly changing world, these numbers are no longer real. In 2007, the United Nations (2022) established that half of the world's population lived in cities, likely meaning that around 15% live in earthen structures (Correia 2016). Unfortunately, many earthen dwellings worldwide, including a large variety of earthen building cultures, are rapidly disappearing.

The Creation of the Earthen Architecture Committees

The original ICOMOS earthen architecture committee, the International Committee for the Study and Conservation of Earthen Architecture, was founded in 1987 following four ICOMOS-supported international scientific symposia on earthen architecture. The first president was Cevat Erder (Turkey, 1987–90), followed by Alejandro Alva (Peru, 1990–96), and Fernando Pinto (Portugal, 1996–99). By the 9th International Conference in Yazd, Iran (2003), the committee had become inactive and was dissolved the following year by the international ICOMOS Board. John Hurd and Pamela Jerome were tasked with its restructuring. The International Scientific Committee on Earthen Architectural Heritage (ISCEAH) was founded in 2005 with Hurd and Jerome as acting president and vice president, respectively. Elections were held in 2005, with John Hurd formally elected president (UK, 2005–14). Presidents since then have been Julio Vargas Neumann (Peru, 2015–17), Mariana Correia (Portugal, 2018–20), and Maddalena Achenza (Italy, 2021–23).

The Importance of Terra Events

One of the main events associated with the committee is the Terra conferences, listed as follows: international meetings (1972 and 1976, Yazd, Iran), international symposia (1980, Ankara, Turkey; 1983, Lima and Cuzco, Peru), international meetings of experts (1987, Rome, Italy), international conferences (Adobe 90, Las Cruces, New Mexico, USA; Terra 93, Silves, Portugal; Terra 2000, Devon, UK; Terra 2003, Yazd, Iran; Terra 2008, Bamako, Mali; Terra 2012, Lima, Peru), and world congresses (Terra 2016, Lyon, France; Terra 2022, Santa Fe, New Mexico, USA). General interest and specialized participation have grown internationally, providing a framework for concerted actions for preservation of earthen architecture, as well as for the establishment of networks, associations, and entities for its protection.

The earliest international meetings, held in Yazd in 1972 and 1976, were the first attempts to characterize earthen architectural heritage. The events that followed also produced preliminary recommendations for earthen archaeological preservation. During the first international symposia, it was noticed that the general term "earthen architecture" was used in addition to several other alternative terms such as mud architecture, unbaked earth architecture, raw earth architecture, and clay architecture. Some of the terms contained negative connotations or were not correctly applied, and during the 3rd International Symposium on Mudbrick Preservation, in Ankara (1980), it was recommended that the term "earthen architecture" be used to represent architecture built with earth (Terra 93 1993).

Since Terra 93, each subsequent conference has had different approaches (Correia 2016). Terra 93 introduced a broader view of the field, addressing not only adobe and archaeology but also different earthen techniques and research fields, resulting in the adjustment of the conference title from Adobe 90 to Terra 93. Additionally, Terra 93 brought a deeper concern for the development of comprehensive recommendations. In Terra 2000, there was a specific interest in the archaeological and landscape approach, as well as a more technical and constructive perspective (Terra 2000). In Terra 2003, the focus related more to material knowledge and structural performance. Case studies of earthen architecture in Asia were also widely valued (Terra 2003). In Terra 2008, the thematic approach had a relevant intangible knowledge and social perspective, especially regarding the continuance of living traditions, emphasizing cultural values in earthen architecture on the African continent (Rainer, Rivera, and Gandreau 2011). Terra 2012 developed aspects related to climate change and natural disasters, including disaster preparedness and seismic mitigation with a focus on the Latin American region (Correia et al. 2016). Terra 2016 integrated a yearlong program of activities (exhibitions, roundtables, workshops, thematic events) in archaeology, conservation, earthquake resistance, and artistic programming in different facilities, museums, and galleries (Joffroy, Guillaud, and Sadozai 2018).

An effort has been made by ISCEAH to have the event rotate among different continents. The Terra events have been organized four times in Asia (1972, 1976, 1980, 2003), four

times in Europe (1987, 1993, 2000, 2016), four times on the American continents (1983, 1990, 2012, 2022), and one time in Africa (2008). The main themes and activities for each have been adapted to the geographic and cultural area where the event is being organized, but also to the knowledge, experience, and mission of the organizers, as well as the trends that are being discussed internationally during the preparation period for the event.

Where ISCEAH Stands Today

Since 2005, ISCEAH has been an active committee contributing to the awareness, knowledge, and preservation of earthen architectural heritage at the international level. ISCEAH's five scientific themes—In-Use, Archaeology, Landscape, Technology, and Seismic—aim to advance knowledge within the committee. In 2018, a new ISCEAH Bureau was elected, reactivating its membership network and reenergizing its five research themes. By April 2021, ISCEAH had 142 experts, associate members, and emerging professionals, making it one of the largest ICOMOS International Scientific Committees (ISCs). Consistent work from each sub-theme is being developed: Guidelines for Conservation Practice (In-Use); Glossary of Earthen Materials Deterioration Patterns (Archaeology); review and translation of the Earthen Cultural Landscape concept and questionnaire (Landscape); Glossary in Technology (Technology); and post-earthquake assessment research and earthquake mitigation guidance on what to do and what not to do after an earthquake (Seismic). Each sub-committee has regular group meetings coordinated by its chairperson. The work aims to have a critical approach that considers different international perspectives and experts' backgrounds. These materials will establish a conceptual consensus for ISCEAH's work going forward.

ISCEAH also developed and co-organized several international activities, including the 1st World Heritage Workshop, in Yazd, Iran, in 2019 (fig. 1); collaborations with other ISCs such as the 2019 International Conference of CIAV-ISCEAH in Pingyao, China (fig. 2); the online Inter-ISC meeting between six ICOMOS-ISCs in 2020; and the launch of the four joint-ISCs conference in Malmo, Sweden, in 2021. In addition, ISCEAH produced a Tentative List of earthen architectural sites for the Arab region; organized the Exhibition of Earthen Architecture in the Arab States in 2020 in Bahrain requested by the Arab Regional Center for World Heritage (ARC-WH) (fig. 3); revised nominations for the World Heritage Fund; launched the expression of interest in organizing Terra 2022 and Terra 2025; and



FIGURE 1 Participants visiting Fahraj during the 1st World Heritage Workshop, Yazd, Iran, organized by ISCEAH, Yazd Municipality, and Yazd University, in February 2019. Photo: Clara Pimenta do Vale.



FIGURE 2 Front and back covers of the CIAV-ISCEAH 2019 proceedings from the joint conference and meeting held in Pingyao, China, in September 2019. Photo: Tongji University.

contributed to the Climate Change Working Group. ISCEAH responded to different assessments regarding earthen World Heritage nominations; established focal points for climate change, emerging professionals, heritage impact assessment, COVID-19 impact, sustainable development goals, and human rights, and revised its bylaws.

The reactivation and reorganization of ISCEAH created a stable committee foundation, guiding the identification of challenges and opportunities. The overall intent is to address a more strategic and inclusive approach for earthen







FIGURE 3 Exhibition of earthen architecture in the Arab region, co-organized by ARC-WH and ISCEAH, Manama, Bahrain, in February 2020. Photos: ARC-WH.

architectural heritage. A critical assessment of ISCEAH's strengths and weaknesses, as well as the recognition of opportunities and needs, will continue to be addressed to strategically establish priorities of action. Notwithstanding, more needs to be accomplished, especially regarding capacity building, conservation guidance, and critical response to challenges related to the survival of earthen heritage in the twenty-first century.

Alignment with ICOMOS's Work Program

The ICOMOS Board is guided by the Advisory Committee (Ad Com), consisting of the presidents of 119 National Committees and 29 ISCs. The latter belong to the Scientific Council (SC). For every Triennial General Assembly, the SC develops a three-year scientific plan that is adopted by the Ad Com, which proposes interdisciplinary research in major

areas. The topics are reinforced by resolutions adopted during the Triennial General Assembly.

In New Delhi in 2017, ISCEAH was one of six ISCs that co-signed a resolution on climate change, after which the ICOMOS Board created the Climate Change and Heritage Working Group (CCHWG). ISCEAH actively contributes to the work of CCHWG and, in 2020, contributed to the updated draft of the 2007 climate change policy. The climate change emergency was adopted as the focus of the SC's three-year scientific plan for the 2020 ICOMOS Triennial General Assembly. All ISCs will collaborate on climate change over the next three years in their respective areas of expertise.

Another major focus of ICOMOS has been the establishment of the Sustainable Development Goals Working Group (SDGWG), in order to bring culture into the discussion of the United Nations' SDGs. ISCEAH contributed actively to the revision of the SDG report, also nominating SDGWG focal points.

In response to the ICOMOS mandate for emerging professionals (EPs) in ISCs, ISCEAH approved ten new members to the Emerging Professional Working Group (EPWG); four are currently ISCEAH board members. ISCEAH-EPWG members contributed to the transversal overall research, Journeys of Authenticity. It is fundamental for ISCEAH-EPWG to participate in an active way, adopting the next generation's contribution to the committee.

Future Activities

Preservation and Reuse of Rural Heritage

During the current mandate, ISCEAH is working on the recognition of rural heritage sites and their associated tangible and intangible values. Old settlements represent the backbone of country-places where people live differently from those in large cities, often with a better quality of life on a more human scale. These are places of contemplation and slowness, well represented by the craftwork of artisans, high-quality agriculture, and protection of biodiversity. These concepts require protection, awareness, and support in order to make living in peripheral places more attractive.

The international debate suggests that the rehabilitation of small villages could be the future of many developed countries as a means of stopping uncontrolled soil erosion, assuring energy efficiency, and enhancing circular economies as key instruments in response to climate change and the COVID-19 crisis. Current worldwide political trends are directed at the preservation and reuse of rural heritage, present-day comfort adaptation, and compliance with norms on energy consumption. The European Union's recent Green Deal policy focuses on the built environment as a vehicle to boost a new green economy based on the use of natural building materials produced with circular and virtuous processes. This could be a source that inspires change for rural earthen architecture.

Rural villages have proven resilient and adaptable over centuries, responding to crises and contemporary ideas of sustainability. ISCEAH aims to dedicate a more focused attention to their conservation, use, and rehabilitation.

Technology as a Resource for Protection

The use of technology (photogrammetry, 3D models, digital reconstructions) in recording earthen architectural heritage has permitted an effective and efficient diagnosis of internally and externally caused damage, allows for a planned strategy for intervention, and protects the integrity and authenticity of earthen World Heritage. Digitalization becomes a powerful resource for awareness raising, and ISCEAH could have a more dynamic approach in this regard.

The accelerated progress of tools and techniques for data collection raises the potential for better information management that, along with dissemination through multimedia and publications, has a positive impact on conservation and protection of cultural heritage internationally. Dissemination of earthen architectural heritage's intrinsic significance contributes to its educational value, raising communities' awareness and understanding so that they can be part of the solution of monitoring and protecting earthen architectural heritage.

Stronger Research and Technical Capacity

There has been growing demand for ecological and sustainable construction as a response to climate change. Lessons from earthen architecture hold great value, reducing the carbon footprint through rehabilitation and construction. Universities and the forty-one members of the UNITWIN network of the UNESCO Chair for Earthen Architecture, Constructive Cultures, and Sustainable Development, as well as PROTERRA, the Iberian-American network of earthen architecture and construction (redproterra.org), are engaged in the dissemination of scientific and technical knowledge of earthen architecture. Several members are also ISCEAH members. Strengthening the connection of ISCEAH with other networks and entities—such as the UNITWIN-UNESCO Chair, PROTERRA, and the Getty Conservation Institute's Earthen Architecture Initiative—could help address a more

strategic and sustainable international approach by reinforcing collaborations between ISCEAH, academics, researchers, and professionals in different regions of the world.

Collaborations could focus on pooling resources for the development of research and educational activities. Many tools have been developed with ISCEAH support, including the VERSUS project (esg.pt/versus), which facilitates the analysis of vernacular heritage values for sustainable architecture; ECVET-Pirate (ecvetearth.hypotheses.org), which supports the validation of qualifications for earthen architecture through the European Credit system for Vocational Education and Training; and 3DPAST (esg.pt/3dpast), which is dedicated to digital documentation of vernacular World Heritage. Interactions between universities and the private sector will facilitate multidisciplinary approaches, innovation in pedagogical methods, and better teaching activities by professionals. ISCEAH should have a key role in this concern in the future.

Conservation and Material Technical Support

ISCEAH is tasked with carrying out specialized scientific studies and disseminating information for the protection and conservation of the earthen architectural, archaeological, and cultural landscape heritage. Currently, ISCEAH shares research developed by its members on building cultures, construction methods, conservation approaches, structural design, and other issues through conferences and published proceedings (e.g., CIAV-ISCEAH 2019; see fig. 2).

However, more needs to be done to tackle the gap in knowledge regarding guidance for earthen architectural heritage conservation. ISCEAH has started the development of a Charter for Earthen Architectural Heritage. This is a long process that will be carried out with consistency, inclusiveness, and common sense. To support this endeavor, the In-Use subcommittee is also creating guidelines for earthen architecture that will address technical knowledge, specific activities, and processes for the conservation of earthen architecture. Because there is a lack of basic guidance documents on earthen architectural heritage in most countries, the charter and guidelines will instruct professionals and nonprofessionals in the preservation, conservation, and rehabilitation of historic earthen resources.

Moving Forward/Future Innovations

ISCEAH has developed a considerable body of work in the field of earthen architectural heritage. It remains an international repository for the field's technical expertise and resources. Terra congresses will continue to convene the largest group of professionals and researchers in earthen architectural heritage conservation and practice.

Increasing urbanization and growing climate change concerns are shifting focus from current construction to more sustainable methods, presenting an opportunity for ISCEAH. Lessons learned from earthen architectural heritage study are also relevant to contemporary earthen architecture development.

The committee sits at the unique nexus of both contemporary and earthen architectural heritage, each constructed of the world's most environmentally sustainable resources. Earth as a building material has low embodied energy and is naturally insulative, readily available, and appropriate for multiple building types. Contemporary earthen architecture can provide ecological and economical housing. Adaptive reuse of historic earthen architecture can further the availability of economical housing. ISCEAH can assist with technical knowledge leading the next wave of environmentally sustainable buildings, and future construction will look to the inherent sustainable aspects of traditional methodologies. To do this effectively, ISCEAH will need to expand its capacity-building efforts for different audiences by increasing its presence on all continents and providing targeted training.

The conservation of earthen architectural heritage strengthens people's identities and building cultures worldwide. Actions that encourage its protection should be promoted by civil society through continuous and sustainable work.

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Reflections on Earthen Architecture Heritage—A New Mexico Perspective

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Abstract: *This paper presents reflections on earthen architecture conservation initiatives from a New Mexico perspective spanning the past three decades. The author was directly involved in organizing Adobe 90: 6th International Conference on the Conservation of Earthen Architecture, held in Las Cruces, New Mexico. Thirty-two years and seven international conferences later, the event is again taking place in New Mexico. The author briefly cites examples of earthen architecture conservation programs and initiatives that have taken place regionally since Adobe 90. The paper highlights successful programs in New Mexico and the greater southwestern US that represent relevant examples of earthen architecture conservation practices involving communities and users/managers of historic earthen buildings and structures. Taylor also discusses how serendipitous opportunities presented themselves, beginning with his upbringing in a New Mexico adobe home, subsequent work with earthen architecture conservation that led him to ICCROM, and meeting pioneers such as Alejandro Alva Balderrama (ICCROM) and Hugo Houben (CRAterre) who were instrumental in forging partnerships and training professionals in the global field of earthen architecture conservation.*

Resumen: *En este artículo, se presentan reflexiones sobre las iniciativas de conservación de la arquitectura de tierra desde la perspectiva de Nuevo México, que abarcan las últimas tres décadas. El autor participó de manera directa en la organización de Adobe 90, la 6.ª Conferencia Internacional sobre Conservación de la Arquitectura de Tierra, que se llevó a cabo en Las Cruces, Nuevo México, Estados Unidos. Luego de treinta y dos años y siete conferencias internacionales, el evento vuelve a realizarse en Nuevo México. El autor cita de forma breve algunos ejemplos de los programas y las iniciativas de conservación de la arquitectura de tierra que se llevaron adelante en la región desde Adobe 90. En este artículo, se destacan los programas que funcionaron correctamente en Nuevo México y en el suroeste de los Estados Unidos, ya que son ejemplos pertinentes de las prácticas de conservación de la arquitectura de tierra en los que se involucra a las comunidades y a los usuarios o gestores de los edificios y estructuras de tierra históricos. Asimismo, Taylor habla de la manera en la que se presentaron oportunidades fortuitas; para empezar, su educación en una casa de adobe de Nuevo México, el trabajo posterior con la conservación de la arquitectura de tierra que lo condujo al Centro Internacional de Estudios para la Conservación y la Restauración de los Bienes Culturales (ICCROM) y a conocer a pioneros como Alejandro Alva Balderrama (ICCROM) y Hugo Houben (CRAterre), cuya participación fue fundamental para forjar asociaciones y formar a profesionales en el campo global de la conservación de la arquitectura de tierra.*

Keywords: test walls, ICCROM, CRAterre, adobe, consolidation, protective shelters

The organizers asked me to make some remarks since, as a New Mexican, I have been involved over the past three decades with many of the events and issues that are being discussed during this congress. My personal experience with earthen architecture started seventy-one years ago—when I was born. I was raised in a mid-nineteenth-century adobe home in southern New Mexico, along with my six brothers and sisters. Our parents moved into the sprawling adobe property that was in much need of repair on the west side of the Mesilla Plaza in 1951. Many thought it was beyond hope, but our parents had the foresight to begin slowly restoring the adobe home and adding to it as the family grew.

A few of you may remember that house from Adobe 90, the 6th International Conference on the Conservation of Earthen Architecture, held thirty-two years ago in Las Cruces, New Mexico, about four hours south of Santa Fe. We had a reception in our home and some of you may remember our father, who today, at 102 years of age, still lives in the venerable home that he and our mother began preserving seventy years ago. On our father's passing, the home will become a functional state historic site, one that will highlight its earthen architectural legacy and history of the Mexican-US borderlands.

Our father is descended from many of the Spanish settlers who, over the past sixteen generations, have built their homes with earth here in Santa Fe and northern New Mexico. I know those of you who are Native American far exceed that timespan, as well as others of you from various parts of the world whose ancestors have lived in earthen architecture for centuries. My wife and I raised our son in our adobe home (she built the house and then I moved in), where we have lived on the outskirts of Santa Fe for the past thirty-seven years. I was also fortunate to work the last eighteen years of my career in the Old Santa Fe Trail Building, a National Park Service (NPS) edifice here in Santa Fe and the largest adobe office building in the US (fig. 1). So, I know the comfort that living and working in an earthen environment brings. I also know the challenges: the need for cyclical maintenance and use of compatible building materials for repairs. P. G. "Buz" McHenry, a mentor for many of us here in New Mexico, used to say that all an earthen building needs is a good hat and good boots, meaning a good roof and a good foundation. As we know, sometimes it can get a little more complicated than that, but we also know that earthen buildings can last for centuries as long as they are regularly maintained and used. This world congress aims to share information on the latest research and best practices in the study and conservation of our earthen architectural heritage.



FIGURE 1 National Park Service Old Santa Fe Trail Building, Santa Fe, New Mexico. Photo: US NPS.

Earthen architecture is found throughout the US, even in places like New York. But the US Southwest, including Arizona, California, and Texas, is where the majority of earthen structures are located, with most of them found in New Mexico.

Prior to the 1598 arrival of the Spanish in New Mexico, Native Americans in this region had been using earth as a building material for centuries, most commonly using coursed (or puddled) earth or stone with earth as mortars and plasters. With the arrival of the Spanish along what later became El Camino Real de Tierra Adentro (the Royal Road to the Interior Land) (fig. 2), formed adobe brick was introduced and is still the most common type of earthen architecture in the US today. During three centuries of Spanish rule, followed by three decades of Mexican rule, earthen homes and towns continued to be built in the American Southwest. At the culmination of the Mexican American War, in 1848, what is known as the American Southwest became part of the United States. With the arrival of the railroad in the late 1870s and easily accessible building materials from the east, the use of adobe in New Mexico began to decline. Many vernacular adobe buildings continued to be constructed and maintained throughout the twentieth century until, paradoxically, the high cost of labor resulted in mainly wealthy newcomers having adobe homes built, with local residents many times living in manufactured housing on the outskirts of towns. The built earthen environment of Santa Fe has morphed over the past 400 years to what you see today.

My experience with the conservation of earthen architecture started in 1977. I was asked to lead the stabilization of



FIGURE 2 Map of El Camino Real de Tierra Adentro. Illustration: US NPS.

a seventeenth-century earth-and-stone Franciscan church and adjoining Native American village at the site of Giusewa in the Jemez Mountains, 60 miles west of Santa Fe. That job led to other projects dealing with earthen architecture that eventually resulted in my involvement with the adobe test wall project at Fort Selden Historic Site. Fort Selden is an abandoned nineteenth-century adobe military fort in southern New Mexico (fig. 3). The archaeological site with standing walls is very modest in size and significance compared to the type of earthen architecture that many of you have worked with and manage.

The project was implemented and monitored between 1985 and 2000, and by 1987 the Getty Conservation Institute (GCI) became a partner through the collegial and expert collaboration of Neville Agnew and his team. The program investigated the efficacy of various preservation treatments on adobe test walls that were built at the edge of the site, including protective shelters, capping, reburial, chemical consolidation, and amended mortars used as protective coatings (Oliver 2000; fig. 4). Those treatments that yielded promising results were subsequently implemented on select sections of the historic walls.



FIGURE 3 Adobe walls at Fort Selden Historic Site, Radium Springs, New Mexico. Photo: US NPS.



FIGURE 4 Fort Selden test walls, Radium Springs, New Mexico, 1990. Photo: Neville Agnew, © 1990 J. Paul Getty Trust.

The early years of the test wall project coincided with my being fortunate to have been accepted to the six-month Architectural Conservation Course taught at the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), in Rome, Italy. When I first walked into the lobby of ICCROM to begin the course in 1987, I will never forget Alejandro Alva Balderrama, then assistant course coordinator, introducing himself and asking if I was one of the persons interested in adobe from New Mexico. It was a time when the idea of conservation of earthen architecture was gaining momentum on an international scale, and Alejandro was one of the key players in the initiative. During our ICCROM studies, my fellow students and I were constantly amazed by Alejandro's passion for the venerable building medium of earth that we have all come to love and dedicate much of our lives to. A few years earlier, he had partnered with Hugo Houben, who was then director of CRAterre, one of the other key players at the time. Building in part on early earthen conferences in Yazd and Ankara, these two venerable gentlemen were setting in motion a global initiative that has helped bring us to where we are today. Sadly, Alejandro and Hugo have left us within the past few years, as have John Hurd and other pioneers, but their legacies live on in the work that we do.

Later in 1987, the 5th International Meeting of Experts on the Conservation of Earthen Architecture was held at ICCROM in Rome. It was at that small meeting where the proposal to hold the next meeting in Las Cruces, New Mexico, was accepted, in part to visit and critique the Fort Selden test wall project that was near the conference venue. This 6th International Conference on the Conservation of Earthen Architecture—Adobe 90—was held under the aegis of the ICOMOS International Scientific Committee on Earthen Architecture (today's ISCEAH) and sponsored and organized by ICCROM, GCI, CRAterre, and the Museum of New Mexico (fig. 5). Funding through this partnership helped enable the participation of over 300 delegates representing thirty countries, resulting in the presentation of close to eighty papers (Agnew et al. 1990). The conference provided fertile ground for the interaction of professionals from across the globe, helping sow seeds of collaboration that have yielded important research into the conservation of our earthen architectural heritage. A good example is the Getty Seismic Adobe Project, which has advanced the understanding of how adobe buildings perform during earthquakes and has led to the development of a set of protective measures that could be taken to minimize structural damage from earthquakes.

Another initiative that emerged from Adobe 90 was the transborder collaboration with Mexico, Taller Internacional de Conservación y Restauración de Arquitectura de Tierra (TICRAT) (fig. 6). Now in its twenty-seventh year, this highly successful annual workshop seeks to exchange practical information on common earthen architecture conservation issues facing extant buildings and archaeological sites along the US-Mexico borderlands. In collaboration with the Mexican Instituto Nacional de Antropologia e Historia (INAH), the workshop alternates each year between Mexico and the US. Prior to Terra 2022, the TICRAT workshop took place in the nearby village of Abiquiú, where approximately seventy participants (most of whom then attended the conference

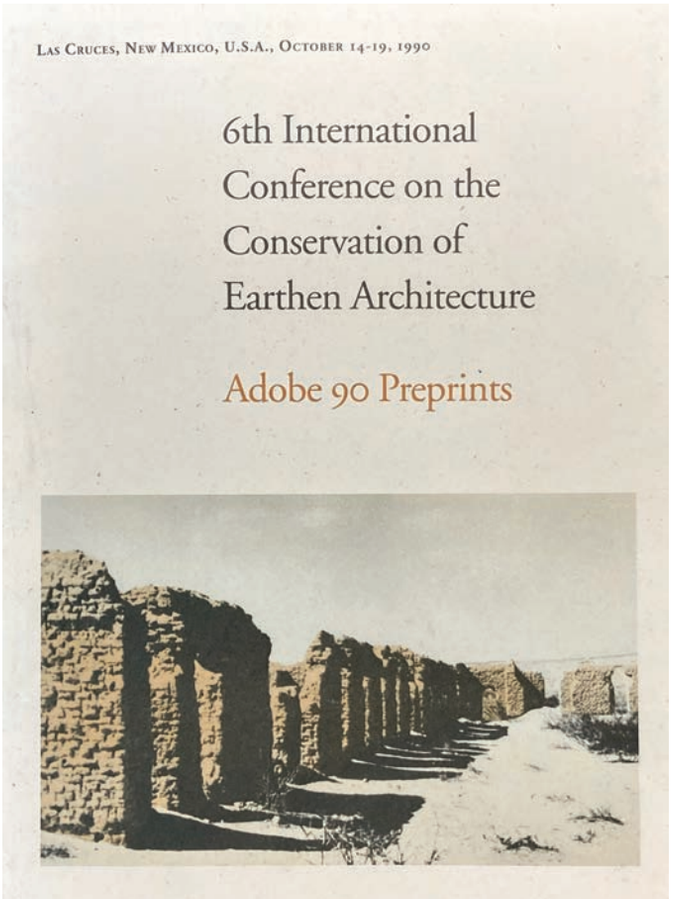


FIGURE 5 Cover of Adobe 90 Preprints. Photo: J. Paul Getty Trust.



FIGURE 6 Participants in Taller Internacional Conservación y Restauración de Arquitectura de Tierra (TICRAT) workshop at Pecos National Historical Park, New Mexico. Photo: US NPS.

in Santa Fe) continued the tradition of sharing technologies, hands-on experience, and friendship.

Over the decades, many other regional initiatives in Asia, Africa, Europe, and South and North America have furthered the awareness and preservation of our earthen architectural heritage. I would like to focus briefly on the US Southwest, where a number of important earthen conservation programs, led by experts such as Jake Barrow, Francisco Uviña, Eric Calvert, Ed and Jess Crocker, David Yubeta, Jeremy Moss, Anita Rodriquez, Tony Crosby, and Pat Taylor have made an impact on our profession.

Examples of such initiatives are the University of New Mexico's Historic Preservation and Regionalism Program, which combines proven earthen preservation techniques with a spectrum of contemporary planning and design approaches for engaging history, culture, and place. Adobe in Action works with the planning, preservation, and construction of adobe homes in New Mexico. Since the 1990s, the NPS's Vanishing Treasures Program has supported the preservation of traditionally built architecture in the western US, perpetuating traditional skills and promoting connections between culturally associated communities and places of their heritage. The Stuart Weitzman School of Design at the University of Pennsylvania, Center for Architectural Preservation, has partnered with the NPS and other entities in the Southwest US to realize important conservation projects at earthen sites through graduate and postgraduate internships. The rehabilitation of forty traditional adobe homes in the 600-year-old Indigenous village of Ohkay Owingeh's historic core has taken place through a tribal-led planning and implementation process, directed by the tribe's cultural values and self-determined principles. Numerous other entities in New Mexico and the Southwest, such as the Earth Guild and Solar Adobe, focus on new earthen building technologies and construction.

Cornerstones Community Partnerships is New Mexico's flagship program dedicated to preserving earthen architectural heritage and cultural traditions, using a hands-on approach to teach and reinforce earthen architectural methods to both adults and youth (fig. 7). Since 1986, Cornerstones has assisted at more than 380 architectural treasures and historic sites. Cornerstones is a strong advocate for using traditional methods in the process of earthen architecture conservation, making quality adobe bricks, repairing adobe walls, and applying earthen plasters, instilling community relevance to its built environment.

Thirty-two years and seven very productive international conferences later, we are meeting again in Santa Fe, New Mexico, a special place that I hope all of you will have the time to enjoy.



FIGURE 7 Work by Cornerstones Community Partnerships on San Miguel Chapel, Santa Fe, New Mexico, 2012. Photo: Cornerstones Community Partnerships.

Santa Fe was named a UNESCO Creative City in 2005 because of its vibrant arts and crafts scene, cuisine, fine hotels, and day trips to some amazing landscapes. There are numerous museums here that tell the stories of our place in the world and how the nexus of historic roads, including the Camino Real, the Santa Fe Trail, the Old Spanish Trail, and Route 66, have shaped these stories.

So much has changed since this congress last met in New Mexico three decades ago. Email and the internet were just emerging as a means of instant communication between colleagues working in various parts of the world, the eerie sounds of faxes were filling hallways, and Hugo Houben had just discovered the magic of using digital images in our PAT training course at Chan Chan, Peru. These technical innovations have all helped our field to advance training and understanding of our earthen architectural heritage.

It is always important to ask ourselves, on the occasion of these congresses, why are we here? Since our first assembly in Iran fifty years ago, what have we learned about the relevance for conserving our earthen architectural heritage in today's society, and for creating new earthen buildings that add to our earthen heritage? With supply chain issues related to imported building materials, will we finally start looking at the dirt under our feet again for commonsense, sustainable construction where we live and work?

I have grown to understand that our earthen architectural heritage is much more than conserving the physical fabric of a building: it is also the need to understand the building's context. How do we balance and consider economic, spiritual, scientific, and aesthetic values? I believe, as many of you do as well, that there is an ongoing need for us to be in regular dialogues with other disciplines as well as to be represented in other ICOMOS scientific committees.

Unexpected priorities have emerged over the past decades in how we regard our earthen architectural heritage. Climate change, caused by rising temperatures, increased drought, and growing populations, is an example of a once-remote concept in my mind that had no immediate impact on my way of life. This past May, however, it burst on the scene in New Mexico with devastating fires in the northern mountain villages that burned many adobe homes. These fires have displaced hundreds who have for centuries kept adobe traditions alive. Climate change has accelerated catastrophic rain events across our parched lands that cause serious erosion problems for villages and earthen archaeological sites. Pandemics, aging populations in rural communities, and youth moving to urban areas for work have interrupted essential maintenance cycles. Changes such as these, along with other economic and demographic factors, have led to a loss of way of life and how we regard our earthen architectural patrimony. What will happen to these communities? I know these questions and challenges face many of us in our work as we consider our common earthen architectural heritage.

In closing, we truly hope that you enjoy your visit here in Santa Fe and northern New Mexico and that your time with us is enriched with dialogue and new knowledge about our common earthen architectural heritage.

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PART 2

Plenary Presentations / Presentaciones plenarias

Challenges and Consequences in Preserving Monumental Mud Brick Structures

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Abstract: *The final evaluation of a conservation project's success is twofold: how well the conservation plan and subsequent interventions respond to an understanding of the treatment consequences, and how well the treatments correspond with the site values. A site is defined by its values and architecture, and these can include the physical and visual conditions and important associations with people and events, as well as symbolic, emotional, and educational significance or context. In order to develop and implement a conservation plan, a clear understanding of these components and their relative significance is imperative. All values are not equal, and the conservator must develop a plan that involves the prioritization of those values. The protection of earthen archaeological sites involves the conservator in considerations that can result in practical conflicts and necessary compromises. Conflicts often arise when the treatment for one aspect of site conservation and site management conflicts with other concerns. Additionally, site conditions are affected by changing human populations or the environment, which can in turn require a modification of the conservation plan. An understanding of original materials, processes, and construction methods is important, but it should be recognized that the conservator must respond to a site's current conditions that result from both the techniques and materials used in the original construction and the effects of decay. And while the conditions of the site and site architecture may not meet current or even traditional building standards, they are the conditions the conservator must address.*

Resumen: *La evaluación definitiva del éxito de un proyecto de conservación se basa en el nivel en que el plan de conservación y las intervenciones responden a la comprensión de las consecuencias de todos los tratamientos y las intervenciones, al igual que el nivel en el que ambos se corresponden con los valores del sitio. El valor de un sitio y de su arquitectura está dado por las características y condiciones que lo definen, las cuales incluyen el estado físico y visual, las asociaciones importantes con las personas y los acontecimientos, así como su relevancia simbólica, emocional y educativa. Para planificar e implementar un plan de conservación, es imprescindible comprender con claridad los valores del sitio y su importancia relativa. Dado que no todos los valores son iguales, el conservador debe elaborar un plan de conservación que incluya la priorización de esos valores. La protección de los sitios arqueológicos de tierra implica que el conservador debe tener en cuenta aspectos que pueden dar lugar a conflictos prácticos, lo que requiere de una cierta negociación. Muchas veces, los conflictos surgen cuando un aspecto de la conservación y la gestión del sitio se enfrenta a otros intereses. Las condiciones del sitio que se ven afectadas por la población humana y el entorno pueden cambiar y afectar al sitio, lo que hace necesario un cambio o una modificación en el plan de conservación. Comprender qué materiales y procesos forman parte de los planes y la construcción originales es importante, sin embargo, es necesario reconocer que el conservador no tiene una hoja en blanco con la cual trabajar, sino que debe abordar y tener en cuenta las condiciones existentes que resultan tanto de las técnicas y materiales utilizados en la construcción original como también de los efectos del deterioro. Es posible que las condiciones y la arquitectura del sitio no cumplan con las normas actuales de construcción y tal vez ni siquiera cumplan con las normas de construcción tradicionales, pero son las que el conservador debe abordar.*

Keywords: conservation, ruins, presentation, collaboration, consequences, challenges, architecture

Introduction

As members of this community whose responsibility is to preserve cultural heritage, we are faced with choices, and those choices have consequences. Sometimes the choices are easy, but they are often more difficult than we would like, as they may demand compromises that are less than optimal. A prescribed treatment that addresses physical decay may well be successful on its own, but if its effect on all site values is not considered, the treatment may not be viable and a compromise may be necessary. Compromises often result in sound conservation projects. But to achieve that status, the compromises must be based on several principles.

Important to the success of the conservation project is that the responsible conservator, regardless of specialty, thinks like a generalist and considers all aspects in the development of the treatment plan. While they may be stated differently, there are three aspects to consider when developing and executing a conservation plan: (1) the identification of the important site values, (2) the determination of the decay factors—the cause-and-effect relationships that result in deterioration and loss of value, and (3) the planning and execution of conservation solutions that recognize and evoke the important values of the site and either eliminate or significantly mitigate the causes that adversely impact those values. These components are not easily separated, as changing conditions can affect earlier decisions and the conservator must be able to gauge the efficacy of the treatment plan as it is implemented and adjust as necessary. A treatment that is visually successful under one lighting condition, for example, may be too visually jarring under another one. The successful conservation project will respond to changes on the site as they occur, and which affect the three aspects listed above.

In preparing this paper, I recognized that because the three primary factors are interrelated, there may be confusion when discussing each separately. When discussing decay factors and conservation treatments, for example, the potential consequences on the other values cannot be ignored. Similarly, when considering a site's values and how best to protect and present them, the specifics of decay and treatment possibilities are imbedded in those discussions as well. I begin with a brief discussion of the process of determining a site's values and structures, followed by a discussion of some causes of material decay and the effects on site and feature values. The remainder of this paper addresses the implementation of a treatment or protection plan, emphasizing conflicts that require critical thinking when developing practical solutions.

Values

> We need to understand what's special about a building, what makes it tick.
>
> (Barton 2020, 25)

> Conservation must preserve and if possible enhance the messages and values of cultural properties.
>
> (Feilden 1982, 6)

> A better understanding of a ruin will allow for better preservation.
>
> (Thompson 1981, 27)

The identification of a site's values begins with research and an understanding of its significance. The process continues with the necessary surveys and inspections that address the physical factors of decay, developing an understanding of the educational value of the site. A listing of all values can be extensive and, while each site and its features have different values, there are several that are present in most all sites. These include symbolic, social, architectural, archaeological, educational, research potential, and character values. Determining the character of a site and site architecture is a value that is often overlooked, and I examine it here in more depth.

Identifying the character-defining features of a site and its structures can begin by utilizing the five human senses: sight, sound, touch, taste, and smell. Because our visual sense is often the strongest, preservation of a site's visual aspects is important in many cases. Part of the process is understanding how the characteristics may have changed over time by comparing existing features with the ones we know or assume existed in the past. In determining the character-defining features of a site, it is important to understand that all are not equal. For example, the inter-geometric relationship of a site's structures, including the structures' relationship to the surrounding landforms, is more important than the actual color and texture of mud brick walls. The standing adobe walls at Fort Union National Monument in New Mexico have an important relationship to their site, which includes a short-grass prairie and the undulation of the distant hills. Specific architectural details are important, but not as important as the ruins and their relationship to the land. A treatment plan to protect the color and texture of a structure at the expense of its geometry would be unacceptable.

The visual character of a site also varies depending on the vantage point. Obviously, the geometries of the site and

its structures become more important the farther away the vantage point. The exact replication of a bonding pattern may be important at 5 m, but less so at 50 m. Also, the character of a mud brick wall will change as the light changes—the color and texture that evoke the appropriate value in one lighting condition may be less evocative when the light is different. A unified treatment of repointing a wall may be the goal, but if one wall is continually in shade, it will not appear the same as walls in sunlight. These are factors that the conservator must consider.

Values may also be different as a site evolves and changes with historic alterations and uses. In *Ruins: Their Preservation and Display*, M. W. Thompson recognized that combining features from different epochs presents special challenges (1981). The site of At-Turaif in the Kingdom of Saudi Arabia was occupied from the mid-eighteenth century as the First Saudi State until ca. 1820. It was then reoccupied in the mid-twentieth century by 200 families that built on the ruins of the earlier mud brick buildings. The significance of both occupations, with associated new constructions and changes and modifications to existing buildings, was important, and conservation plans addressed both (Crosby 2007).

The Shunet el Zebib at Abydos, Egypt, remained a symbol of the birthplace of the Pharaonic period for the majority of its 4700-year history. During the early Christian period, Coptic priests established a community by carving living quarters into the massive mud brick walls, plastering the walls and floors, and building new rooms that extended out from the large mud brick walls (fig. 1). Over hundreds of years, these cavities, several of which were as deep as the walls were thick, collapsed and resulted in walls that were unstable. A conservation plan to address the structural problems had to respect both aspects of the site's history.

Educational values are represented by the research potential a site offers as well as the stories that it tells, as these may well vary over time with changes in inhabitants and political climates. The conservator must be aware of the present and potential future stories but cannot be overly influenced by either, as there are management and conservation implications in deciding which stories are told (Stanley-Price 1999). And herein lies a special challenge whose solution is an awareness of the essence of the site and, in presenting the site and its architecture, allowing it to provide the main influence for the stories rather than the stories themselves overly influencing the site's presentation.

In his book *The Necessity for Ruins and Other Topics*, J. B. Jackson argues that one value of a ruin is that it is an echo from the remote past, not to please the public, but as a memory of an event and, even, "to remind us of our obligations" to protect those things associated with the past (1980, 89–92).



FIGURE 1 Detail of a wall section showing the remains of a Coptic cell constructed in a wall, causing the collapse of a large section of wall near an ancient gateway of the Shuneh at Abydos. In the background is another Coptic cell where a tall mud brick wall has collapsed. Photo: A. Crosby, 2004.

Determining the Factors of Decay

> Of the causes of decay, the most uniform and universal is gravity, followed by the actions of man, and then by diverse climate and environmental effects—botanical, biological, chemical, and entomological. Human causes nowadays probably produce the greatest damage.
>
> (Feilden 1982, 2)

> The simple identification of alterations is obviously not enough. It is also necessary to establish their origin and the processes involved by working backwards from the effects to the causes.
>
> (Mora, Mora, Philippot 1984, 17)

It is necessary to understand the cause-and-effect relationships of decay in order to plan for the interventions that eliminate or, at a minimum, mitigate the causes of decay and the factors that result in the denigration of site values.

A condition requiring a treatment compromise might simply be that while the cause of decay is understood, it might not be possible to eliminate. A solution simply may not exist or may be unreasonable and require heroic efforts, or the means for instituting such an effort are not available. Also, while a reasonable intervention to address the causes of material and system loss is feasible, the solution might compromise other values of the site or the site's structures.

Bernard Feilden describes conservation as "the action taken to prevent decay" (1982, 3). Although he believes that conservation is more than just preventing physical decay, the emphasis for many seems to be just that. I argue that understanding the decay processes is the easy part, as it is relatively objective. The harder, more subjective part of conservation is giving equal attention to all factors and all subsequent actions that affect the values of the site.

Addressing the causes of physical and mechanical decay is important, but solving these specific problems can also reduce or even destroy other values. At Tumacácori National Historic Park, an adobe mission in southern Arizona, a small adobe wall remnant of the former convento was leaning, and an engineering analysis suggested constructing buttresses to support it. Two buttresses were constructed that were larger in mass than the wall they were intended to protect. The actual eighteenth-century fabric was protected but more important values were lost: the wall's relationship to the land and to the other convent walls, as well as the purpose of the original wall itself. If that solution were the only viable one, it would have been better to simply let the wall fall considering that the most significant values were lost by the construction of the buttresses.

Human presence is a direct cause of decay at many archaeological sites, as earthen structures are affected to a greater extent than other building materials. Visitors walk and climb on walls, displacing and eroding surface material. Historically, human factors also contributed to the decay of sites by the salvaging of building materials. At archaeological sites in Egypt this was certainly the case as mud bricks were removed from walls and reused for agricultural purposes (fig. 2). At historic sites in the southwestern US such as Forts Davis, Union, and Selden, windows, doors, and other building materials were removed and reused. At one Spanish colonial mission site in northern Mexico, near the Arizona border, eighteenth-century beams were removed and carted off to Tucson to save them for prosperity, or perhaps it was only for the enjoyment of the person who removed them.



(a)



(b)

FIGURE 2 (a) A missing wall section at the Shuneh at Abydos, from the salvaging of mud brick to reuse for agricultural purposes and partial collapse, and (b) the same wall after structural stabilization. Photos: A. Crosby, 2004, 2005.

Treatments and Interventions—The Consequences

> . . . the conservator shall endeavor to use only techniques and materials which, to the best of current knowledge, will not endanger the cultural and physical integrity of the cultural property.
>
> (Weaver 1993, 2)

This section primarily addresses the actual process of implementing site treatment plans and the issues, problems, and site conditions that can result in changes to well-developed

conservation plans. These often require the conservator to think creatively when solving problems.

In preparing treatment specifications for a particular project, the architect or architectural conservator might specify equipment, materials, and actions that are standard for most projects. However, the specified materials and equipment, along with the skill level of labor, might not be available. In these cases, locally available equivalents must be considered, and this may well result in a modification of the specific treatment plan and, potentially, in a plan that is less effective.

A preservation project to stabilize the monumental standing adobe walls of an archaeological site will require the reconstruction of missing portions to ensure structural stability. The responsible preservation architect understands the issues and will supervise the actual preservation work. For example, the plan is to replicate the bonding pattern on the exposed surfaces and to change the original bonding pattern of stacked mud bricks to alternating courses of headers and stretchers on the interior of the walls. The workers begin by following the instructions but stop laying alternating courses of headers and stretchers after a few courses, in keeping with their different traditions and experiences. Should the preservation architect insist on alternating courses or accept the approach of the workers? The conservator must consider the effect it would have on the supervisory relationship with the workers to insist that the plan be followed exactly.

It must be recognized and incorporated into a treatment strategy that the causes of decay can, and frequently do, change with the passing of time. In some cases, the actual causes of decay might change and, in other cases, different materials and approaches may become available. A treatment strategy that is perfectly appropriate at one time may no longer be the best choice. In an area of extremely low annual rainfall, the erosion of the tops of walls might not be a significant issue, and the conservation plan may not include protective measures. That approach could very well change when local rainfall patterns increase.

Low earthen walls of an archaeological site have been subject to deterioration by people walking on the tops of the walls. Limiting access to the walls would be the optimum approach in mitigating this damage. At one location people could climb to the top of the high walls resulting in additional damage, as well as being a safety concern. Depending on the amount of rainfall, differential erosion of the original mud bricks below the mud brick cap could also be a factor and influence the treatment choice.

Human activity can also have indirect effects on the deterioration process. The Shunet el Zebib at Abydos is in the Nile valley, on the edge of the desert. A growing population in the area necessitated more irrigated land and, with the enlargement of the fields, there was a corresponding increase in birds that feed in the fields and nest in the mud brick walls. The erosion caused by the nesting birds has dramatically increased, and a conservation strategy to address the problem is critical. Potential options must consider not only the mitigation of the damage caused by the nesting birds but also how such a treatment might affect the surrounding environment.

The structural integrity of the mud brick walls at the Shuneh at Abydos was compromised by the loss of sections of walls, leaving many walls that were essentially freestanding, primarily from the collapse of the Coptic cells that were carved from the standing walls. The losses occurred over hundreds of years and resulted not only in the partial collapse of the Second Dynasty walls but also in the formation of vertical structural cracks across their thicknesses, approximately 1–2 m from the exposed ends of the walls. Over another few hundred years these cracks widened and the ends of the walls partially collapsed. The structural approach was to reconstruct a portion of the missing wall to serve as a buttress for the ends of the wall. In some cases, the height of the reconstructed portions were themselves several meters high, adding considerable weight to the original wall. Empirical on-site testing and additional engineering tests indicated that the capacity of the existing walls might not be adequate to support the additional loads. An engineered structural bracing system could have added the needed support and would not have appreciably compromised the bearing capacity on the existing walls. However, that approach would compromise the overall values of the monument. A solution to reconstruct portions of the missing walls might well result in some deformation to the original walls, a result that the conservator might have to accept. The decision would have been to proceed with the approach of adding new wall sections and accept the possible consequences (see fig. 2).

Capping mud brick walls with materials or a system that reduces the effect of erosion to the tops of exposed walls has been an acceptable intervention utilized at many locations. Even in the most limited applications of this approach, the conservator accepts that original material is lost. The normal erosion pattern results in a rounded, or slightly rounded, wall top and, depending on whether the top of the wall is leveled to accept the new protective cap or the top is stepped back for the installation, original material is lost. At the Shuneh in



FIGURE 3 Temporary sandbag buttresses supporting a wall at the Shuneh at Abydos undercut by nineteenth-century archaeological excavations. Photo: A. Crosby, 2005.

Abydos, we estimated that the original battered walls in 2700 BCE were 14–15 m high and, with some walls still 12 m high, we can estimate that the average rate of erosion is less than 1 mm/year. Establishing a base for a mud brick protective layer necessitated the removal of one to two partial courses of deteriorated brick, meaning that we were removing several hundred years of natural decay. We accept that the intent of the preservation program is to preserve the walls for centuries, not decades.

It is important that we also recognize the difference between a temporary solution and what is designed as a permanent solution. The large sandbag buttresses shown in figure 3 are intended as a temporary support for walls that had been undercut by archaeological excavation in the mid-nineteenth century, and they appear as such. Solutions intended to be temporary should look temporary. If not, they may indeed become permanent.

A practical conflict can arise when the architectural conservator is supervising site work while site archaeology is underway. An understanding of the site and its features is important prior to planning site conservation, but there is a benefit in the collaboration between the conservator and the archaeologist, as the interpretation of a feature might vary based on different backgrounds and experiences. The problem arises when the archaeology is not completed prior to the conservation work; treatment areas may have to be continually shifted if the archaeology and documentation continues longer than planned. When working on large monumental mud brick architecture, it is imperative that several work areas are simultaneously available as new mud brick masonry requires time to cure before applying additional loads.

The conservation work must be understood in the context of the overall site values. Treatments that compromise the most important values should be avoided. This is the most subjective aspect of architectural conservation, and here the architectural conservator will benefit from approaching the issue through the lens of a paintings conservator who speaks of retaining the unity of a painting and of treating the subject so that the interventions recede visually (Mora, Mora, and Philippot 1984). Our interventions should be identifiable but should similarly recede into the background. Figure 4 illustrates two different solutions to a structural problem.

Conclusion

The conservator of a mud brick site and its architecture faces many challenges in protecting both physical remains and their values. They must also respond to human needs of safety, accessibility, and interpretation. The first challenge is to understand the site so that its character and intrinsic/extrinsic values are identified and incorporated into a conservation plan. Initial values and interpretation of conditions can change once site conservation begins, as new information will inevitably surface, and adjustments will be necessary. Changes in site conditions, both human and environmental, will also warrant a reevaluation that could result in treatment compromises.

A conservation emergency might arise without the presence of an appropriate specialist, and someone must respond. Interactions with other conservation disciplines will also be factors in the final conservation of the site. It is all a complicated balancing act that must be negotiated, one that is the responsibility of both management and conservation.

Finally, a site and its architecture should be presented as a cohesive ensemble work of art. Within that treatment approach, the whole is protected, structural and visual deficiencies are addressed, and the site's patterns of evolution are respected and presented. The site and its architectural values should be the initial impression of an observer. A cohesive presentation of volume and massing of details and related associations and of scale and relationships to landforms and the environment should be the first impressions formed. After the initial awareness of the site's essence, the observer could then become aware of the conservation interventions. If the first impressions and the first thoughts are of



(a)



(b)

FIGURE 4 (a) Structural stabilization of a standing mud brick wall at Hierakonpolis, Egypt, and (b) a structural buttress of mud bricks supporting an unsound mud brick wall at the Shuneh at Abydos. Compare stabilization approach with (a). Photos: A. Crosby, 2012, 2019.



(a)



(b)

FIGURE 5 East wall of the Shuneh at Abydos, (a) prior to preservation intervention and (b) after preservation. Photos: A. Crosby, 2005, 2012.

conservation interventions, then the conservator has failed. If the final conservation approach responds to and presents the important values of the site, it has succeeded. It is as simple as that (fig. 5).

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How Will Earthen Architectural Heritage Be Represented on the World Heritage List by 2022?

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Abstract: *The first efforts to generate a list of earthen architectural heritage properties on the World Heritage List were undertaken in 2007, resulting in a selection of 106 properties. The list was updated and revised in 2011 in preparation for Terra 2012 (Lima), taking into account more criteria. In addition to structures, considerations included sites with load-bearing walls, rammed earth, adobe, cob, hand shaping, infill in wooden structures (wattle and daub), the use of earthen mortars to bind stones or burned bricks, roofs and floors often associated with wooden structures, exterior and interior coatings and paints, and extensive landscaping involving some level of engineering. The addition of these criteria led to the publication of a new list comprising 150 properties that included statistical information on geographic distribution, typologies, etc. In 2021, a similar exercise was undertaken within the framework of the World Heritage Earthen Architecture Programme (WHEAP) of the UNESCO World Heritage Center, taking into account information that had been received from some heritage conservators on the properties under their custody. Of course, this new exercise also involved the identification of such assets within the properties inscribed on the list up until 2021. As a result, the 2022 list comprises 203 properties. This paper presents updated statistical information for these sites (geographic distribution, predominant building techniques, building typologies, etc.), with a specific focus on the recent evolution of the list, resulting from new inscriptions. It also highlights the fact that 34% of the properties on the List of World Heritage in Danger are currently on this "earthen list," including unique cultural landscapes, major archaeological sites, and emblematic urban ensembles and monuments.*

Resumen*: Los primeros intentos por elaborar una lista de bienes del patrimonio arquitectónico de tierra para la Lista del Patrimonio Mundial se llevaron a cabo en 2007. Esa primera lista comprendía 106 sitios. Para Terra 2012 en Lima, se actualizó y revisó la lista en 2011 teniendo en cuenta más criterios. Además de las estructuras compuestas por muros de carga — tapial, adobe, tierra apilada, moldeado a mano y entramados (quincha o bahareque)— con muchas variantes, se consideró el uso de morteros de tierra para unir piedras o ladrillos cocidos, techos y pisos usualmente hechos con estructuras de madera, revestimientos y pinturas para exteriores e interiores, así como un importante paisajismo con cierto nivel de ingeniería. Todo esto llevó a publicar una nueva lista de 150 obras con información estadística sobre distribución geográfica, tipologías y más. En 2021 se realizó una tarea similar en el marco del WHEAP (Programa del Patrimonio Mundial para la Arquitectura de Tierra del Centro del Patrimonio Mundial de la UNESCO), teniendo en cuenta la información que se había recibido de algunos encargados del patrimonio, de los sitios bajo su custodia. Por supuesto, esta nueva tarea comprendió también la identificación de tales bienes dentro de los sitios inscritos hasta 2021. Como resultado, la lista del 2022 incluye 203 bienes. Esta ponencia presenta información estadística actualizada sobre esta lista (distribución geográfica, técnicas de construcción predominantes, tipologías de construcción, etc.), con especial atención a su evolución reciente a partir de las nuevas inscripciones. La ponencia también destaca el hecho de que, actualmente, el 34 % de los sitios en la Lista del Patrimonio Mundial en Peligro están en esta "lista de tierra", incluidos paisajes culturales únicos, sitios arqueológicos importantes, así como conjuntos y monumentos urbanos emblemáticos.*

Keywords: earthen architectural heritage, World Heritage List, inventory, representation, building technologies, architectural typologies, state of conservation, List of World Heritage in Danger

Introduction

Over the last fifty years, earthen architecture has been increasingly taken into consideration by heritage professionals (Joffroy and Guillaud 2017), resulting in numerous nominations and new inscriptions on the World Heritage (WH) List, some of which are among the best known on this prestigious list (fig. 1).[1] Efforts to prepare a formal inventory of earth-built properties within this list are rather recent, with a first attempt in 2007 resulting in the identification of 106 properties. The outcome of this first attempt was considered unsatisfactory by several experts and further work was launched within the framework of the first World Heritage Earthen Architecture Programme (WHEAP) in 2010. With more precise criteria for identification and selection, this exercise led to the development of a new list, published in 2012,[2] which included 150 properties, representing at the time 20% of the total WH List. Updates were carried out in 2015 and 2019, with the most recent revision after the 44th meeting of the World Heritage Committee in Fuzhou, China, in July 2021. This latest list now includes 203 properties, composing 17.6% of the total World Heritage List. However, in the meantime, and for various reasons, several of these properties have been inscribed on the List of World Heritage in Danger. Thus, earthen heritage properties now represent 34% of the properties on the List of World Heritage in Danger, including 51% of cultural properties in danger (eighteen out of thirty-five): a worrying situation.

Methodology and Criteria

Inventories aim to be as comprehensive as possible. Therefore, in 2011 and again in 2015, the criteria were revised by involving professionals from various cultural areas who have knowledge of the properties in their region. In fact, a major difficulty for the selection is that few properties are specifically nominated with reference to their building materials, but rather for other (outstanding) values. Thus, in many cases, a very detailed reading of the description of the property in the nomination file is necessary, and because sometimes the presence of earth is only assumed, this must be verified by contacting the site manager or institution in charge (fig. 2). Since 2015, properties are inscribed on this



FIGURE 1 The historic city center of Quito, Ecuador, inscribed on the World Heritage List in 1978. Photo: © CRAterre, T. Joffroy.



FIGURE 2 Main street of La Croix-Rousse, a neighborhood in Lyon and part of its World Heritage Sector. Photo: © CRAterre, S. Moriset.

inventory if earth is used for at least one of the following building components:

- Load-bearing walls: made from different techniques including rammed earth, adobe, cob, hand-shaped earth;
- Mortars: in stone or burnt brick walls;
- Filling of wooden structures: mainly in "wattle-and-daub" constructions, with many variations;
- Roofs and floors: in the form of vaults or domes, or in connection with load-bearing wooden structures;
- Coatings and paintings, exterior or interior;
- Large-scale landscaping works requiring specific technical solutions.

Properties where earth is not used specifically for the purpose of "building," making use of at least one of the intrinsic properties that the material has to offer in terms of cohesion, compressive strength, or water resistance (e.g., earth fills as part of foundations, wall bases, and gardens), are not taken into account. Conversely, the presence of earthen structures in the buffer zone has been considered where there are clear links with the assets within the core zone, thus contributing to the overall significance and understanding of the inscribed property (e.g., rock-hewn churches, Lalibela in Ethiopia, and M'Zab Valley in Algeria).

Results of the Latest Inventory (July 2021)

The last update of the inventory was achieved by adding the properties inscribed at the 44th session of the World Heritage Committee. The inclusion of these fifty-three new properties[3] led to a new total of 203 properties (fig. 3). This brings the proportion of earthen sites within the WH List to 17.6%, which is lower than in 2011 but similar to the situation in 2015. Over the past ten years, the change has come mainly from the Asian (+20, almost 45%) and Arab (+9) regions, with more modest contributions from Latin America (+6), Africa and North America (both +4), and Europe (+3).

As stated in the introduction, these new listings have had little effect on the proportion of earthen properties on the WH List, resulting in a slight reduction (from 20% to 17.6%). And while some efforts have been renewed during this period for greater recognition of earthen architecture in general, it is difficult to sense a specific trend other than the significant increase in the proportion of properties in Asia. Actually, the overall number of inscriptions each year has been reduced, which did not favor a radical change in representation. But what can be mentioned is the irregularity of these entries. Indeed, in 2014, fourteen new earthen sites were listed, whereas there were only two the previous year and only one in 2016. Another aspect is the tendency to nominate large groups of properties. A major example is the Silk Roads: the Routes Network of Chang'an-Tianshan Corridor, which includes properties in China, Kazakhstan, and Kyrgyzstan and groups many earthen architecture sites under one single inscribed property. Of particular note is the case of 2021, when properties already proposed in 2020 were also examined by the World Heritage Committee during its 44th session, resulting in nine new inscriptions of properties with earthen structures.

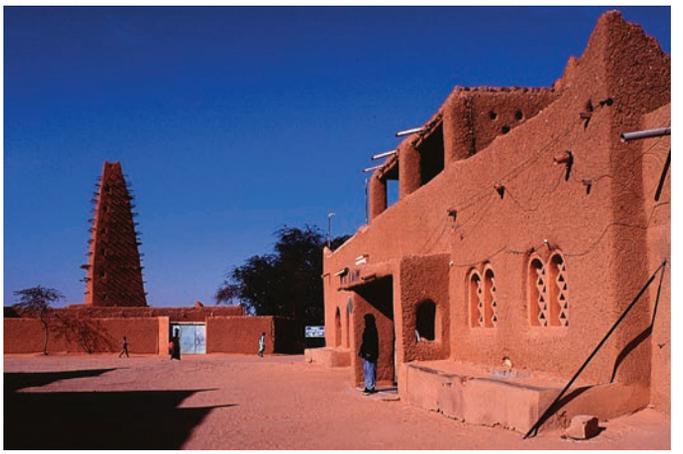


FIGURE 3 The historic center of Agadez, Niger, inscribed in 2013. Photo: © CRAterre, T. Joffroy.

In terms of the building techniques' representation, or their presence in the structures and heritage categories (Jokilehto et al. 2005), the proportions also remain similar, with a predominance of Historic Ensembles and Archaeological Sites (34%), Historic Cities (28%),[4] and Monuments (27%).

With regard to the criteria[5] proposed and recognized by the Committee, there is also still a predominance of criterion iv (72%), with criteria iii (58%), ii (49%), and v (24%) having moderate representation, and very rare use of criteria vi and i. This results from the fact that earthen architecture sites are mostly archaeological sites (fig. 4) or best examples of traditional/vernacular architectures (fig. 5). This specificity is clearly linked to the progressive consideration of the notion of cultural landscape, as building with earth is often an opportunity to carve the land chosen to establish settlements through the careful choice of locations for the extraction of the large volumes of earth often required. This may also illustrate that the choice of location for a settlement would have taken



FIGURE 4 The great Kyz Kala, Merv, Turkmenistan, under restoration; 2015 campaign. Photo: © CRAterre, G. Gandreau.



FIGURE 5 Koutammakou, the Land of the Batammariba in Togo, inscribed as a cultural landscape in 2004. Photo: © CRAterre, T. Joffroy.

into account the availability of this important resource, representing as much as the criteria of water availability or natural security.

The distribution of the criteria also illustrates the fact that the values presented rarely refer to the use of the building material itself. In some cases, the presence of earth is not properly quoted, if not totally absent,[6] leading to the misinterpretation of the role that earth, as a ready-made building material, has played in facilitating the rapid development of many settlements around the world. Moreover, this underrepresentation often leads to conservation problems as the specificities[7] of this building material are not sufficiently taken into account in the conservation process. There is also often confusion



FIGURE 6 Maintenance of the Friday mosque in Bandiagara, Mali, by members of the local community under supervision by their master masons; May 2007. Photo: © CRAterre, T. Joffroy.

about the building techniques used historically, which sometimes leads to inappropriate conservation decisions. As for the rare use of criterion vi, it could illustrate the persistence of an insufficient consideration of the intangible aspects of the listed properties. In the field of earthen construction, this is probably a weakness considering the important role of communities in the proper maintenance and conservation of built structures (fig. 6). Although this is a long-standing situation, it is surprising that the efforts of international organizations (UNESCO, ICOMOS, ICCROM) to promote the role of local communities seem to have so little impact.

Inscription on the List of World Heritage in Danger

In 2012, we wrote:

> Earth architecture plays a vital role in defining the identity of local communities, involving sustainable building techniques and often conveying true artistic expression. There is a growing interest in its ability to contribute to social, ecological and cultural development. However, earthen architecture is increasingly affected by natural and human threats, including floods and earthquakes, damage caused by industrialization, urbanization, modern building technologies, disappearance of traditional conservation practices, etc. It is thus not surprising that about ¼ of sites included on the World Heritage List of Sites in Danger are earthen sites. (Joffroy, Gandreau, and Delboy 2012, 6)

In 2021, this situation unfortunately changed drastically with the proportion of earthen properties on this list reaching 34%, resulting from the emergence and establishment of new threats linked either to climate change or to conflict and post-conflict situations, in many cases adding to already fragile situations due to some level of poverty. Currently, most of the earthen properties on this list, fourteen of eighteen, are in countries affected by conflicts: Afghanistan, Iraq, Libya (fig. 7), Mali, Syria, Venezuela, and Yemen. The impact of conflict, particularly in countries that were already struggling to meet their protection and conservation responsibilities, is tremendous, with some situations at high risk. For example, during the occupation of Timbuktu, Mali, by armed groups, no maintenance for the three old mosques of the WH property could be organized and a large majority of the listed mausoleums were destroyed. Fortunately, the Malian government and UNESCO (with the support of the international community) were able to organize emergency work, but the long-term conservation of these monuments depends on the goodwill of the local populations and their ability to plan for maintenance. But such interventions are not possible in all the places concerned, and with limited resources—due, in some part, to the total disappearance of tourism activities during times of conflict—what can people and institutions do? The current tendency of these conflicts is that they are prolonged, often with less intensity. This type of permanent insecurity is a major hindrance to the reestablishment of favorable conditions for the preservation, maintenance, and, especially, the proper conservation of many heritage sites.

Continuities of the Dynamics

On a positive note, there is now a worldwide revival of interest in earthen architecture as a discipline. Not only is its character—as a symbolic expression[8] of the human capacity to build and make the best use of the resources available in the nearby environment—widely recognized, but earth is also increasingly seen as a potential resource for achieving some of the United Nations' Sustainable Development Goals. While this requires specific research and the multiplication of formal training,[9] the role of heritage sites is essential. Generally built with few resources (tools, equipment, transport), they are often very good examples of how to build a settlement with frugality, one of the concepts promoted by the international community to mitigate our impact on our planet (Radjou and Prabhu 2015).

In this respect, and in addition to these sites being living spaces and sources of income through tourism activities, earthen World Heritage properties also have a great potential as examples of past best practice in earthen architecture: location, implementation, (town) planning, design, organization and management, construction techniques, technical details, maintenance, and adaptation(s). From these different aspects of property production, we can use reverse engineering (fig. 8) and design processes that allow us to benefit from



FIGURE 7 The old town of Ghadames, Libya, inscribed in 1986, and on the List of World Heritage in Danger since 2016. Photo: © CRAterre, T. Joffroy.



FIGURE 8 The old city of Yazd, Iran, inscribed in 2017, currently subject to reverse-design works in view of developing adaptations to contemporary needs. Photo: © CRAterre, T. Joffroy.

the long-lasting knowledge behind these outstanding heritage properties, while providing possibilities for reinterpretation with contemporary means (materials and techniques) to adapt to today's needs and expectations.

Many organizations are now working on this concept, responding to the UNESCO recommendation for the historic urban landscapes approach. A major example of such initiatives is the one undertaken in Iran, which brings together organizations such as UNESCO, ICOMOS, and the Iranian Cultural Heritage, Handicrafts and Tourism Organization (ICHHTO), along with the municipality of Yazd, with substantial contributions from CRAterre, as well as the universities of Yazd and Grenoble (ENSAG). Sponsored by the European Union, this development project includes several complementary activities aimed at identifying the strengths and weaknesses of heritage structures in order to propose and implement both revitalization and new construction projects. The University of Yazd's main role is to promote the continuing education of architects but also of engineers and craftspeople. Similar projects have been carried out by UNESCO-WHC in Cuenca, Ecuador, and Timbuktu, Mali, while a major new project is also being facilitated by ALIPH[10] at the Tombeau des Askia in Gao, Mali. Other initiatives are carried out within the UNITWIN/UNESCO Chairs Programme[11] and by ICOMOS-ISCEAH.

Conclusion

Thanks to more than a fifty-year effort by a growing number of professionals around the world, there is an increasing awareness of earthen architecture. The fact that earth is one of the oldest building materials is of course reflected in the composition of the World Heritage List and, over the last ten years, its presence has stabilized with a representation between 17% and 20% of the total number of properties therein. An important evolution since the first inscription in 1978 is that today the presence of earth as a building material is almost systematically mentioned, even if its presence does not necessarily contribute to the Outstanding Universal Value of the property inscribed on this prestigious list. However, this was not necessarily the case for past inscriptions, which may have led to situations that were not conducive to a good understanding of the specific conservation approaches, methodologies, and practices to be followed. Nevertheless, the latter have been studied in specific projects such as Gaïa (undertaken by ICCROM and CRAterre) and Terra (ICCROM, CRAterre, and GCI), with continuities in the Terra series of conferences that culminated in 2016 in the establishment of the Declaration of Lyon, which sets out both general and specific recommendations for the identification, protection, appropriate conservation, and enhancement of earthen architectural properties.

In spite of a situation that seems on the whole quite positive (recognition, practices) for earthen architectural heritage inscribed on the WH List, there is a recent evolution that is worrying. With eighteen properties, earthen architecture represents 34% of the properties inscribed on the List of World Heritage in Danger, and this number rises to 51% when only cultural properties are considered. This situation seems to be strongly linked to the fact that many of the properties concerned (fourteen out of eighteen) are located in areas exposed to climate change or are in areas where armed conflicts have occurred and/or are ongoing. This, combined with the fact that most of these properties are urban historic centers and are located in areas with development difficulties, unfortunately confirms the relevance of the three axes[12] that were set in 2018 for the second phase of the World Heritage Earthen Architecture Programme (WHEAP; UNESCO/WHC-CRAterre). Terra 2022 and the series of seminars to be organized on the occasion of the fiftieth anniversary of the 1972 Convention will provide new opportunities to discuss these three topics and possibly raise more specific issues to be addressed over the next decade. These will include the likely identification of issues strongly related to the need to anticipate climate change, as well as those issues related to practices that better promote the implementation of sustainable development goals, taking better advantage of the potential of earthen architecture around the world.

Notes

1 First inscriptions in 1978: City of Quito (Ecuador) and Rock-Hewn Churches, Lalibela (Ethiopia). In 1979: Ancient City of Damascus (Syria) and Ancient Thebes with its necropolis (Egypt).

2 On the occasion of Terra 2012: 11th International Conference on the Study and Conservation of Earthen Architectural Heritage, organized in Lima, Peru, by the International Scientific Committee on Earthen Architectural Heritage (ISCEAH) and the Peruvian Ministry of Culture.

3 This includes nine properties inscribed in 2021, thirty-seven properties inscribed since 2015, and seven already on the list before 2011 for which evidence of the use of earth has been recently demonstrated.

4 This percentage needs to be understood with the presence of several typologies at the same properties.

5 List of criteria available at: https://whc.unesco.org/en/criteria/.

6 For example, Ancient Thebes, with its necropolis in Egypt; the Historic Site of Lyon, France; and Sukur Cultural Landscape, Nigeria.

7 Knowing that, historically, conservation practices are often linked to prevention or regular maintenance practices that are important to take into account when willing to intervene with best results in terms of authenticity (Joffroy et al. 2005).

8 See WHEAP presentation flyer (Eloundou and Joffroy 2008).

9 To compensate gradual disappearance of traditional modes of knowledge and the transmission of know-how.

10 ALIPH is the Alliance internationale pour la protection du patrimoine dans les zones en conflit, https://www.aliph-foundation.org/.

11 https://terra2016.sciencesconf.org/.

12 Those axes are: (1) architectural earthen heritage in post-disaster situations, (2) historic city centers built in earth, and (3) earthen heritage and sustainable development.

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PART 3

Advances in Research / Avances en la investigación

Micro-CT Evaluation of Calcite In Situ Precipitation System (CIPS) in the Consolidation of Earthen Cultural Materials

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Abstract: *In 2005, the archaeological remains of two Chinese miners' huts at Butchers Gully, Castlemaine, Australia, were consolidated using a novel calcite in situ precipitation system (CIPS). The treatment did not change the color, texture, or appearance of the clay-rich soil material used to form the walls of the huts. After fifteen years of exposure to the local weather, visual observations indicate that the clay walls of the two huts remain in much the same condition as they were after treatment, with no signs of further erosion. In this paper, we examine how CIPS works to create greater particle cohesion by looking at changes in the porosity and density in two granular materials: a loose quartz sand and a clay-rich soil from Butchers Gully. Cementation in once- and twice-treated samples was evaluated by comparison to untreated samples (controls) using X-ray computed tomography to record—via scanned images and profiles—changes in volume fractions of porosity (open pore spaces) and low- and medium-density phases (calcite cement) throughout the samples after the first and second CIPS treatments. Results show that the first treatment decreased the porosity and increased the proportion of calcite precipitate and that the second treatment further changed these parameters. CIPS is therefore an effective treatment for stabilizing earthen cultural materials, suggesting that improvements in erosion resistance can be gained by more than one treatment. Furthermore, the method has the added advantages of being nontoxic and water soluble, reducing the hazards and risk to humans and the environment.*

Resumen: *En 2005, los restos arqueológicos de dos viviendas de mineros chinos en Butchers Gully, Castlemaine, Australia, se consolidaron mediante el uso de un nuevo sistema de precipitación de calcita in situ (CIPS). El tratamiento no produjo cambios en el color, la textura ni la apariencia del material de suelo rico en arcilla que se utilizó para construir los muros de las viviendas. Luego de quince años de exposición a las condiciones climáticas locales, las observaciones visuales indican que los muros de arcilla de las dos viviendas se mantienen en casi las mismas condiciones que justo después del tratamiento, sin signos de avance de la erosión. En este artículo, examinamos cómo trabaja el CIPS para crear una mayor cohesión de las partículas mediante la observación de los cambios en la porosidad y la densidad de dos materiales granulares, una arena de cuarzo suelta y un suelo rico en arcilla de Butchers Gully. La cementación en muestras tratadas una y dos veces se evaluó por medio de tomografías computarizadas de rayos X para registrar, con imágenes y perfiles escaneados, cambios en la porosidad en fracciones de volumen (espacios porosos abiertos) y fases con densidad baja y media (cemento de calcita) en las muestras después del primer y segundo tratamiento con CIPS, comparadas con muestras sin tratar (controles). Los resultados demuestran que el primer tratamiento disminuyó la porosidad y aumentó la proporción de precipitado de calcita, y que el segundo tratamiento produjo una modificación aún mayor de estos parámetros. Por lo tanto, el CIPS es un tratamiento eficaz para estabilizar los materiales patrimoniales de tierra, pudiéndose alcanzar mejoras en la resistencia a la erosión al realizar más de un tratamiento. Asimismo, tiene otras ventajas, como el hecho de que no es tóxico, es soluble en agua y no modifica la apariencia del material original.*

Keywords: conservation, archaeological sites, calcite in situ precipitation system (CIPS), consolidation, micro-CT

Introduction

In 2005, the archaeological remains of two Chinese miners' huts were treated with a new calcite in situ precipitation system (CIPS). The two huts sit on the northern bank of Butchers Gully, an ephemeral creek 11.5 km south of Castlemaine in Central Victoria, Australia. The remains of the huts had been exposed two years earlier in an archaeological assessment project. The lower courses of their walls are composed either of a packed local clay-rich soil or of locally sourced rocks assembled with the same packed soil as a mortar and, in places, as a surface render (Price, Bannear, and Jamieson 2008).

When first uncovered, it was obvious that the wall remains were being actively eroded, with loose soil scree present at their bases. Their erodibility was evaluated using spot water spray tests, as described in previous studies (Price, Bannear, and Jamieson 2008; Loo et al. 2017). In brief, a simple method was developed to measure the rate at which the clay matrix and pebbles were physically washed off the wall surfaces during a simulated rain event. Using a handheld spray wand, water was sprayed from a fixed distance, at an angle of incidence, and at a set flow rate and pressure (80 mL of water over 10 s applied to a circular area of 78.5 cm^2). Clay and pebble debris that washed off eleven small vertical sections of the walls was collected. CIPS treatment was then applied by hand, spraying the wall surfaces until no further CIPS fluid could penetrate. Based on visual observations, depth of fluid penetration was estimated at about 10 mm. The walls were left uncovered until they were reexamined in 2019, when it was revealed that they were in much the same condition as they were immediately after CIPS treatment, with no evidence of any significant new erosion or change in appearance.

Given their diversity and complexity, and despite the abundant research in this area, there are still difficulties in the conservation of earthen cultural materials (Avrami, Mason, and de la Torre 2000). The most common methods used in the conservation of earthen architecture have been borrowed from other associated sub-disciplines such as masonry and stone conservation, but these have proven to be unsuitable due to the very different natures of their material requirements (Warren 1999; Avrami, Guillaud, and Hardy 2008). In this paper, we briefly describe the chemical components of CIPS and the chemical reactions that produce the cementation component—the mineral calcite. We also demonstrate that CIPS-produced changes in the porosity and distribution of calcite precipitate inside samples of two granular materials using micro computed X-ray tomography (micro-CT).

Materials and Methods

CIPS Chemicals and Reaction Process

CIPS was developed as an in situ cementation method by one of the authors, Graham Price (Price, Bannear, and Jamieson 2008; Price 2013). It is a water-based chemical process for cementing loose, unbonded particulate materials such as sands, soils, sediments, and weak porous rocks, transforming such materials into bonded aggregates with considerable strength. Multiple CIPS treatments can produce strengths comparable to that of natural rocks or industrial concrete (Price 2013). The method begins as two equal volumes of separate solutions, A and B, are mixed immediately prior to application to form a charged fluid. Solution A contains the reaction chemicals: water, calcium chloride ($CaCl_2$), and urea ($(NH_2)_2CO$). Minor additives of sodium ethylenediaminetetraacetic acid (EDTA), sodium sulfite, and sodium carbonate remove heavy metals, sterilize the solutions, and help keep the pH around neutral, respectively.

For an application, the charged CIPS fluid is permeated into the target material, either by pressure injection at depth or by surface spraying and permeation under gravity and capillary action. The objective is to fill all open pore spaces between the constituent particles and then allow a sequence of chemical reactions to proceed without disturbance.

The reaction steps are as follows: (1) the urease-catalyzed hydrolysis of urea to form carbamate ions ($NH_2CO_2^-$), (2) the hydrolysis of carbamate ions to form carbonate ions (CO_3^{2-}), (3) carbonate ions combine with calcium ions (from the calcium chloride) to form calcium carbonate molecules ($CaCO_3$), and (4) once the concentration of calcium carbonate in solution exceeds its solubility limit, it precipitates as thin rinds of small calcium carbonate crystals (calcite) on the outer surfaces of the particles that constitute the target material.

The chemical reactions are stoichiometric, so concentrations of calcium chloride and urea were chosen to produce a conveniently large mass of calcite. The first reaction must be catalyzed by the enzyme urease, which was extracted aqueously from finely ground Jack beans (*Canavalia ensiformis*). The amount of urease and its corresponding enzymatic activity were chosen so that the reaction rate was slow enough to allow the calcite crystals to grow to an optimal size that would reach between adjacent particles inside the target material and form effective cementation bonds. The amounts and concentrations selected produced 125 g of calcite from each liter of the charged CIPS fluid in two hours.

Important features of CIPS are that the calcite crystals grow only on the particle surfaces and do not fill the pore spaces between grains, and that cementation bonding only occurs where the thin crystal rims of adjacent particles intergrow and lock together, forming crystal bridges (Price 2013). This means that more than one CIPS treatment can be applied, with each treatment further increasing the material's strength.

CIPS-Treated Materials and Application Method

Two types of materials were selected for testing: (1) a loose clean quartz sand (QS) of only one grain size and (2) clay-rich soil from Butchers Gully (BG Soil). A sample of each material was tightly packed up to the very top into 15 mL polypropylene Falcon tubes. These were then scanned using micro-CT, with the first scan (Scan 1) of the untreated materials as the control. These were subsequently treated with CIPS by pouring 5 mL of the CIPS fluid into the top of each tube, allowing it to penetrate into the top several centimeters of the material, after which the samples were left to dry for seven days before being scanned again by micro-CT (Scan 2). This process was then repeated for both samples and a second CIPS treatment was applied to these using the same technique before being scanned a third time (Scan 3).

Micro Computed Tomography

The top 14 mm section of each sample was analyzed using micro-CT. Samples were scanned with an X-ray energy of 60 kV and 300 Å wavelength at a resolution of 10 µm and run for twelve minutes in fast scan mode, collecting 1558 projections through a 360-degree rotation of the specimen. Volume reconstruction of the micro-CT data was performed using Phoenix Datos|x reconstruction software (Waygate Technologies), applying an inline median filter, region of interest (ROI) filter, and beam-hardening correction during reconstruction. The data were exported as 32-bit volume files for imaging and analysis in Avizo (Thermo Fisher Scientific).

Micro-CT images of the treated samples were roughly registered to the initial images of the samples by aligning their material/air interfaces. A watershed segmentation tool (Beucher and Meyer 1993) built into Avizo was used to segment four different phases representative of different material densities: (1) zero density = porosity (black phase), (2) low-density solids (dark gray phase), (3) intermediate-density solids (light gray phase), and (4) high-density solids (bright gray to white phase). The same initial thresholds were used for each scan as input to the watershed algorithm so that the phase segmentations would be comparable.

Results and Discussion

Figure 1 shows vertical cross sections through the micro-CT data collected for the untreated (control) and once- and twice-treated samples. The top row of images includes the QS samples (figs. 1a–c) and the lower row are the BG Soil samples (figs. 1d–f). In all images, black areas represent cavities, pore spaces between quartz grains, or cracks in the clay-rich material. White and gray areas represent mineral grains of different sizes and densities, such as individual quartz grains in the QS sample and the fine-grained, clay-rich soil matrix in the BG Soil sample.

The calcite grains produced by CIPS treatment cannot be directly seen due to their small size, typically less than 10 µm, but their effect can be recognized in two ways: in the Scan 2 and Scan 3 images as a general increase in the brightness of the CT gray value of an area or by comparing the entire sample to the Scan 1 control images. Two examples of this increased brightness in CT value can be seen in figures 1b and 1c. A fine-grained bright patch can be seen slightly above and left of center in figure 1b. This area is noticeably brighter in figure 1c, representing a further increase in the amount of calcite precipitation after CIPS treatment. The increased brightness was obvious only in this area, indicating that CIPS treatment may not have been homogeneous throughout the sample, a common problem in a simple surface application without any way to encourage uniform permeation. However, further higher-resolution techniques such as SEM would be required to confirm this.

The effectiveness of CIPS cementation can also be seen in figures 1e and 1f when compared to figure 1d. In figure 1d, the larger grains are relatively light, whereas the fine-grained soil matrix is notably darker. In figure 1e, the matrix is notably brighter, indicating an increased density caused by the presence of calcite from the first CIPS treatment. In figure 1f, the matrix is even brighter still, indicating a further increase in density caused by the presence of even more calcite precipitation from the second CIPS treatment. Furthermore, in figures 1e and f, there are several horizontal and vertical thin black wavy lines that were not in the untreated BG Soil sample. These cracks are likely to have formed when the samples dried after CIPS application due to the characteristics of the clay material. However, further testing with other materials is required for validation.

Figure 2 presents the volume fractions of the different density phases in the micro-CT data for Scans 1–3 of the QS (fig. 2a) and BG Soil (fig. 2b) samples plotted against depth from the upper material/air interface.

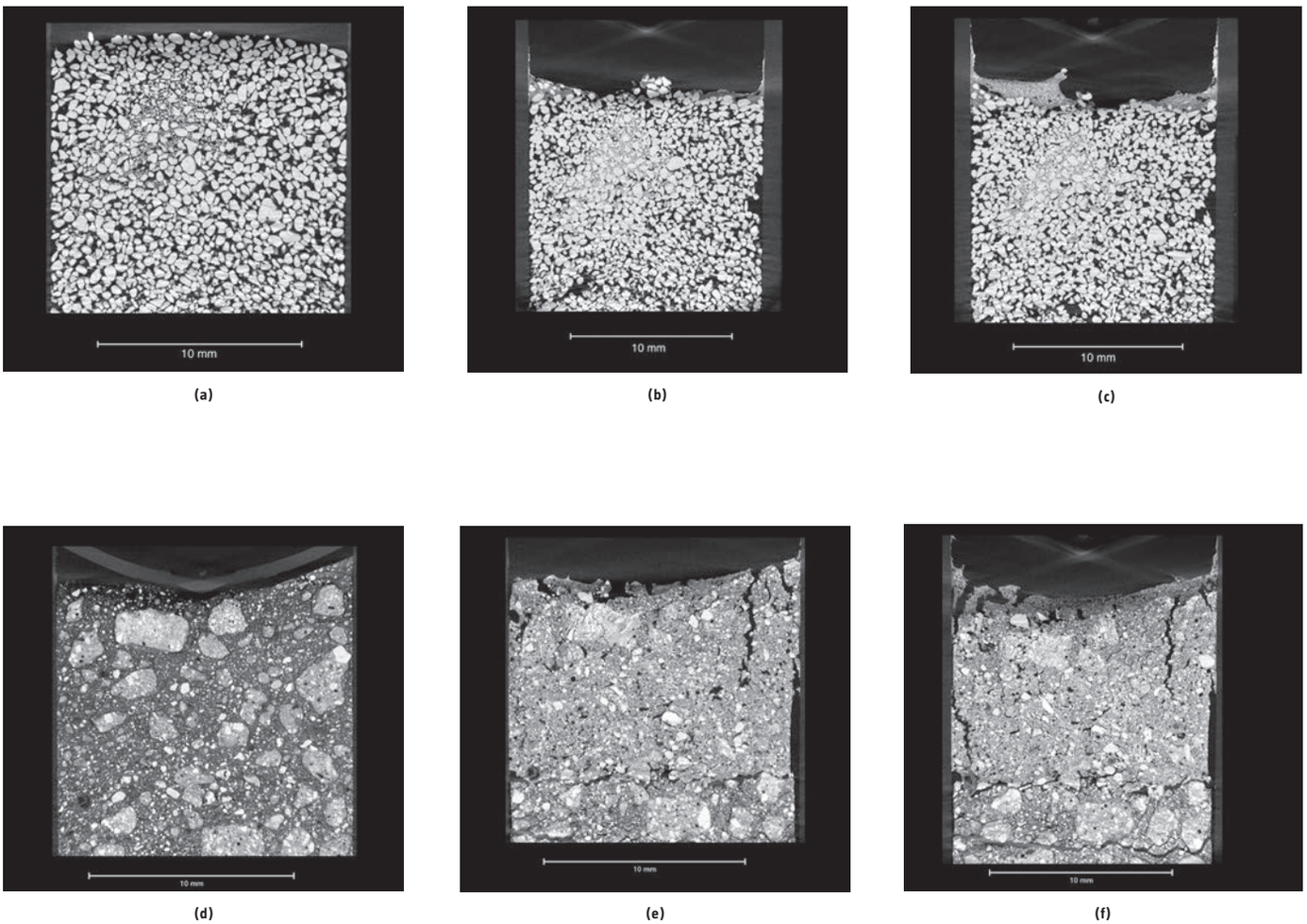
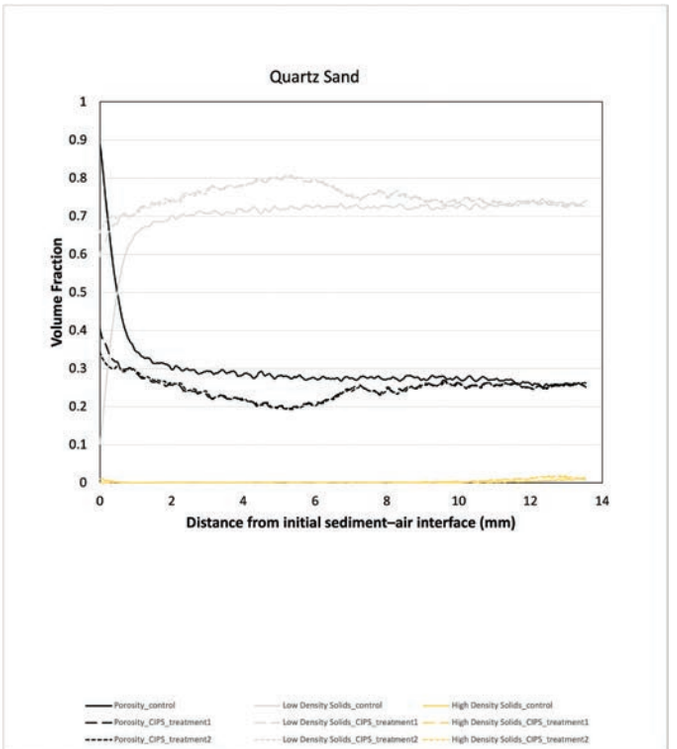


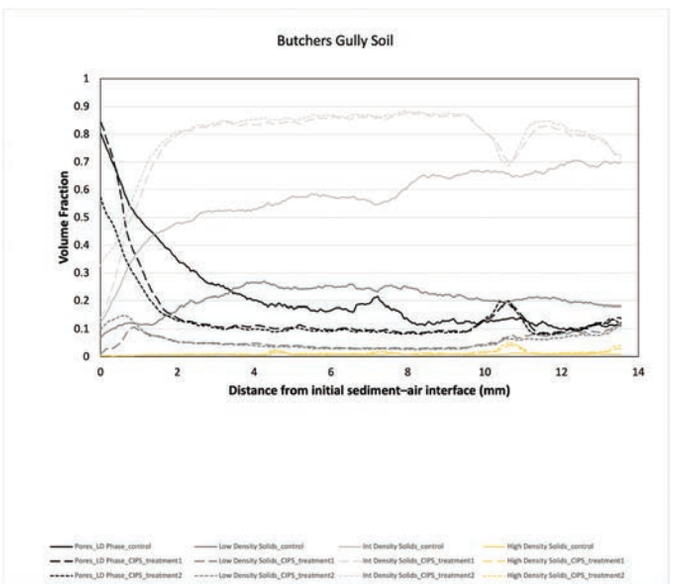
FIGURE 1 A vertical cross-sectional slice through micro-CT scans of the quartz sand (QS, top row): (a) QS untreated (control, Scan 1), (b) QS treated once with CIPS (Scan 2), (c) QS treated twice with CIPS and Butchers Gully Soil (BG Soil, bottom row) samples, (d) BG Soil untreated (control, Scan 1), (e) BG Soil treated once with CIPS (Scan 2), and (f) BG Soil treated twice with CIPS (Scan 3). Scale bar is the white horizontal line = 10 mm.

Figure 2a shows that the volume fraction of porosity in the QS quickly dropped as the depth increased, plateauing around 0.3 or 0.2 mm at a depth of around 1.0 mm and beyond. The volume fractions of low- and intermediate-density phases behaved differently, quickly rising from zero at the material/air interface to plateau around 0.7 mm at ~0.2–0.5 mm depth and beyond. The data indicate that there are minor inclusions of high-density phases in the QS samples, the volume fraction of which was relatively unchanged after CIPS treatment. The presence of calcite precipitate from both CIPS treatments is indicated by a change in the volume fraction values of the low- and intermediate-density phases, which increased relative to the control in both the once- and twice-treated samples.

Figure 2b shows that the porosity in the untreated control sample of BG Soil decreased from 0.8 to around 0.2 mm at a depth of 4 mm, thereafter varying somewhat as cracks were passed toward the bottom of the scanned sample. A horizontal crack through the material is apparent in figure 2b as a small peak in the porosity and a trough in the intermediate-density phase at a depth of ~10.5 mm. The change in porosity in the top ~2 mm may be more a reflection of the uneven material/air interface, as air above the sample was included as part of the area masked for analysis and included in the estimate



(a)



(b)

FIGURE 2 Graphs showing the volume fractions of different density phases from the micro-CT data for the control, (a) once- and twice-treated Quartz Sand and (b) BG Soil plotted against depth from the upper material/air interface. Different treatments are represented by line type: initial control = solid lines; first CIPS treatment (long dashed lines); second CIPS treatment (short dashed lines).

of porosity. The change in volume fraction of the low- and intermediate-density phases in the BG Soil sample is a reflection of the consolidation of low-density clay matrix material (decreasing from ~0.2 to 0.05 after treatment) into the intermediate-density phase (increasing from ~0.6 to ~0.85 after treatment). This may be an indication of the presence of calcite precipitate from the CIPS treatment consolidating the material.

Because this study was limited to two types of sample materials, the results may not be representative of how CIPS would interact with other earthen materials. Nevertheless, these preliminary observations indicate that CIPS may be effective at consolidating clay-rich materials into higher-density substrates. Further studies are needed to improve the application technique and understand the finer-scale effects of CIPS treatment on different materials.

Conclusion

The changes in volume fractions of low- and intermediate-density phases in the once- and twice-treated BG Soil in figure 2b clearly match the increased brightness in the CT value of the fine-grained matrix of the BG Soil sample, as seen in figures 1d–f. Both the micro-CT images and the graphs show the presence and distribution of calcite precipitate produced by CIPS treatment. Although our results should be taken as preliminary and in need of replication, they do provide interesting insights into this treatment method.

The observation that the wall remains at Butchers Gully have not been significantly eroded since treatment with CIPS is probably due to the presence of calcite cement within the soil matrix. The micro-CT analysis results demonstrate that the particles and grains in the clay-rich parts of the walls were consolidated by the CIPS treatment and thus may help reduce the rate at which erosion occurs. Furthermore, the results show that a second CIPS treatment is likely to be even more effective at reducing the rate of erosion. Because CIPS is nontoxic, water-soluble, and does not produce any changes in the appearance of the treated material, it has the potential to be an effective method for the consolidation of earthen materials.

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An Investigation into the Potential Use of Time Domain Reflectometry (TDR) Measurement Systems to Accurately Assess the Moisture Content at the Center of Completed Earthen Walls

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Abstract: *As the impact of high moisture levels in the interior of an unbaked earthen wall can lead to structural, thermal, infestation, and durability problems, it is important to establish realistic moisture measurements from the centers of load-bearing earthen walls. With the increase in use of Time Domain Reflectometry (TDR) and similar soil probe sensors, there is a need to understand how well modern moisture detection systems perform. The work described in this study is supported by the EU CobBauge project and investigates the performance of in situ sensors embedded in the interiors of experimental earthen walls.*

Resumen: *Los niveles altos de humedad en el interior de un muro de tierra pueden provocar problemas estructurales, térmicos, de infestación y de durabilidad; por ello, es muy importante establecer mediciones realistas de la humedad desde el núcleo de los muros de carga construidos con tierra. Con el aumento del uso del reflectómetro de dominio del tiempo (TDR) y los sensores de suelo por sonda de usos similares, se hace necesario comprender el desempeño de los sistemas modernos de detección de la humedad. En el trabajo que se describe en este estudio, que cuenta con el apoyo del proyecto CobBauge de la Unión Europea, se investiga el desempeño de sensores incrustados en el interior de muros experimentales de tierra.*

Keywords: moisture, earth, cob, CobBauge, light-earth, sensors, measurement

Introduction

When conserving or enlarging historic buildings, the ability to improve a fabric's thermal performance is often limited by the traditional nature of the original material. This limits the ability for historic buildings to adapt to our changing climate. Following greater awareness of the climate emergency, there is a growing argument that traditional building materials and methods should evolve to become more climate resilient. While traditional cob has inherent thermal qualities, its inability to meet stringent thermal insulation standards is the rationale behind this study.

The CobBauge walling system is one iteration of the traditional cob building technique to allow cob and other historic earthen building methods to conform to many countries' thermal building regulations. The moisture content of earthen walls has a well-known impact upon the development of wall strength and corresponding rates of shrinkage when repairing and extending historic earthen buildings. There is a known relationship between the density and thermal conductivity of earthen walls (Volhard 2016; Minke 2000), yet the ability to safely construct an earthen wall system that incorporates two layers of different densities to improve the thermal performance of historic earthen buildings raises questions concerning differential shrinkage. To assess the shrinkage, this research develops a methodology that can be used to investigate moisture distribution and shrinkage movement within an innovative composite cob walling system (CobBauge) that can be used to repair or extend historic earthen structures.

Objectives

- To design a moisture measurement system that uses Time Domain Reflectometry (TDR) probes and can be placed within existing, upgraded, and extended composite earthen walls;
- To analyze the impact upon accuracy of positioning of TDR sensors in an earthen wall;
- To compare the shrinkage of small-scale samples with a full-scale CobBauge wall throughout the build process in relation to the moisture readings provided by the TDR moisture measurement system.

Literature

The impact of high moisture levels on the interior of an unbaked earthen wall, both in repairs and in extensions of historic earthen buildings, can lead to movement and shrinkage (Goodhew et al. 2021; Jaquin and Augarde 2012; Pearson 2015; Warren 1999). This issue is particularly pertinent when assessing the shrinkage of and between two vertical layers of different densities of earth and fiber material within the CobBauge wall. It is therefore important to establish realistic moisture measurements from the centers of load-bearing earthen walls and relate those to measured shrinkage.

Researchers have utilized different in situ moisture measurement techniques for appropriate conservation of earthen building materials (Pinchin 2008), specifically the dowel method (Ridout and McCaig 2016) and wood block sensors (Carfrae et al. 2011; Goodhew, Griffiths, and Woolley 2004). With the increase in use of TDR and similar soil probe sensors (Lekshmi et al. 2018; Sinha et al. 2017), there is a need to understand how well modern moisture detection systems perform when located at the center of a 600 mm earthen wall.

In association with these moisture measurements, the authors will build on the work that has focused wholly or in part upon the shrinkage of earthen walls and plasters/renders (Hamard et al. 2013).

Methodology

The CobBauge construction system comprises two layers of cob with different material densities (Goodhew et al. 2021). One 300 mm layer is composed of low-density "thermal" cob (50% fiber by dry weight), with the other 300 mm layer composed of high-density "structural" cob (2.5% fiber by dry weight). The aim of this composite construction is to provide a new version of traditional cob that meets thermal and structural building standards. However, questions remain over how the two cob materials respond to differential drying and shrinkage. The experiments in this paper seek to investigate the moisture content and shrinkage rate of a trial wall over a three-month period, from August to November 2020. To measure moisture and shrinkage, a CobBauge experimental wall (600 mm thick, 700 mm high, and 3000 mm long) was constructed with a mesh formwork in a well-ventilated laboratory at the University of Plymouth, Devon (fig. 1).

As the wall was being constructed, two different soil-specific TDR moisture sensors were set into the low- and high-density cob layers: one 0.5 m long SoilVue10 sensor and three CS655 sensors, both of which are typically used to monitor the moisture content of ground-based soils, though similar TDR sensors have previously been used on earthen constructions with good success (Chabriac et al. 2014). Both types were



FIGURE 1 The experimental CobBauge wall and construction process in the background. Photo: University of Plymouth (CobBauge project), Lloyd Russell.

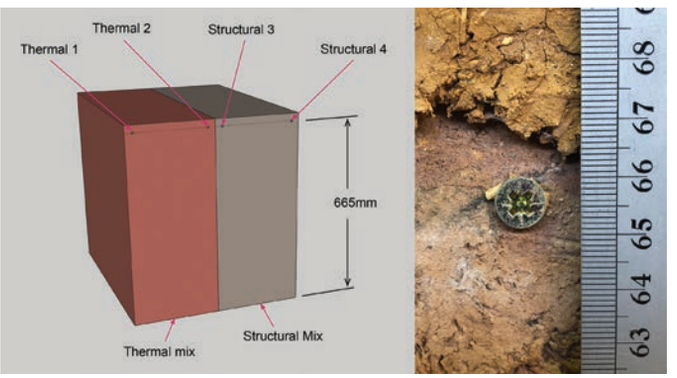


FIGURE 3 3D representation (left) and photo (right) of screw locations for measurement (mid-experiment). Photo: University of Plymouth (CobBauge project), Jim Carfrae.

connected to a Campbell CR1000X data logger via an SDI-12 protocol. This was programmed to record volumetric water content (VWC) every fifteen minutes. All the sensors were located 350 mm from the ground, which was at the midpoint of the lift. Figure 2 shows the TDR sensors located within the trial wall before being buried. Two different TDR sensors were used to verify results and compare measurement methodologies. Internal laboratory conditions were recorded using a HOBO MX1011.

A variety of methods were used to measure the shrinkage rate over the three months of the trial wall. For reasons of clarity in the context of this paper, we are using the results from four threaded construction screws embedded into the wall. These were inserted across the width of the wall at approximately 665 mm (fig. 3). As a shrinkage reference, a series of six representative 300 × 150 mm diameter cob cylinder samples were made of the same material.

Results

Cylinder Samples

Initial results from the cylinder samples found that the high-density cob cylinders shrank in height by an average of 5.9%, from 300 to 282 mm. In comparison, the low-density cob cylinders expanded in height by around 0.55%, from 300 to 302 mm (fig. 4).

Moisture Monitoring

Overall results from the two different sensor types are presented in figure 5, which illustrates the drying rate of the two cob layers over the monitoring period. These results were then collected at weekly intervals over the thickness of the entire wall (figs. 6, 7). This method enabled further comparison between the different layers of the wall as well as a deeper analysis of the flow of moisture through the wall.



FIGURE 2 Location of TDR sensors within the CobBauge trial wall: three CS655 sensors (left), one SoilVue10 sensor (right). Photo: University of Plymouth (CobBauge project), Kevin Owen.

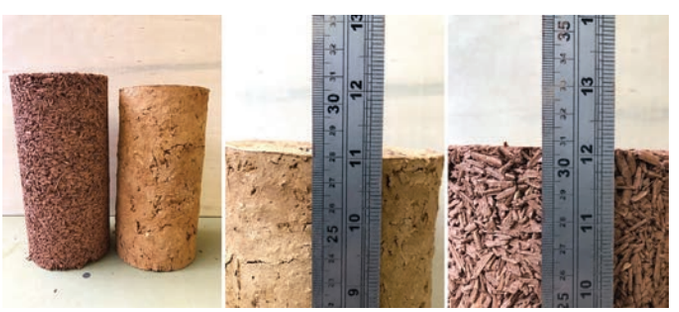


FIGURE 4 Comparison of low-density (left in first image) and high-density (right in first image) cob cylinder samples. Photo: University of Plymouth (CobBauge project), Kevin Owen.

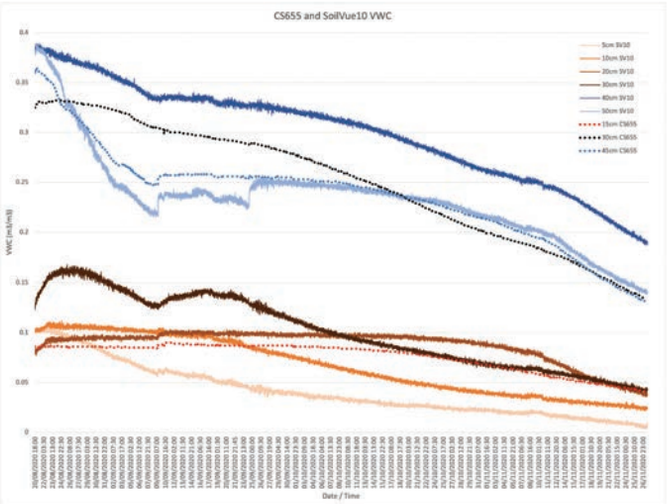


FIGURE 5 VWC results from CS655 and SoilVue10 sensors. Blue lines = high-density cob layer. Amber lines = low-density cob layer. The darker the line, the closer the sensor is to the center of the 600 mm thick wall. Dimensions noted on the key are measured from the external face of the low-density cob layer. Figures 5–7: University of Plymouth (CobBauge project), Matthew Fox.

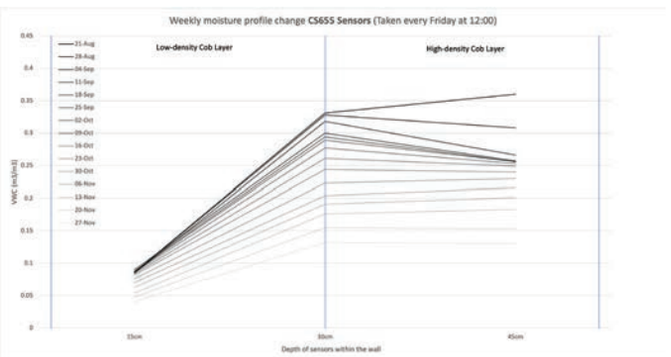


FIGURE 6 CS655 VWC results. The darker the line, the earlier the data. Blue vertical lines denote the approximate thickness of the wall, showing the approximate location of the sensor within each layer.

Shrinkage Monitoring

Figure 8 shows the change in height of the screws over the six weeks of the initial drying of the measured first lift. The outer edge of the high-density cob experienced the greatest degree of shrinkage.

Discussion

A number of interesting findings were encountered on review of the moisture monitoring. While the low-density cob

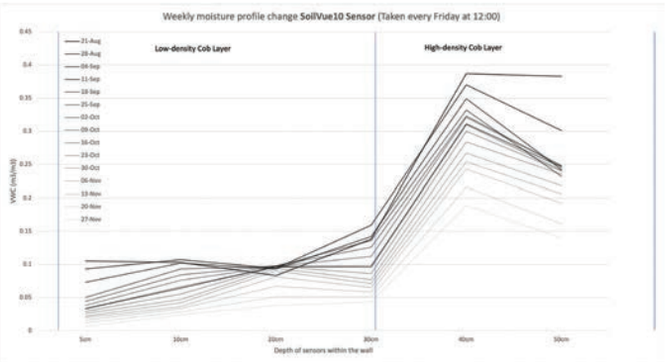


FIGURE 7 SoilVue10 VWC results. The darker the line, the earlier the data. Blue vertical lines denote the approximate thickness of the wall, showing the approximate location of the sensor within each layer.

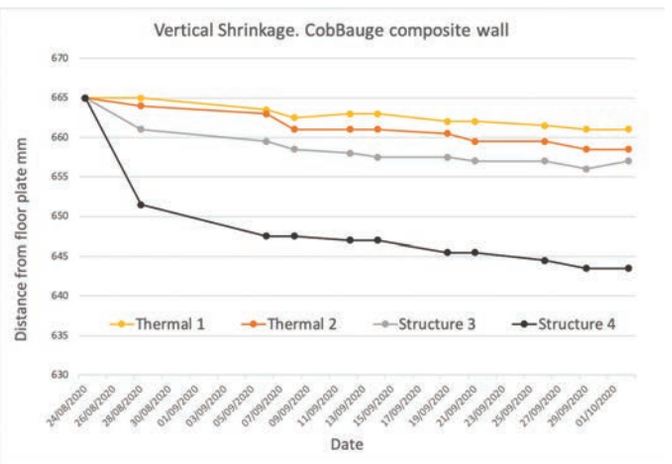


FIGURE 8 Graph showing measurements from the fixed screws over time. University of Plymouth (CobBauge project), Jim Carfrae.

generally had a lower VWC at the start of the experiment and dried at a slower rate than the high-density cob, the material closest to the high-density layer appeared to gain moisture after placement. This was likely due to a transference of moisture from the high-density layer to the low-density layer. After losing some of this moisture, this sensor location showed an increase in VWC in the second week. This was due to the addition of a second lift of CobBauge, representing the impact of the traditional construction process, with additional moisture passing from the new lift to this measured lift by way of gravity. After these initial rises in VWC, the low-density layer closest to the center of the wall dried at a similar rate to that of the high-density layer in the same position.

VWC results between the CS655 and SoilVue10 sensors at similar depths were comparable, which gave confidence between the two data sets. However, there was a disparity in results at the midpoint through the wall. The central CS655 measured a higher VWC than the SoilVue10 sensor at a similar depth (30 cm), due to the CS655 sensor straddling the two cob materials and the 30 cm SoilVue10 sensor located only inside the low-density cob layer. While there were three CS655 sensors spread throughout the wall, the SoilVue10 had six sensors along its 0.5 m length and at least two sensors in each cob material. When comparing figures 6 and 7, the added resolution in data from six sensors gives greater clarity over the movement of moisture through the depth of the wall.

Upon reflection of the shrinkage measurements, it is clear that the greatest degree of shrinkage is at the outer edge of the high-density layer (Structural 4; see fig. 3 for a visual description of the wall's components) and that the majority of this shrinkage occurred within the first week of measurement. This corresponds with the moisture data, which also show that the outer edge of the high-density cob (50 cm SV10) dried more quickly at the start before gradually slowing. When compared with the findings from the high-density cob sample cylinders, these results could be expected.

Yet an unexpected measurement was gained in Structural 3, the high-density cob shrinkage measurement closest to the center of the wall. Here results appeared to mirror the measurements taken in the low-density cob layer, counter to findings from Structural 4. While this could be due to the slower drying rate at the center of the wall, another explanation came from reviewing the low-density cob layer. Shrinkage results in the low-density layer found that the material was expanding slightly at the outer edge (Thermal 1). This could be due to the fibers taking their original shape after initial compaction into the formwork that replicates, to a certain extent, the results from the cylinders (fig. 4). Despite this, the material appeared to be pulled down by the shrinkage of the high-density layer when the low-density cob was measured close to the center of the wall (Thermal 2), as is confirmed by the Thermal 2 and Structural 3 results, suggesting that the two layers are working together rather than separating. It is also backed up by visual inspections, which show that the two layers do not separate at the junction.

Conclusion

The TDR-based moisture measurement system trialed in the full-scale CobBauge wall proved to be an effective method to measure moisture content within a 600 mm thick composite CobBauge wall. While some variations between the SoilVue10 and CS655 TDR systems were encountered, these were associated with sensor positioning between the two different density earth layers.

The shrinkage associated with the composite CobBauge wall was generally far less than what was exhibited by the small-scale samples of the same material. The moisture measurement system played an important role in informing the researchers about the position of moisture within the wall at particular points in time. This then allowed the team to observe that the two layers of the CobBauge wall were influencing the moisture content through a cross section of the wall. This influence tended to even out the areas of differential shrinkage and maintain the walls' overall dimensions in a way that was not observed in the smaller samples. This method of moisture monitoring can be beneficial when assessing the drying, shrinkage, and movement of new earthen material when placed immediately against existing historic earthen material, which will have a more stable moisture state and is especially important when using new material around fenestration apertures.

Future Work

The CobBauge team will be monitoring the current full-scale walls over the remainder of 2021 to the end of 2023 to ensure that the current results can be compared to the completed work. Links between the moisture and shrinkage of these walls will be compared with published data from repairs undertaken in similar historic cob buildings in the southwestern UK. A new Prototype CobBauge building will be built on the University of Plymouth campus and will be monitored using the system described in the paper. The new building will offer opportunities to investigate the influence of internal conditions on wall moisture contents and the part that rendering plays in relation to weather conditions of maritime climates such as those in Plymouth.

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The Effectiveness of Nature-Based Conservation Strategies for Minimizing the Modeled Risk of Earthen Heritage Deterioration

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Abstract: *Many earthen archaeological sites in dryland regions experience substantial deterioration driven by environmental conditions. Nature-based conservation strategies can minimize deterioration by reducing the erosivity of environmental conditions without altering the historical material. However, predicting the effectiveness of such strategies over long periods (centuries) is challenging owing to the uncertainty of future climate change in many dryland regions. Furthermore, conservation strategies must fulfill site management requirements (e.g., cost, aesthetic impact) to be implemented. We present a framework to assess trade-offs between two key aspects of nature-based conservation strategies: (1) their ability to reduce deterioration and (2) their suitability for site implementation. We use an enviro-heritage model, Vegetation and Sediment TrAnsport model for Heritage Deterioration (ViSTA-HD), to spatially resolve the risk of deterioration across earthen wall faces under a range of nature-based conservation strategies: increasing natural vegetation, building windbreaks, and doing nothing. We apply this model to Suoyang Ancient City, an earthen site located in northwestern China. We find that irrespective of fluctuations in future windspeed and rainfall, increasing natural vegetation coverage causes the greatest reduction in deterioration risk and is the cheapest effective strategy. In contrast, the impact of windbreaks on deterioration risk is minimal, even if they tend to have smaller environmental footprints. The versatility of the ViSTA-HD model allows our proposed framework to be applied to a diversity of earthen sites in dryland environments. It could thus help improve the efficacy of decision making for conservation strategies in these vulnerable environments.*

Resumen: *Muchos sitios arqueológicos de tierra ubicados en regiones áridas experimentan un deterioro importante a causa de las condiciones ambientales. Las estrategias de conservación basadas en la naturaleza pueden minimizar el deterioro por medio de la reducción del impacto erosivo de las condiciones ambientales y sin alterar el material histórico. Sin embargo, resulta difícil predecir la eficacia de esas estrategias durante períodos largos (siglos) debido a la incertidumbre que genera el cambio climático futuro en muchas regiones áridas. Asimismo, para poder implementar las estrategias de conservación, estas tienen que cumplir con los requisitos de gestión del sitio (p. ej., costos, impacto estético, entre otros). Presentamos un marco para evaluar la compensación entre dos aspectos clave de las estrategias de conservación basadas en la naturaleza: (i) su capacidad para disminuir el deterioro; y (ii) su nivel de adecuación para la implementación en el sitio. Utilizamos un modelo basado en el patrimonio y el ambiente, ViSTA-HD (que significa "modelo de transporte de vegetación y sedimentos para el deterioro del patrimonio") con el objetivo de resolver el problema del riesgo de deterioro en todas las caras de los muros de adobe, sobre todo, siguiendo una serie de estrategias de conservación basadas en la naturaleza: el aumento de la vegetación natural, la construcción de cortavientos y no hacer nada. Aplicamos este modelo en la antigua ciudad de Suoyang, un sitio de edificios de tierra ubicado al noroeste de China. Descubrimos que, independientemente del aumento o la disminución que se produzca en las precipitaciones y la velocidad del viento en el futuro, aumentar la cobertura de la vegetación*

natural genera una reducción importante en el riesgo de deterioro y constituye la estrategia eficaz más económica. Por el contrario, los cortavientos tienen un impacto mínimo en el riesgo de deterioro, aun cuando su huella ambiental tiende a ser menor. La versatilidad del modelo ViSTA-HD permite aplicar el marco que proponemos en distintos sitios con edificios de tierra, que se encuentran en entornos áridos. Permite tomar decisiones más eficaces en relación con las estrategias de conservación en estos entornos vulnerables.

Keywords: nature-based conservation, rammed earth, modeling, environment, deterioration, China

Introduction

Many earthen heritage sites in dryland regions are experiencing substantial deterioration driven by environmental conditions such as wind, sediment transport, and rain (Shen et al. 2017; Cui et al. 2019; Shao et al. 2013). This deterioration can result in the loss of historic, scientific, and cultural values (Richards et al. 2018). To minimize further deterioration, there is an urgent need to manage the impact of these environmental drivers of deterioration into the future. However, future climate projections for many dryland areas are highly uncertain (Christensen et al. 2013), making it difficult to assess the long-term effectiveness of potential conservation strategies.

Increasingly, nature-based conservation options are being implemented at earthen sites (e.g., Li et al. 2013) with heritage experts based in China and the UK expressing a preference for this approach (Richards et al. 2018). However, for nature-based conservation strategies to be successful, they need to (1) fulfill the management specifications for the given site (e.g., cost, visual aesthetics, maintenance) and (2) remain effective under future climates. Robust ways of assessing long-term performance are now required in order to inform conservation decision making.

Modeling is increasingly being used within earthen heritage research to investigate environmental interactions with earthen sites at spatial and temporal scales beyond those easily observable in the laboratory or field (Luo et al. 2019; Du et al. 2020). To improve the efficacy of conservation decision making, we use data produced from an enviro-heritage computer model to develop a framework for assessing a range of benefits and trade-offs of potential nature-based conservation strategies over a centennial timescale. Our research focuses on the earthen site of Suoyang Ancient City (锁阳城, hereafter Suoyang), located in semi-arid northwest China. Suoyang was built during the Han (206 BCE–220 CE) and Tang (618–907 CE) dynasties primarily from rammed earth, and was enlisted in 2014 as one of thirty-three sites that form the Silk Roads World Heritage Site (fig. 1). Many parts of the site have experienced extensive deterioration. The versatility of this modeling approach means this could easily be applied to other earthen sites in dryland regions.

Enviro-Heritage Model

Model Overview

To assess the effectiveness of potential nature-based conservation strategies under a range of current and potential future climate scenarios, we use the Vegetation and Sediment TrAnsport model for Heritage Deterioration (ViSTA-HD) (fig. 2).

ViSTA-HD is a cellular automata model developed to spatially resolve the risk of environmentally driven deterioration at rammed earth sites (Richards et al. 2020b). The model simulates the risk of three common deterioration features found on rammed earth (pitting, polishing, and slurry) across the wall face. The risk is determined by (1) the environmental conditions interacting on a given area of wall, (2) the extent of deterioration occurring around a given area of wall, and (3) the deterioration previously occurring on a given area of wall. The environmental conditions that can impact earthen heritage structures, including wind speed and direction, sediment movement, and rainfall, are determined by the model's environmental module.

More information on the model is provided by Mayaud, Bailey, and Wiggs (2017) and Richards et al. (2020b). The model code is openly available from the Oxford University Research Archive.

Model Setup

Input conditions are based on environmental, climatic, and structural data collected from Suoyang. We ran a spin-up of 400 iterations for each model run to ensure the system was in dynamic equilibrium before running it for a further 400 iterations for the experiment. Four hundred iterations represent 100 years in real time. Further details on the model setup can be found in Richards et al. (2020b).

Future Climatic Input Conditions

Global and regional climate models show large uncertainties in future wind speed and rainfall projections for northwest China (Wang and Chen 2014; Guo et al. 2017). We therefore

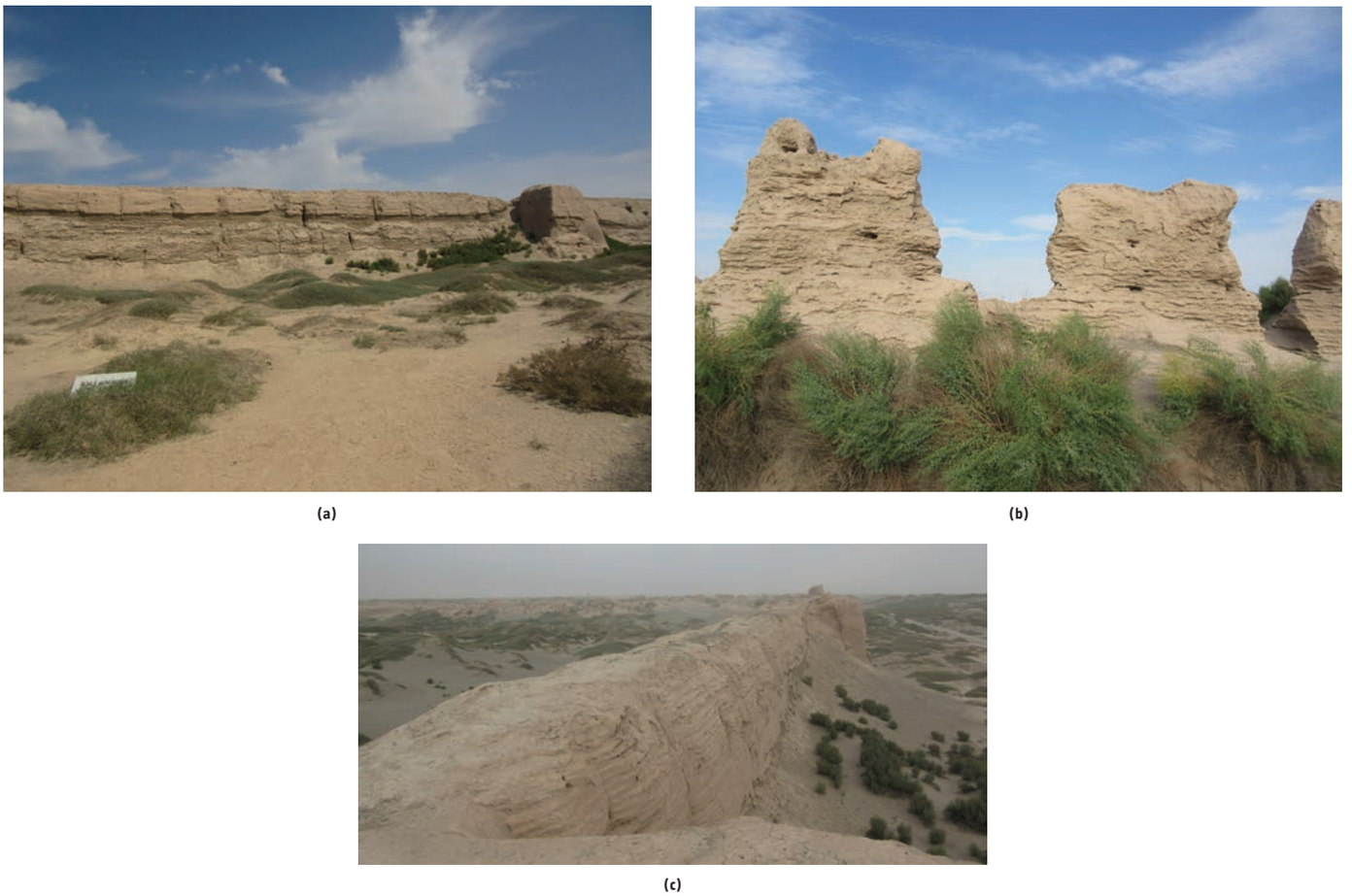


FIGURE 1 Suoyang Ancient City: (a) a section of the south inner-city walls with fortification tower, (b) a section of the highly deteriorated east inner-city wall, and (c) a view from the top of the southeast corner of the inner-city wall. Photos: J. Richards.

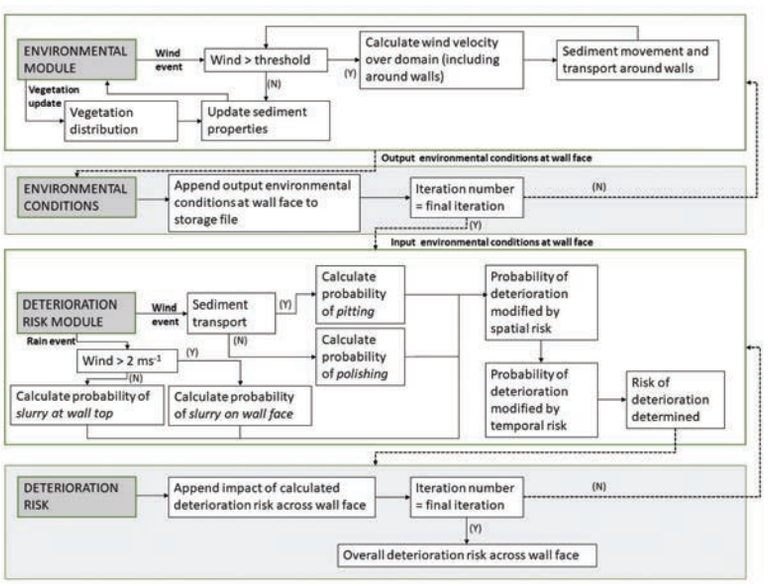


FIGURE 2 A schematic of ViSTA-HD outlining the processes in the environmental and deterioration modules. Reproduced using Creative Commons License BY 4.0 (https://creativecommons.org/licenses/by/4.0/) from Richards et al. (2020b). Illustration: J. Richards.

used a scenario-neutral approach, based on a range of possible values, to capture potential conditions. Wind velocity and rainfall parameters were deliberately pushed to extremes to understand the system response under a wide variety of conditions. The "low change" scenario simulated a 10% decrease in rainfall and 1 ms^{-1} decrease in wind velocity, while a "high change" scenario simulated a 50% increase in rainfall and 5 ms^{-1} increase in wind velocity.

To assess the extent to which nature-based conservation strategies could help minimize deterioration risk, we considered three potential conservation strategies:

- Doing nothing;
- Installing a windbreak formed of 5 m high shrubs, located 30 m upwind of the earthen wall;
- Increasing the natural vegetation cover from 30% (average coverage at Suoyang) to 80% (the densest vegetation coverage found at Suoyang).

The deterioration risk for each conservation strategy was modeled under present-day conditions, as were the low- and high-change climate scenarios.

Relative Cost and Spatial Footprint

The relative cost of implementing and maintaining a strategy is calculated using the implementation and maintenance cost breakdowns provided by the Chinese Forestry Partnership (PRC-GEF Partnership 2008). This partnership is seen as a source of best practices for land degradation control in dryland areas of China. The relative costs are based on a single implementation cost and maintenance for 100 years. The relative footprint, or area of land required for a strategy, was based on the spatial area of the implemented strategy in the ViSTA-HD model.

Cost-Benefit Framework

We suggest a four-stage schematic framework (fig. 3) to enable informed decision making about the relative benefits/trade-offs of implementing conservation strategies at sites such as Suoyang. Stage 1 highlights the need for field data in order to establish the extent of deterioration and heritage values of a site (e.g., Douglas-Jones et al. 2016). This could be achieved by undertaking field visits as well as workshops with a range of stakeholder groups. Stage 2 uses the data from ViSTA-HD to consider the relative benefits or trade-offs associated with implementing a given

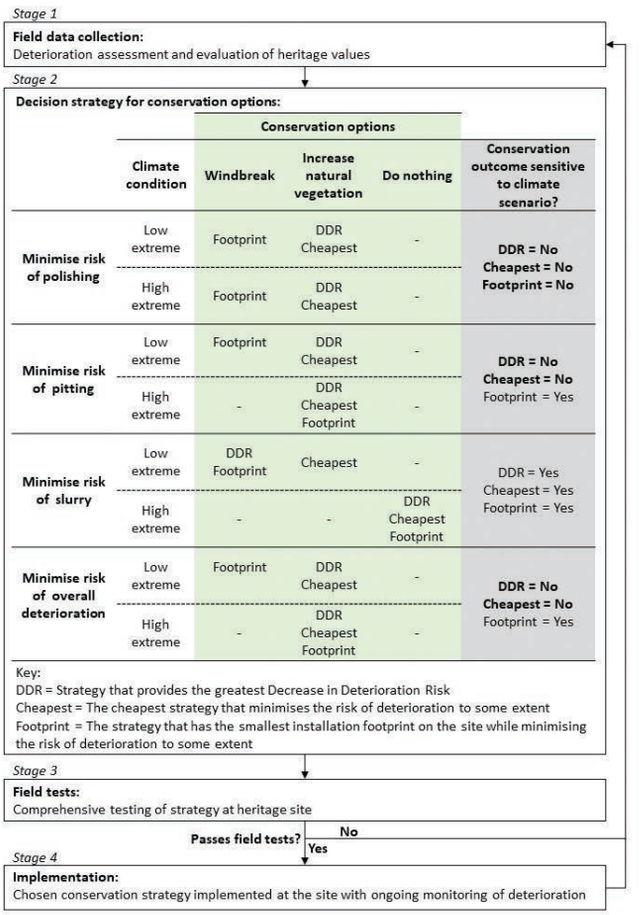
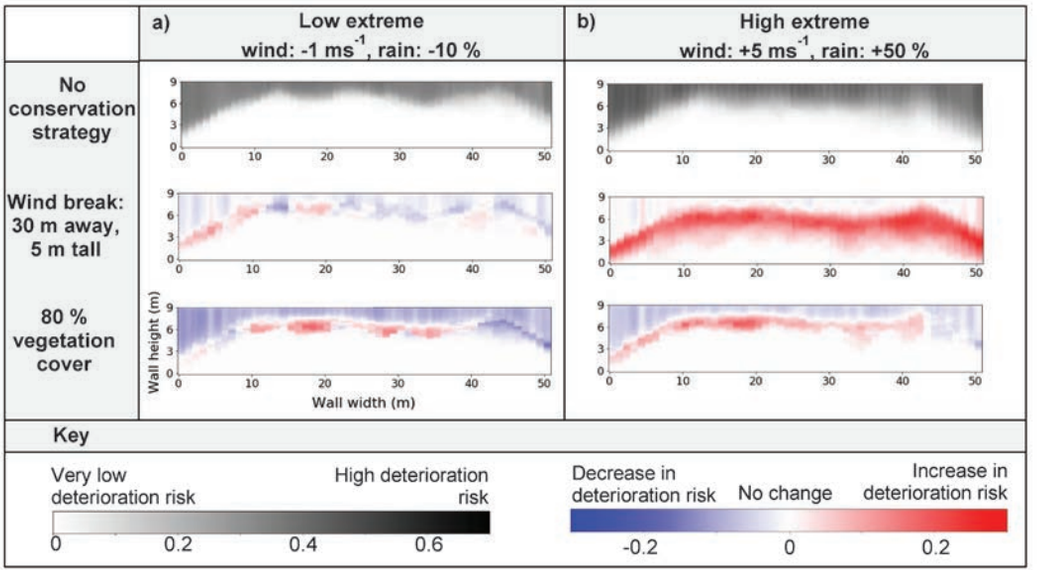


FIGURE 3 A schematic showing a four-stage approach to assessing the relative benefits and trade-offs when implementing conservation strategies. Illustration: J. Richards.

conservation strategy. It assesses the impact of the conservation strategy on the deterioration risk through polishing, pitting, and slurry, as well as the overall risk of deterioration under the low- and high-extreme future climate conditions (fig. 4). For a conservation strategy to be selected as a potential option within the framework, the strategy has to reduce the risk of deterioration *to some extent*.

If this condition is met, the relative benefits would be assessed by a further three factors, as seen in table 1:

- The ability for a strategy to cause the *greatest* decrease in deterioration risk (fig. 3: DDR);
- The relative cost of implementing and maintaining a strategy (fig. 3: Cheapest);
- The smallest relative footprint or area of land required for a strategy (fig. 3: Footprint).





(c)

FIGURE 4 The overall deterioration risk and difference in deterioration risk with different conservation strategies after 100 years of model time, under (a) a regime of low mean annual wind velocity and rainfall, and (b) a regime of high wind velocity and rainfall. Conservation strategies applied were no conservation strategy, addition of a windbreak, and 80% vegetation cover. Changes in deterioration risk are shown in red and blue, indicating an increased and decreased risk of deterioration, respectively. The east wall at Suoyang Ancient City, China, is shown in (c). Adapted from Richards et al. (2020a, 1217–1302).

The results from the low- and high-extreme climate conditions are compared to determine if the conservation outcome is sensitive to the future climate scenario (fig. 4).

Stage 3 of the framework requires field tests using the chosen conservation strategy to be carried out before implementation, ideally over a minimum of one year (see fig. 3). This would help ensure that the desired impact on deterioration can be achieved without any unforeseen consequences arising (e.g., attracting pests to the site or altering the height of the water table; Li et al. 2013), before applying it to an entire site.

If the field tests produce the desired reductions in deterioration, Stage 4 kick-starts the implementation of the conservation strategy (see fig. 3). As this framework is iterative, ongoing monitoring of environmental processes at (as well as the deterioration condition of) the site enables the impact of these strategies to be assessed and adjusted if required.

Assessing Future Conservation Strategies

Our framework enables the effectiveness of nature-based conservation strategies to be assessed using a range of criteria that can be altered depending on the site's management requirements. By applying this framework to the site of Suoyang we show that, of the strategies tested, increasing natural vegetation cover to 80% (1) causes the greatest reduction in deterioration risk and (2) is the cheapest strategy, irrespective of whether future climatic changes cause a low- or high-extreme scenario to occur (see fig. 3). Given the uncertainty of the direction or magnitude of future changes in climate in the region, this lack of sensitivity between the strategy's effectiveness and potential climatic conditions suggests that it could be a robust long-term conservation option for sites such as Suoyang.

Increases in vegetation cover could occur naturally at Suoyang as a result of conservation measures already in

place, such as the banning of herding within the buffer zone (UNESCO 2014) or could be induced by future climate change (Bailey 2010). Increases in rainfall could promote vegetation growth. However, decreases in rainfall and increases in wind speed might have the opposite effect (Mayaud, Bailey, and Wiggs 2017). If additional planting is required to increase vegetation coverage, programs such as those widely implemented in semi-arid China could be used (PRC-GEF Partnership 2008). Such schemes have been successful at heritage sites such as at Mogao Grottoes, Gansu Province, China (Li et al. 2013; Tan et al. 2016). In this situation, native species should be chosen where possible and modifications implemented gradually to allow natural changes in vegetation coverage to occur and minimize the risk of unforeseen consequences caused by introducing new, potentially invasive species to a site.

The framework also shows that under low-change conditions the windbreak has the smallest footprint while still reducing deterioration. However, under high-change conditions the windbreak has little impact on reducing deterioration. Windbreaks are commonly used in dryland areas to minimize soil erosion and are often irrigated (PRC-GEF Partnership 2008; Dunhuang Academy, pers. comm. 2017). Irrigation can result in changes to water table depth; insect, bird and other animal abundance; and vegetation patterning (PRC-GEF Partnership 2008). Therefore, additional monitoring of these factors should be undertaken if irrigation schemes are implemented. If changes occur, site managers would need to consider the relative cost/benefit of continuing the strategy.

These findings suggest that, unless it is essential for the conservation strategy to have a small footprint, increasing vegetation cover to 80% is likely to be the most suitable conservation strategy for minimizing deterioration regardless of future climatic changes. For dryland areas facing future climatic uncertainty, the ability for increasing vegetation to be effective under a range of deterioration impacts is highly beneficial for management and decision making.

Implications for Earthen Heritage Conservation

This framework provides an evidence-based, site-specific approach for the recommendation of nature-based conservation strategies at earthen heritage sites over decadal to centennial timescales. In applying this approach to Suoyang, we found that the most effective strategy for decreasing deterioration risk would be to increase vegetation coverage because it was the most effective under a wide range of possible climatic scenarios.

Table 1 Trade-off Factors for Conservation Strategies Based on the ViSTA-HD Model Domain

Conservation strategy	Description	Extent of decrease in deterioration risk	Relative cost	Relative footprint
Windbreak	Shrub-based windbreak as preferred by the Chinese Forestry Partnership. Requires irrigation.	Variable but generally some decrease	Double vegetation cover cost	<1/15th of the vegetation cover footprint
Vegetation coverage	Hand sowing seeds of species tolerant to low moisture	Variable but generally greatest decrease	Half the windbreak cost	>15 times the windbreak footprint
Do nothing	No interventions	Variable but generally limited change	No capital input required	No additional space required

Using ViSTA-HD within the proposed framework allows users the ability to iteratively assess the trade-offs posed by conservation decisions in the face of climatic uncertainties. The ability to alter model inputs as climate and site conditions change enables the technology to provide dynamic management advice for a given site. Furthermore, the versatility of ViSTA-HD means that the model inputs can easily be altered to reflect environmental, climatic, and structural conditions at other rammed earth heritage sites located in dryland environments, such as Kunya-Urgench, Turkmenistan, and Ksar of Ait-Ben-Haddou, Morocco, aiding future conservation decision making. This approach has great potential for providing a holistic assessment of the suitability of potential strategies—especially when future environmental and climatic conditions are uncertain. Future research on earthen deterioration processes will help refine and improve the model, and further research is needed to investigate the potential for nature-based conservation strategies to cause unintended consequences, such as altering the water table or increasing the number of rodents in the area.

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Bacterial Consolidation of Earthen Structures: Preliminary Results at the Alhambra Fortress in Granada, Spain

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Abstract: *A significant part of the architectural heritage in the Mediterranean Basin—including monuments as emblematic as the Alhambra in Granada, Spain—is built using earth as the construction material. Due to the material's intrinsic characteristics, chemical and physical weathering is continuous under the prevailing climate conditions, requiring constant maintenance and, in many cases, consolidation treatments. Past organic and inorganic consolidants have not always offered satisfactory results. An alternative bacterial biomineralization treatment based on the activation of the substrate's own carbonatogenic microbiota is proposed in this paper. The treatment not only results in improved cementation but also confers certain hydrophobicity to the treated substrate. This bacterial biomineralization treatment has successfully been applied on limestone and gypsum, but its effectiveness for the protection and consolidation of earthen material has not been established so far. We present findings regarding improvements in weathering resistance and mechanical strength of adobe samples treated in the laboratory, as well as preliminary results on the treatment's effectiveness in the case of a selected pilot area at the Alhambra fortress. The outcome of this study lays the basis for the development of effective consolidation treatments for earthen structures based on an environmentally friendly bio approach.*

Resumen: *Una parte importante del patrimonio arquitectónico de la Cuenca Mediterránea, que incluye monumentos tan emblemáticos como la Alhambra, en Granada, España, se edificó utilizando la tierra como material de construcción. Debido a las características intrínsecas del material, su alteración química y física es continua bajo las condiciones climáticas imperantes, requiriendo un mantenimiento constante y, en muchos casos, tratamientos de consolidación. Sin embargo, los consolidantes orgánicos e inorgánicos convencionales no siempre han ofrecido resultados satisfactorios. Aquí se propone un tratamiento alternativo de biomineralización bacteriana basado en la activación de la propia microbiota carbonatogénica del sustrato. Este tratamiento de conservación se ha aplicado con éxito en piedra caliza y yeso, pero hasta ahora no se ha establecido su eficacia para la protección y consolidación de material de tierra. Nuestros resultados muestran que el tratamiento de biomineralización bacteriana de carbonato cálcico no solo da como resultado una cementación mejorada, sino que también confiere cierta hidrofobicidad y protección al sustrato de tierra tratado. Se observan mejoras en la resistencia a la intemperie y resistencia mecánica de muestras de adobe tratadas en laboratorio. Además, se evalúan los resultados preliminares de la efectividad del tratamiento aplicado en un área piloto (tapial) de la fortaleza de la Alhambra. El resultado de este estudio sienta las bases para el desarrollo y aplicación de tratamientos de protección y consolidación mediante la biomineralización, que sean eficaces y ecológicos para estructuras de tierra.*

Keywords: bacterial biomineralization, earthen architecture, adobe, rammed earth

Introduction

A significant part of the world's architectural heritage is built using earth as construction material, including monuments as emblematic as the Alhambra in Granada, Spain. As a result of the prevailing climate conditions in the city of Granada (i.e., important diurnal changes in temperature and relative humidity of up to 20°C and 50%, significant precipitation during the winter months, and a very hot and dry summer season), the material undergoes continuous chemical and physical weathering, consequently requiring maintenance and, in many cases, consolidation treatments (Elert et al. 2019). The consolidation of earthen material is especially challenging due to the material's intrinsic characteristics, namely its significant clay mineral content, which respond to changes in the substrate's moisture content with volume fluctuations and ultimately material failure and loss. Indeed, past organic and inorganic consolidants (i.e., synthetic polymers and alkoxysilanes) have not always offered satisfactory results, as they lose efficacy over a relatively short period of time (Doehne and Price 2010).

An alternative treatment based on bacterial biomineralization is proposed in this paper, a process that improves not only cementation but also the weathering resistance of the treated substrate. Several bacterial biomineralization strategies have been tested for the consolidation of heritage materials. All rely on the precipitation of a hybrid cement consisting of nanostructured bacterial calcium carbonate and bacterial derived organics (i.e., cell debris and bacterial exopolymeric substances, or EPS), the latter conferring a certain hydrophobicity to the treated substrate (Jroundi et al. 2017). Originally, exogenous or stone-isolated single bacterial cultures were applied for the biomineralization of weathered stone along with a nutritive solution (Tiano, Biagiotti, and Mastromei 1999). More recently, the treatment was simplified by solely applying a patented sterile nutritive solution (the source of Ca and amino acids) to selectively activate the carbonatogenic bacteria among the indigenous microbial community of the stone without the need for the isolation and culture of a carbonatogenic bacteria inoculum in the laboratory prior to application (Jimenez-Lopez et al. 2008). To date, biomineralization treatments have been successfully applied on limestone, marble, and gypsum plaster. However, no study has focused on their effectiveness for the protection and consolidation of earthen structures. Here we present findings regarding improvements in weathering resistance and mechanical strength of adobe samples treated with the patented sterile nutritive solution in the laboratory, as well as preliminary results on the treatment's effectiveness in the case of a selected pilot area: a rammed earth wall at the Alhambra fortress (figs. 1a, 1b). The outcome of this study lays the basis for the development of effective consolidation treatments for earthen structures based on an environmentally friendly bio approach.



FIGURE 1 (a) General view of the palaces at the Alhambra fortress (Granada, Spain) and (b) section of rammed earth wall showing different levels of degradation. The red frame indicates the test area for the bacterial biomineralization treatment and the inset shows a detail of the severely eroded earthen wall, with arrows indicating alternating clay and lime-rich layers. All photos: K. Elert.

Materials and Methods

Adobe blocks (4 cm^3) were prepared with a solid:water ratio of 5:1 (by weight) using soil (≤1 mm fraction) from the nearby Alhambra Formation, which was historically used for the construction of rammed earth structures in Granada (Elert et al.

2019). Blocks were prepared manually (without any additives or additional compaction) according to traditional methods using wooden frames that were previously wetted to facilitate demolding. Blocks were dried under laboratory conditions (20 ± 5°C, 40 ± 5% RH) for two months prior to the application of the consolidation treatment.

A south-facing rammed earth wall at the Alhambra fortress was selected as a pilot area considering that it presents different levels of erosion due to the direct impact of driving rain and capillary rise (see fig. 1b). The thirteenth-century wall was built with lime-amended soil, and the upper part is still covered by a lime-rich outer layer. The lower part has suffered more severe erosion, leaving the clay-rich core unprotected. In some areas alternating lime and clay-rich layers can be distinguished (see fig. 1b, inset).

For the biomineralization treatment in the laboratory, the water-based patented nutritive solution M-3P (González-Muñoz et al. 2008) was applied on all six faces of the adobe blocks by repetitive spraying during five consecutive days (totaling 1.2 L/m²) and cured during fourteen days at 25 ± 3°C and 80 ± 5% RH. During treatment and curing, samples were protected from daylight while allowing air ventilation. The in situ treatment was performed in a similar manner totaling 10 L/m² of nutritive solution applied on a 0.5 × 1 m area (see fig. 1b). Loose debris was removed by brush prior to application. The treated area was protected from daylight and cured under ambient conditions (i.e., 20 ± 4°C and 44 ± 10% RH).

The total number of culturable bacteria (colony-forming units, CFU/g) was determined before and after biomineralization treatment of adobe blocks and of the rammed earth wall (samples were taken from the reddish zone showing severe erosion). Total bacteria count was performed following extraction of culturable bacteria (see protocol in Jroundi et al. 2017). Optical microscopy was used to estimate the carbonatogenic capacity of bacterial isolates cultured in M-3P based on their $CaCO_3$ production. The mineralogical composition was determined by X-ray diffraction (XRD, X'Pert PRO [PANalytical B.V., UK], Cu-Kα radiation; Ni filter; 45 kV voltage; 40 mA intensity; exploration range of 3° to 60°2θ and goniometer speed of 0.05°2θ s^{-1}). XPowder software (Martin-Ramos 2004) and experimental reference intensity ratio (RIR) values were used for identification and quantification of mineral phases. Field-emission scanning electron microscopy (FESEM, AURIGA [Carl Zeiss, Germany], 10^{-6} Pa vacuum, 3 kV [secondary electron imaging mode], and 20 kV [microanalysis] acceleration voltage) coupled with energy dispersive spectroscopy [EDS] microanalysis [INCA-200, Oxford, UK]) was used to study textural and compositional characteristics of carbon-coated samples. Color changes of untreated and treated adobe blocks were measured with a spectrophotometer (CM-700d, Konika Minolta, Japan) using the CIE L*a*b* color space. The total color change (ΔE*) was calculated according to the following formula: $\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$. Improvements in weathering resistance were determined by immersing untreated and treated adobe blocks in water at predetermined time intervals and measuring weight loss. The increase in compressive strength upon consolidation was determined using an Instron 3345 (Instron Co., Canton, MA, 5000 N load at 3 mm/min) and prismatic adobe samples (4 × 1 × 1 cm), prepared from the 1 cm thick outer surface of adobe blocks.

Results

Total bacteria count revealed that adobe blocks contained abundant indigenous carbonatogenic bacteria that were effectively activated by the biomineralization treatment. The total number of cultured bacteria in the laboratory treated adobe blocks increased from 6.59 ± 1.20 × 10^3 CFU/g before treatment to 2.10 ± 0.04 × 10^7 CFU/g after treatment. The rammed earth wall at the Alhambra contained 7.34 ± 1.37 × 10^3 CFU/g before and 2.71 ± 0.40 × 10^6 CFU/g after treatment. All isolated bacteria were carbonatogenic, capable of inducing the precipitation of calcium carbonate upon inoculation in the sterile M-3P nutritional solution. The original bacterial count values and the corresponding increase after treatment are very similar to those observed for limestone successfully treated using the same approach (Jroundi et al. 2017). According to XRD (fig. 2), the Alhambra Formation soil used for adobe blocks contained significant amounts of clay minerals (30 wt%) and quartz (65 wt%), together with a small amount of feldspars (albite, <5 wt%) and trace amounts of calcite, dolomite, and iron-rich phases (<1 w%) such as hematite and goethite, the latter being responsible for the typical reddish-brown color of the soil. The clay fraction is composed of smectites, illite, paragonite, and kaolinite, which are, with the exception of paragonite, the most common clay minerals found in soils (Ito and Wagai 2017). The presence of smectites suggests a special susceptibility of Alhambra Formation soil toward swelling-induced damage, as this type of clay mineral undergoes intracrystalline swelling, creating swelling pressure of more than 100 N/mm² (Madsen and Müller-Vonmoos 1989). XRD also showed a certain inhomogeneity among soil samples and, consequently, failed to provide unambiguous evidence for

an increase in calcium carbonate as a result of bacterial activity. Indeed, a previous study (Jroundi et al. 2014) revealed that bacterial calcium carbonate amounted to only ~1.5 to 2 wt% in archaeological gypsum treated with the same nutritive solution that was, however, sufficient to provoke a significant strength increase.

XRD analysis of the reddish soil from the rammed earth wall at the Alhambra showed even larger variations in mineral composition, often containing large amounts of carbonates (~20 wt%) and gypsum (~40 wt%). The former is an obvious artifact of the construction technique (lime-amended earth wall). The origin of the latter is yet to be determined (on some occasions gypsum has been used to fill putlog holes in rammed earth walls). The presence of gypsum is of special concern as it likely accelerates the deterioration of the earth wall (Charola, Pühringer, and Steiger 2007). FESEM provided unambiguous proof of enhanced carbonatogenic bacterial activity upon biomineralization treatment in the laboratory and in situ, revealing the presence of calcified bacterial cells attached to the soil matrix together with bacterially derived EPS and calcium carbonate (fig. 3). For comparison, a FESEM image of the adobe sample before treatment is included, exhibiting the typically platy morphology of clay particles.

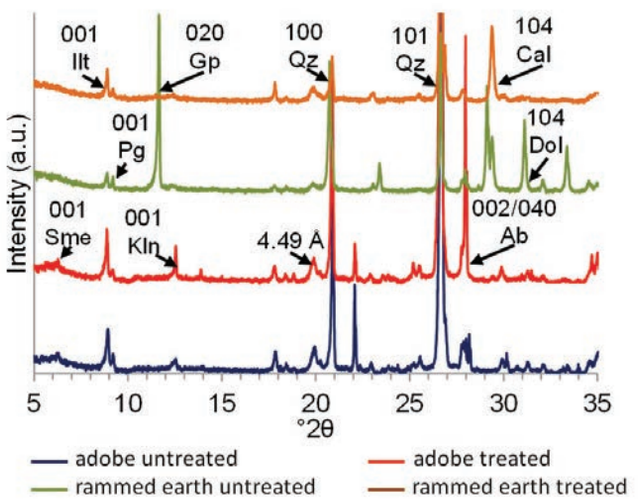


FIGURE 2 XRD patterns of powder samples of the adobe block before (blue line) and after bioconsolidation treatment (red line), as well as the rammed earth wall before (green line)and after treatment (brown line). Sme = smectites, Ilt = illite, Pg = paragonite, Kln = kaolinite, Gp = gypsum, Qz = quartz, Ab = albite (feldspar), Cal = calcite, Dol = dolomite, and 4.49 Å = general reflection of clay. All abbreviations according to Whitney and Evans (2010).

Table 1 Color Measurements (L*, a*, and b*) and Calculated Color Change (ΔE*) of Adobe Samples before (Untreated) and after Biomineralization Treatment

Sample	L*	a*	b*	ΔE*
Untreated	49.57 ± 1.74	11.82 ± 0.26	22.79 ± 0.64	-
Biomineralization	46.47 ± 0.97	12.45 ± 0.24	23.02 ± 0.38	3.21 ± 0.97

Color measurements (table 1) indicated only minor changes due to the biomineralization treatment of adobe blocks, only slightly above the limit of the perception of the human eye (i.e., $\Delta E^* \geq 3$; Berns 2000). The observed color change was predominately caused by a small decrease in luminosity (L*).

The water immersion test (fig. 4) showed that the biomineralization treatment reduced material loss during the first twenty minutes of immersion by 76%, being 23 and 96 wt% in treated and untreated samples, respectively. However, further immersion resulted in a complete disintegration of both treated and untreated adobe blocks.

Strength testing revealed an increase in compressive strength upon biomineralization treatment, which increased by ~25% from 1.00±0.22 MPa in untreated to 1.23±0.10 MPa in treated samples. However, the spread of data was significant, especially in the case of the untreated sample.

Conclusion

Experimental results revealed the effectiveness of the biomineralization treatment, provoking enhanced carbonatogenic bacterial activity both in the laboratory and in situ. Findings of the laboratory study clearly show an improvement in water resistance and mechanical strength. Considering absolute numbers and the relatively wide spread of data, strength increase was rather limited. However, it has been pointed out previously that strength increase might not be the most important parameter to be taken into account in the case of clay-rich substrates (Doehne and Price 2010). Doehne and Price (2010) consider the reduction in clay swelling, which will consequently lead to an improvement in water resistance, far more important to obtain long-lasting consolidation. Bacterial biomineralization seems promising in this respect as the EPS are able to impart hydrophobicity and limit clay swelling through intercalation into the interlayer space of expansive clay minerals (Alimova et al. 2009). Our results revealed an important reduction in material loss during the first phase of water immersion,

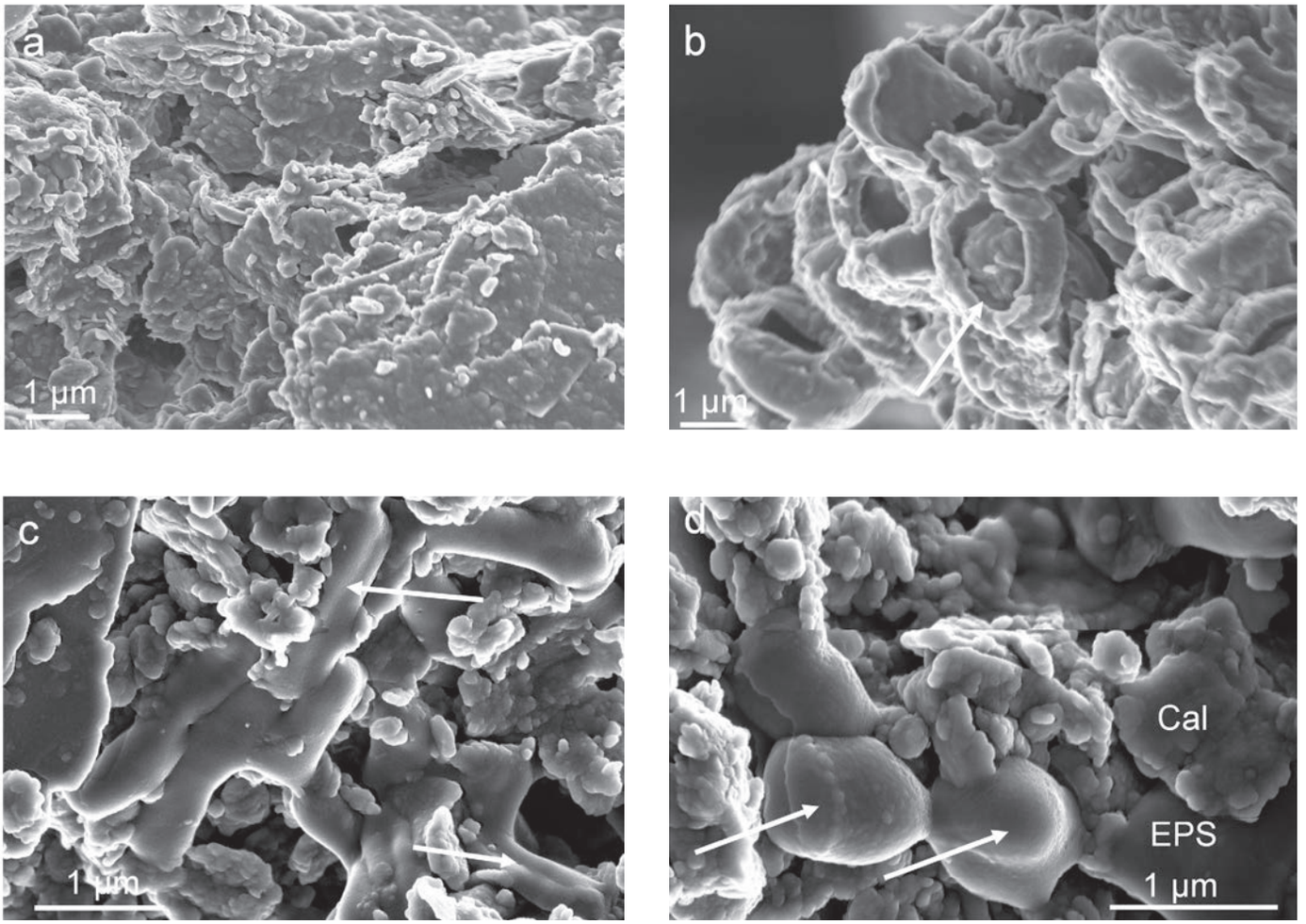


FIGURE 3 FESEM images showing (a) the characteristic platy morphology of clay particles in untreated adobe blocks, (b) detail of calcified bacterial cells (ellipsoidal structures, arrow) attached to the adobe matrix after biomineralization treatment in the laboratory, (c) non-mineralized bacterial cells collapsed due to the high vacuum in the FESEM chamber (arrows), and (d) mineralized bacterial cells (arrows) together with bacterial-derived calcium carbonate (Cal) and EPS in the treated rammed earth wall at the Alhambra fortress.

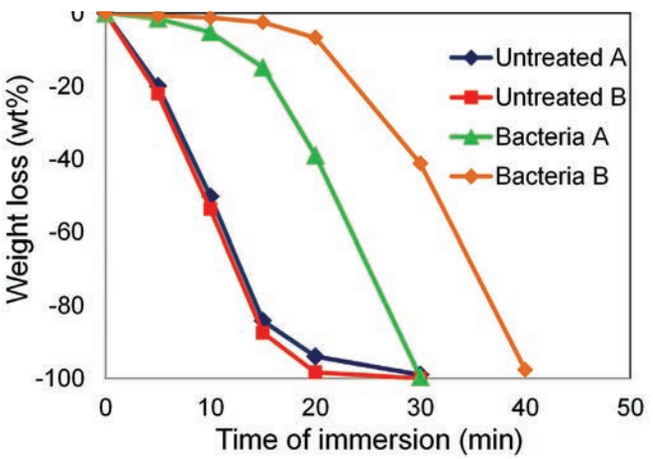


FIGURE 4 Weight loss upon immersion in water of adobe blocks before (untreated) and after biomineralization treatment (bacteria). Tests were performed in duplicate.

suggesting an improved weathering resistance of treated adobe blocks. However, detailed laboratory studies regarding biomineralization-induced changes in the clay structure as well as long-term in situ tests have to confirm this positive preliminary outcome. Unfortunately, as a result of the current health crisis, it has been impossible to evaluate the effectiveness of the biomineralization treatment in situ until now, and non-destructive tests including air permeametry, as well as surface hardness and cohesion, moisture content, and ultrasonic pulse velocity measurements, had to be postponed to fall of 2021.

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Water Repellents in Rammed Earth Heritage Conservation: Using Ancient Products as a Solution for Contemporary Challenges

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Abstract: *Earthen heritage represents an important legacy regarding not only the history of construction but also the knowledge of a millenary practice based on empirical expertise, social conditions, and cultural development. Looking at nature and exploring all the local products that it could provide and how to use them to improve ways of living and building was a common strategy. And while earthen construction requires regular maintenance that is usually done by the local population, the preservation of earthen heritage sites is still a challenging endeavor requiring deeper research, especially from conservation science. It is possible to find natural materials with properties that can prevent degradation phenomena and protect earthen surfaces from typical deterioration agents, specifically from water in the form of rain and humidity. The present work aims to study four water repellents—one synthetic (siloxane) and three natural materials (gum arabic, linseed oil, and beeswax)—applied to rammed earth specimens and offer a case study. Laboratory and in situ tests—namely, the contact sponge method and microdrop absorption—were performed to assess the compatibility and efficacy of the applied products. The main results and conclusions are presented and discussed.*

Resumen: *El patrimonio de tierra constituye un legado importante que tiene que ver no solo con la historia de la construcción, sino también con los conocimientos de una práctica milenaria que se basa en la experiencia empírica, las condiciones sociales y el desarrollo cultural. La estrategia más frecuente consistía en observar la naturaleza y explorar todos los productos locales que pudieran ser útiles, viendo la manera en que se podían utilizar para mejorar la forma de vivir y construir. Asimismo, la construcción de tierra requiere de un mantenimiento regular que, por lo general, realiza la población local. Sin embargo, en muchos casos, la preservación de los sitios patrimoniales de tierra sigue siendo un desafío que requiere una investigación más profunda, sobre todo, desde el punto de vista de la ciencia de la conservación. Es posible encontrar materiales naturales con propiedades que previenen el fenómeno de la degradación y protegen las superficies de tierra. Este tratamiento de protección actúa principalmente contra uno de los agentes típicos de deterioro en la construcción de tierra: el agua. Por lo tanto, la protección contra la lluvia y la humedad es un factor importante cuando se trata de este tipo de materiales. El objetivo de este documento es estudiar cuatro repelentes de agua, uno sintético (siloxano) y tres naturales (goma arábiga, aceite de linaza y cera de abejas), aplicados en especímenes de tierra apisonada, además de un estudio de caso de tierra apisonada. Las pruebas de laboratorio y en el lugar, por ejemplo, el método de la esponja de contacto y la absorción por microgotas, se realizaron con el fin de evaluar la compatibilidad y la eficacia de los productos aplicados. Se presentan y debaten los resultados y las conclusiones principales.*

Keywords: earthen heritage, conservation, rammed earth, water repellents, natural products

Introduction

There is no doubt about the importance of earthen architecture since it walks side by side with the history and evolution of humankind. Acknowledging its significance and impact—not only in ancient civilizations but also in modern societies—is a step forward toward the conservation and continuation of this valuable legacy. Moreover, because local communities play crucial roles in the maintenance of their heritage, earthen construction encompasses the actual buildings as well as the social and cultural intangible values that surround them. Consequently, the involvement of the population and the study of their shared knowledge should not be neglected when designing conservation plans regarding earthen heritage buildings, as this insight can provide valuable solutions for the existing degradation problems.

As of 2019, UNESCO classified 161 earthen properties as World Heritage Sites (Joffroy 2012; UNESCO 2020). Fifteen percent of these are made with the rammed earth technique. Traditionally, rammed earth consists of manually compacting earth into a wood formwork in layers (González 2006). Rammed earth structures are commonly coated with an earthen plaster that acts as a protective and sacrificial layer. However, in severely degraded heritage buildings where this layer no longer exists, it may be necessary to protect the exposed rammed earth by applying products that act as a barrier between the surface and the main deterioration agent—water (Siegesmund and Snethlage 2014). The water repellent products should not seal the material's porous matrix, but should prevent liquid water from penetrating the surface and allow the diffusion of water vapor (Domaslowski 2003).

The Use of Natural Products as Surface Protection

The use of natural and local products, especially as surface protection agents, is a common practice in countries that still use earth as a construction material for dwellings and monuments. The recipes generated by observing nature, including descriptions of products and procedures, have been passed down through generations (Fontaine et al. 2009; Vissac et al. 2017). There are many natural products used in these practices and people employ them based on their availability and efficiency (table 1). The use of these products constitutes proactive measures of keeping traditions alive, engaging the community, and implementing sustainable procedures. However, the use of natural products for conservation actions still requires more scientific research to understand their behaviors and interactions with earthen materials. Additionally, the application of synthetic (mainly siloxane-based) coatings to earthen heritage is gaining popularity (Martínez, Aynat, and Marcos 2012; Mileto and Vegas 2017). Although this procedure is widely studied for stone conservation, there is still a lack of scientific research for the case of earthen materials.

Table 1 Examples of Natural Products Used for the Maintenance of Earthen Buildings

Country	Natural product	Application method	Reference
Peru	San Pedro Cactus	Mixed with earthen mortar	(Checa and Cristini 2012)
Guinea	Karite butter	Mixed with earthen plaster	(Joffroy 2005)
Ghana	Locust bean fruit	Applied on decorative earthen plaster	(Joffroy 2005)
Cameroon	Fish oil	Mixed with earthen plaster	(Joffroy 2005)
France	Linseed oil	Applied on top of earthen materials	(Vissac et al. 2017)
Mali	Gum arabic	Mixed with earthen plaster	(Correia, Guerrero, and Crosby 2016)

Research Aim

Given that water is one of the main causes of earthen material degradation (Aguilar et al. 2016; Elert et al. 2008; Ribeiro, Oliveira, and Bracci 2020), the present study aims to evaluate the efficacy of using natural water repellents on rammed earth. This study is focused on the degradation caused by water in its liquid state and on the protection of external walls. Three natural products and one synthetic product were selected and applied to rammed earth specimens under laboratory conditions and in a case study. The selection of these products was based on the literature review (Vissac et al. 2017) and the availability of the products in the Portuguese context. For the evaluation of the products' efficacy, water absorption (through contact sponge method) and water repellency (through microdrop absorption time) tests were performed, as well as visual assessments of the impacts of the applied treatments.

Materials and Methods

Rammed earth specimens were prepared in the laboratory using soil collected in southern Portugal, a region known for



FIGURE 1 General aspects of the rammed earth specimens. All photos: T. Ribeiro.

its rammed earth heritage. The specimens were produced according to traditional techniques, which involved compacting the earth manually into a wood formwork, creating cubes of approximately 10 cm/side that were then left to dry for four weeks (fig. 1). The raw material was sieved earth with no stabilizer. The size of the specimens was set at 10 cm/side to guarantee a representation of all grain sizes within the samples and to have at least two layers of compaction. The specimens were characterized in terms of density and porosity. Density was calculated by the ratio of mass per volume. Porosity was calculated with the ratio of voids volume to total volume (Das 2011).

Geotechnical, mineralogical, and chemical analyses were performed to characterize the rammed earth specimens in terms of particle size distribution (LNEC E196 1966), density (NP-83 1965), Atterberg limits—liquid limit (LL), plastic limit (PL), and plasticity index (PI) (NP-143 1969), X-ray diffraction (XRD), and energy dispersive X-ray fluorescence (EDXRF). The summary of these results is reported in table 2.

XRD analyses were carried out using a Philips PW-1830 diffractometer with Cu Kα radiation. The operational conditions were 40 kV, 50 mA, a step size of 0.02° 2θ in the 3–90° 2θ range, and a step time of 2.50 s. The samples were dried and ground before testing. For EDXRF, three samples from the same soil were analyzed using an ArtTAX X-ray spectrometer (Bruker), equipped with an Xflash (Si [Li]) detector, with 170 eV resolution, and operating with a molybdenum X-ray source. Elemental composition was acquired through the average of three independent spots using a tube voltage of 40 kV, a current intensity of 600 μA, and a live time of 180 s.

Four water-repellent products were selected, three natural and one synthetic: gum arabic, linseed oil, beeswax, and siloxane. Gum arabic is extracted from acacia trees and is used mainly in Africa as protection from water and for repairing the surface of earthen constructions (Correia, Guerrero, and Crosby 2016; Vissac et al. 2017). It can be dissolved in cold water and its preparation is easy, fast, and inexpensive. Linseed oil has been used since the fifteenth century for paintings and as a protective layer for earthen plasters or surfaces, especially in Europe. This oil is obtained through ground linseeds and has impermeabilization properties since it does not mix with water (Vissac et al. 2017). Beeswax is a natural wax produced by bees and was commonly used as a water repellent in European earthen constructions (Correia, Guerrero, and Crosby 2016). Finally, the siloxane used in this experimental work, SILO 112 from CTS, is a commercial product. All four products were applied directly on the rammed earth specimens' surfaces, on two sequential and perpendicular layers to guarantee a complete coating. Gum arabic was dissolved in cold water in a proportion of 1:4, linseed oil was applied without any solvent, beeswax was prepared in a 5% turpentine solution, and siloxane was applied directly following the supplier instructions (fig. 2). All products were applied to five specimens, each in a controlled laboratory environment (20°C and 60% RH). All specimens were kept in these same conditions for fifteen days for stabilization purposes before and after application of the products.

The contact sponge method was performed following the Italian Standard (UNI 11432:2011 2011), with a sponge and specimen contact time of 60 s. For microdrop absorption time (RILEM 25PEM:1980 1980), a pipette (placed approximately 1 cm away from the specimen) delivered a set of nine drops of distilled water (≈4 μl) to the surface of each specimen. The time that it took for each drop to be completely absorbed or evaporated was measured and compared with a reference surface (non-polished glass).

Table 2 Characterization of Rammed Earth Specimens

Density (g/cm^3)	**Porosity** (%)	**Particle size distribution**	**Bulk density** (g/cm^3)	**Atterberg limits**	**XRD**	**XRF**
2.19	0.53	42% gravel 34% sand 13% silt 11% clay	2.65	LL 45% PL 24% PI 21%	Quartz, kaolinite, feldspar, muscovite	Al, Si, K, Fe, Cu, Zn, Cr

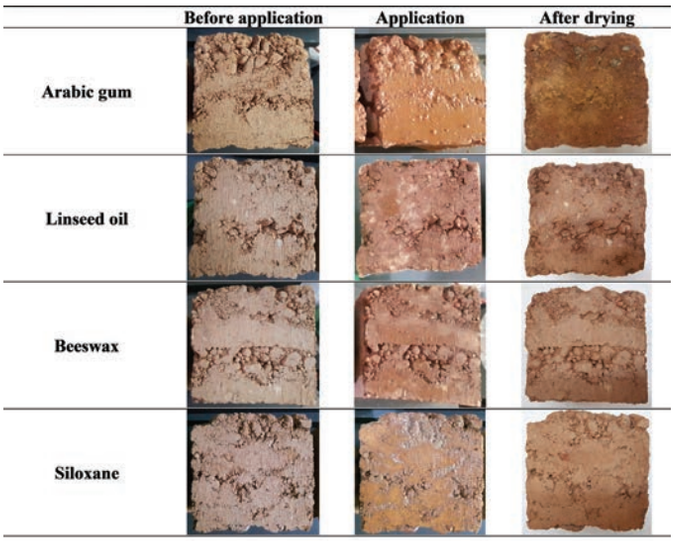


FIGURE 2 Example of one rammed earth specimen before, during, and after the application of the three natural and one synthetic water repellent products.

Laboratory Campaign: Results and Discussion

The contact sponge method was performed to evaluate water absorption and the main results are reported in figure 3. It is possible to observe a drastic reduction in water absorption after the application of all products, with a decrease of 98% for both beeswax and siloxane, 95% for linseed oil, and 87% for gum arabic. Microdrop absorption time was performed to determine water repellency and the obtained values are reported in figure 3. Water repellency increased for all specimens after the products' application, indicating the presence of a barrier between the surface and the water. However, when compared to the natural products, siloxane shows a water

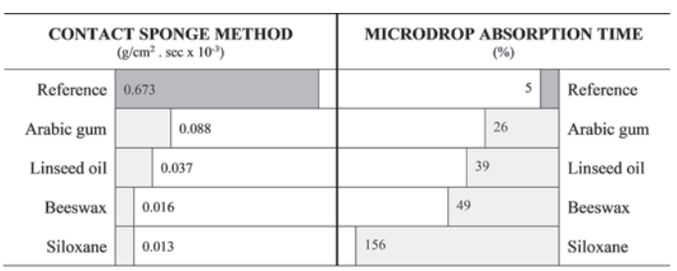


FIGURE 3 Contact sponge method and microdrop absorption time results for the rammed earth specimens with and without the water repellent treatments.

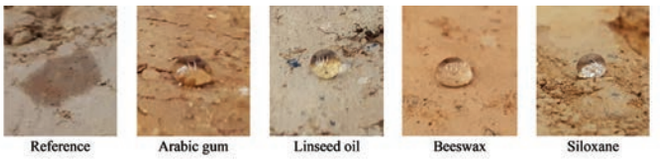


FIGURE 4 Examples of water droplets on top of treated and untreated rammed earth specimens during the microdrop absorption time test.

repellency level value over 100%, indicating that the surfaces became completely hydrophobic.

The microdrop absorption time test showed that all drops of water spread out and were immediately absorbed in non-treated areas and that all drops formed a spherical shape on the areas treated with water repellents (fig. 4). It is important to note that even though the natural products do not exhibit results over 100% (indicating that they are not fully hydrophobic), they still showed strong water repellency as seen by a significant decrease in water absorption, by the increase in water repellency, and by the spherical shape that drops of water assumed when in contact with the treated earthen surfaces.

In Situ Campaign: Results and Discussion

To compare with the laboratory results previously discussed, a case study was selected and in situ tests were performed. The case study involved the Rammed Earth Portico, located at the University of Minho (Guimarães campus), that was built during a training workshop in April 2013. Two types of raw material mixtures were used: unstabilized soil (exclusively clay soil from southern Portugal) and stabilized soil (about 8% portland cement was added to a granitic residual soil from northern Portugal). As shown in figure 5, these two mixtures can be clearly distinguished by the aspects and colors of their structures, with the unstabilized soil in the column on the left, and both the right column and the lintel made with the cement mixture.

The same products tested under laboratory conditions were applied to the left column (fig. 6) using the contact sponge method. As seen in figure 7, there is a decrease in water absorption when comparing the treated and non-treated surfaces, revealing once again the efficacy of the tested products. Even though siloxane shows better results, the natural products also exhibit a significant reduction in water absorption.



FIGURE 5 The Rammed Earth Portico on the University of Minho campus, used in the case study.

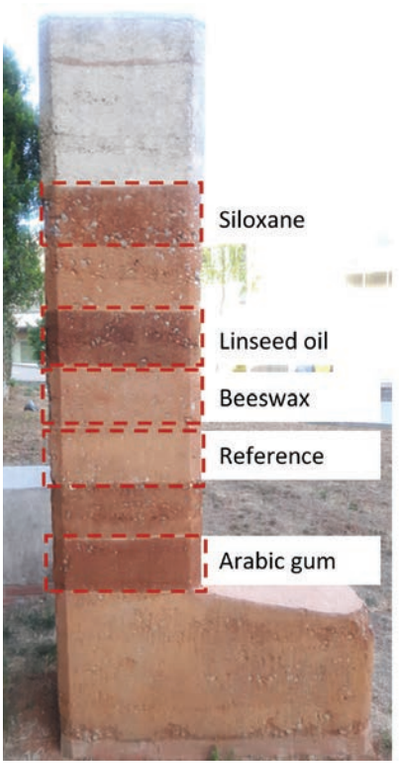


FIGURE 6 Product application on the Rammed Earth Portico.

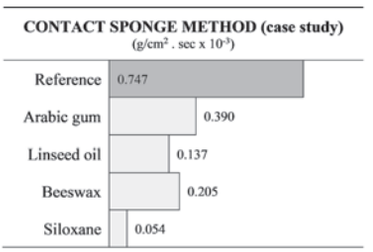


FIGURE 7 Contact sponge method results for the tests performed in situ.

Conclusion

Three natural products—gum arabic, linseed oil, and beeswax—were tested as water repellents and showed promising results when compared to siloxane, a commercial synthetic product. All products significantly reduced water absorption and act as water repellents, compelling the applied water drops to form spherical shapes instead of spreading out on the surfaces. Moreover, the in situ tests performed on the case study corroborated the laboratory tests, showing similar results of all applied products. The application of these products on a real case study, one that is exposed to temperature and humidity variations, will improve the understanding of these products' long-term behavior, especially related to possible degradation factors that may be associated. The natural aging process of both the products and earthen material can provide valuable answers regarding the durability aspect and, consequently, maintenance practices that may be necessary. This means that further work and more scientific research are required to support the use of natural products as a solution for protective coatings and to ensure the continuation of good practices in the maintenance of earthen heritage.

Acknowledgments

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PART 4

Archaeological Sites / Sitios arqueológicos

Reflective Conservation in Practice: Informing Consolidation Strategies at Çatalhöyük, Turkey

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Abstract: *At the UNESCO World Heritage Site of Çatalhöyük, Turkey, a shift in site management policies and presentation demands changed the context of the site's preservation and was the impetus for a change in conservation practice. Moreover, the construction of two permanent shelters over excavated areas created adverse microclimates for preservation. Previous conservation strategies had focused heavily on the concept of polymeric-based consolidation of the in situ earthen structures after excavation. To underpin a new evidence-based conservation strategy, a methodology was developed to examine the impact of previous treatments of aqueous synthetic carbon-based polymer systems. This study used Fourier transform infrared microspectroscopy (FTIR) to map polymer penetration in archaeological and new mud brick. In addition, polymer impact on the compressive strength of mud brick was measured with a Universal Testing Machine (UTM). This integrated approach, combining analysis of archaeological and new earthen materials, verifies the methodology and demonstrates its applicability to the evaluation of other consolidants in this context. Conservators at Çatalhöyük now understand that decades of polymer application at the site had no impact on the mechanical properties of the architectural materials. The outcomes of this work have already influenced conservation practice at Çatalhöyük; conservators have revised treatments for the earthen structures and improved systems for monitoring treatment effects and long-term stability. Conservation materials focus on environmental compatibility for the treatment of the in situ archaeological features. This insight underlines treatment strategies in the present and allows evidence-based planning for the future survival of this unique site.*

Resumen: *En Çatalhöyük, lugar declarado Patrimonio de la Humanidad por la UNESCO, un cambio en las políticas de gestión del sitio y las exigencias de presentación modificaron el contexto de la preservación del lugar, convirtiéndose en el impulso para un cambio en las prácticas de conservación. Asimismo, la construcción de dos cubiertas permanentes en las zonas excavadas creó microclimas adversos para la preservación. Las estrategias de conservación anteriores se enfocaban principalmente en el concepto de consolidación de base polimérica de las estructuras de tierra en el lugar después de la excavación. Con el fin de propiciar una nueva estrategia de conservación basada en la evidencia, se desarrolló una metodología para evaluar el impacto de los tratamientos anteriores de sistemas de polímeros sintéticos acuosos a base de carbono. En este estudio, se utiliza la microespectroscopía de infrarrojo con transformada de Fourier (FTIR) para rastrear la penetración del polímero en los adobes arqueológicos y nuevos. Además, se midió el impacto del polímero en la fortaleza integral de los adobes con una máquina de prueba universal (UTM). Este enfoque integrado que combina el análisis de los materiales de tierra arqueológicos y nuevos verifica la metodología y demuestra que es aplicable para la evaluación de otras sustancias consolidantes en este contexto. Los conservadores de Çatalhöyük comprenden ahora que aplicar polímeros en el sitio durante décadas no tuvo ningún impacto en las propiedades mecánicas de los materiales arquitectónicos. Los resultados de este trabajo ya afectaron las prácticas de conservación en Çatalhöyük; los conservadores revisaron los tratamientos de las estructuras de tierra y mejoraron los sistemas de control de los efectos de los tratamientos y la estabilidad de los materiales a largo plazo. Los materiales de conservación se enfocan en la compatibilidad ambiental para el tratamiento de los elementos arqueológicos del sitio. Esta perspectiva destaca las estrategias de tratamiento que se utilizan hoy en día y permite planificar sobre la base de la evidencia la supervivencia futura de este sitio único.*

Keywords: consolidation, conservation practice, quantitative evaluation, polymers

Introduction

The year 2012 was significant for the site of Çatalhöyük—it was inscribed on the UNESCO World Heritage List and saw a significant team transition. These changes created new challenges in synthesizing existing research while developing new strategies for displaying and interpreting the site. The resulting shift in site management policies and presentation strategies altered the context of the conservation practice and generated support for the development of new preservation strategies for the in situ structures. Underpinning the effectiveness of consolidation practices became a critical aspect of developing future conservation strategies for the built heritage.

Çatalhöyük is a proto-city dated to 7100–5950 BCE near Konya in central Turkey. The site is a Neolithic mound, or tell, covering 37 ha and is 21 m in height from the plain at its apex, with eighteen layers of occupation (Human 2012). Though Çatalhöyük was neither the earliest nor the largest farming community in Anatolia, it was a significant participant in the cultural and economic changes that swept across the Near East in the Neolithic period (Human 2012). There have been various phases of excavation at the site since the 1960s, initially by James Mellaart and later by Ian Hodder from 1993 to 2017. The Çatalhöyük settlement is composed of mud brick houses densely packed together. All walls are constructed of unbaked mud brick, usually of large dimensions, ranging from 10 cm to over 1 m in length and height. Generally, every building had its own four walls, although during the early sequences there was more use of shared walls between buildings (Love 2012).

History of Conservation of the In Situ Structures at Çatalhöyük

When Ian Hodder took on the direction of the site in 1993, one of the principal aims of the project was the inclusion of conservation within the archaeological program. To facilitate the site becoming a place of cultural tourism, conservation measures were sought for open display of the in situ structures on both short- and long-term scales (Matero 2000). Conservators at Çatalhöyük sought to consolidate the structures in situ, as observations suggested this practice kept the plasters in place for a few seasons longer (Pye 2006). For many years, an ongoing part of the conservation strategy at Çatalhöyük was the application of aqueous polymer systems as a consolidation and reattachment method to the plaster and mud brick surfaces. The polymers used were polyvinyl acetate (PVAC), Primal (Rhoplex) B60A (ethyl acrylate and methyl methacrylate copolymers) aqueous emulsion, and its predecessor Primal AC-33 (methyl methacrylate, ethyl acrylate, and ethyl methacrylate copolymers).

Through laboratory and in situ visual and standardized tests, several possible organic and inorganic consolidants were evaluated based on criteria that included, among others, depth of penetration and distribution of consolidant, mechanical durability, physical appearance, reversibility, and ease and safety of application (Kopelson 1996; Matero 2000). Assessment methods in these studies were empirical and largely inconclusive. The results from Kopelson (1996), for example, demonstrated that salt recrystallization sometimes occurred at the surface-substrate interface and that the correlation with deterioration included flaking, delamination, and detachment.

In archaeological field practice historically, aqueous polymer systems are common choices due to their availability and low toxicity (Cooke 2008). While aqueous polymer systems were not initially intended for long-term stabilization at Çatalhöyük, their use eventually became part of the annual conservation maintenance, reapplied when signs of deterioration began to reappear. Eventually Primal B60A became a "fix-all" for both the mud brick walls and plaster at the site. Once excavations finished, many of the earthen buildings were sprayed with Primal B60A (Cooke 2008). Due to discontinuity in team members over the years and limited documentation of conservation treatments of the buildings, the concentration and application methods varied greatly. Discontinuity also meant that consistently documenting deterioration and long-term treatment outcomes was not achievable.

Shift in Conservation Context

The environment at the site has undergone significant changes since Matero and Moss's 2004 study on temporary protection, with the construction of two permanent shelters over the South (2003) and North (2008) excavation areas. The shelters protect approximately twenty-four buildings in the South and twenty buildings in the North from catastrophic loss due to rain, snow, and damage done during the backfilling and uncovering processes. Though a significant step in long-term preservation, shelter design has resulted in a trickle-down effect regarding how the archaeological material can be treated. Deterioration chiefly comes from within the walls themselves: rising damp coupled with high levels of soluble salts resulting in wall undercutting, plaster delamination, and surface erosion leading to collapse. The microclimates generated by the shelters now exacerbate issues associated

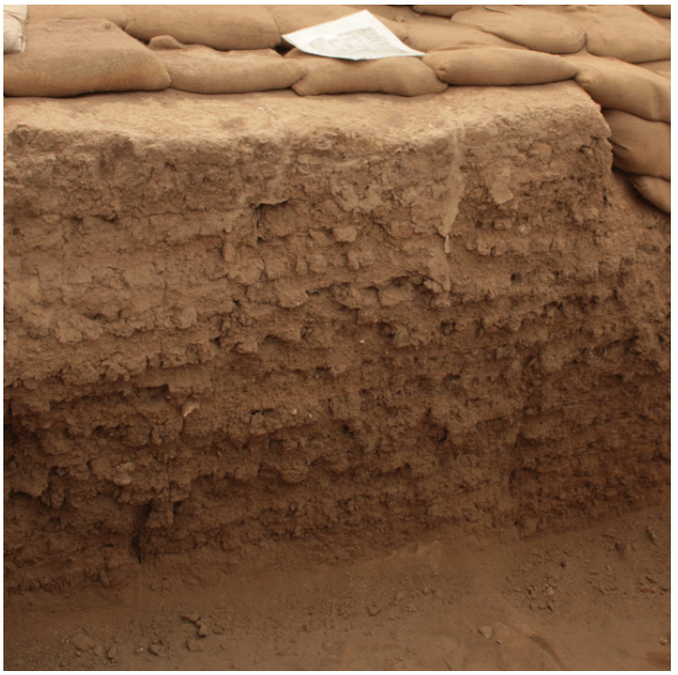


FIGURE 1 Delamination due to consolidant film formation at the top of a wall, Çatalhöyük, Building 5. Photo: Ashley Lingle.

with soluble salts and desiccation of the earthen structures (Campiani, Lingle, and Lercari 2019). Developing a new program for monitoring the climate under the shelters and the behavior of the in situ materials was a key stage in reevaluating conservation practices (Campiani, Lingle, and Lercari 2019). As site monitoring improved, specific deterioration patterns emerged, which correlated with the failure of the polymer rather than the archaeological substrate (Lingle 2020) (fig. 1). Most commonly found on site is polymer film decay presenting as delamination, which happened with greater frequency and severity as temperatures increased under the shelters.

Consolidation Tests

Challenges exist when consolidating mud brick—pores in earthen substrates are irregular and non-contiguous—and it is difficult to obtain accurate porosity measurements as the absorbent nature of clay and the lack of a water-resistant binder make many standard porosity tests uninformative. The added fragility of archaeological materials due to the loss of binding media further limits the types of analysis that can be carried out in the field. The success of applying aqueous systems as consolidants is inherently difficult to visually interpret in mud brick because of the relationship between clay and water. Clays both adsorb and absorb water. This wetting process can give the appearance that a mud brick has been well consolidated, offering no evidence of how far the aqueous polymer system has moved through the material. In archaeological contexts, it becomes even more complicated with walls that are only partially exposed.

This experimental study replicated consolidation practice in a controlled and measurable way to produce quantitative data that contribute to a better understanding of the empirical concept of what consolidation procedures achieve. First, the suitability of the Fourier transform infrared spectroscopy (FTIR) experimental methodology for detecting low levels of polymer within earth matrices was confirmed. This was then used to explore the belief that polymer dispersions applied to mud brick permeate its fabric and strengthen it. A Universal Testing Machine (UTM) was utilized to explore further questions centered on what strength gains can be attributed to empirical field consolidation procedures and what an "ideal" consolidation would produce in terms of increased strength. In the process of doing this, other factors such as the influence of climate, consolidant dispersion relative to volume, and concentration were investigated.

Archaeological and reproduction mud brick material were used for the experimental work carried out. By characterizing and duplicating the original earthen materials, experimental reproducibility was achieved and correlated back to in situ practice. Mud brick components were sourced and fabricated utilizing material studies by Love (2012) and Matthews (2005). For the experiments, samples measured 5 × 2 × 2 cm, specific volumes of polymer systems were measured with a pipette onto the horizontal surface, offering the greatest probability for consolidation to take place (Lingle 2020). Over the course of this study, 61 archaeological samples from Çatalhöyük and 200 reproductions were examined (fig. 2). Examination was undertaken of both the archaeological and reproduction mud bricks with FTIR analysis. Further investigation of the reproduction mud bricks was carried out with UTM compression.

Polymer Mapping

Mapping the depth of penetration of Primal B60A and PVAC into the mud brick substrate was carried out using FTIR, which facilitates the easy analysis of small samples and point-by-point mapping across a sample surface (Chalmers, Everall, and Ellison 1996). Results were acquired by external



(a) (b)

FIGURE 2 Study material from Çatalhöyük (a), consolidated reproduction (b). Photos: Ashley Lingle.

reflectance FTIR microspectroscopy using the Perkin-Elmer Multiscope System Microscope connected to the Perkin Elmer Spectrum One Spectrometer IR radiation source. The microscope is equipped with a liquid nitrogen cooled MCT (Mercury, Cadmium, and Telluride) detector. Spectra were collected after twenty scans, 4 cm^{-1} spectral resolution, 4000–600 cm^{-1} frequency range. Detection limits of the Primal B60A and PVAC polymers within reproduction mud bricks were reliably established by identifying peaks in the region 3000–2850, recording a range of C-H bonds and 1750–1720 representing the -C=O carbonyl groups. The presence or absence of these characteristic peaks was used to determine the FTIR limits of detection of the polymers.

Compression Tests

Building on the study by Lee et al. (2009), the impact of applying selected synthetic carbon-based polymer systems on the physical properties of an earthen substrate was examined using a Zwick/Roell UTM (error ± 0.01%). Compression testing of earthen materials has long been established (Poggi 2006). However, the challenge for this study was to scale the experiments so that fluctuations in polymer performance could be correlated to reflected field consolidation practices. A total of 120 reproduction samples were produced for this experiment, comprising 10 in each sample group. Reproduction samples fabricated for these tests were either left untreated (10 samples), treated on a single surface to reflect consolidation practice (90 samples), or had polymer incorporated during fabrication to reflect idealized consolidation (20 samples). Consolidated samples were treated with a range of polymer concentrations and volumes. Four sample groups were consolidated and dried in conditions equating to climates representing: Arid 50°C/25% RH; Tropical 40°C/90% RH; Temperate 10°C/75% RH; and Continental 10°C/25% RH. The climatic chamber used for relative humidity and temperature-controlled drying procedures was a Binder KBF-240V.

Results of FTIR and Compression Tests

FTIR analysis revealed that polymers were detectable at very low dilutions of 0.00017 g polymer solids per gram of mud brick. Polymer mapping revealed that only 20 of the 61 samples had peaks for polymers present in the FTIR spectra. Moreover, polymer peaks were present only on the surfaces of the archaeological samples. Superficial consolidation was also a consistent feature of the 20 mapped reproduction samples. No polymer systems were detected below the surfaces of the samples across the study (figs. 3–6). These results indicate that the polymer systems form only a surface film and that no actual consolidation takes place in the context of a surface application.

Compression testing results indicated equally superficial performance. Reporting compression testing according to the amount of force applied at the breaking point revealed

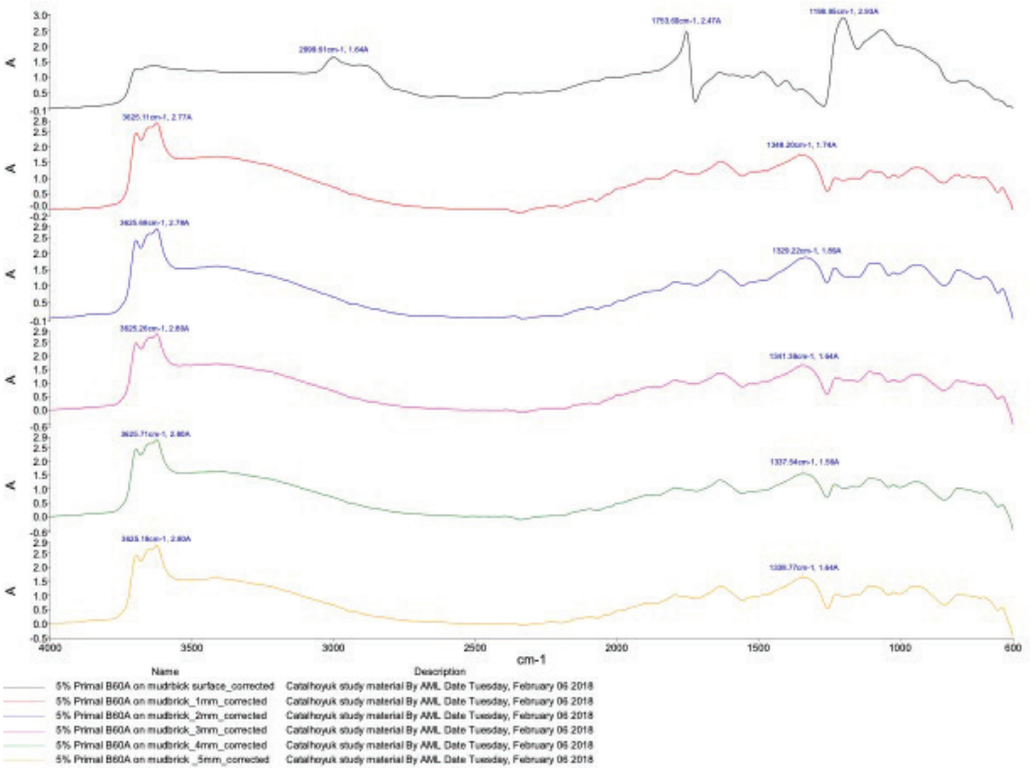


FIGURE 3 Penetration map of 5% Primal B60A in a reproduced mud brick, 1 scan per mm.

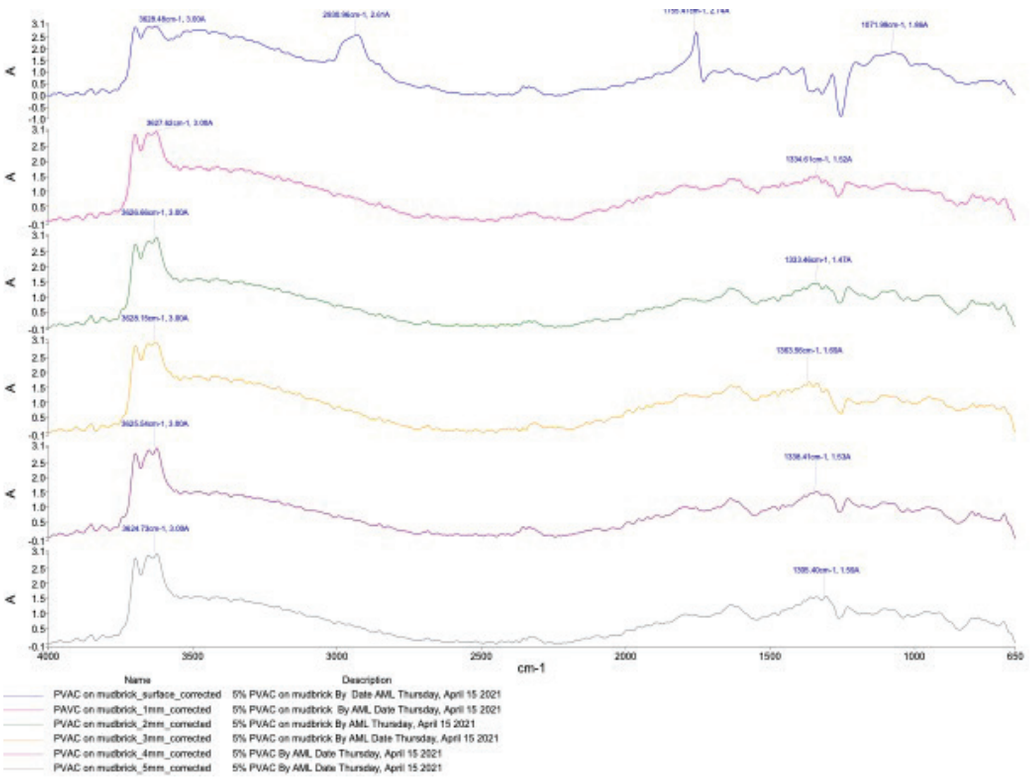


FIGURE 4 Penetration map of 5% PVAC in a reproduced mud brick, 1 scan per mm.

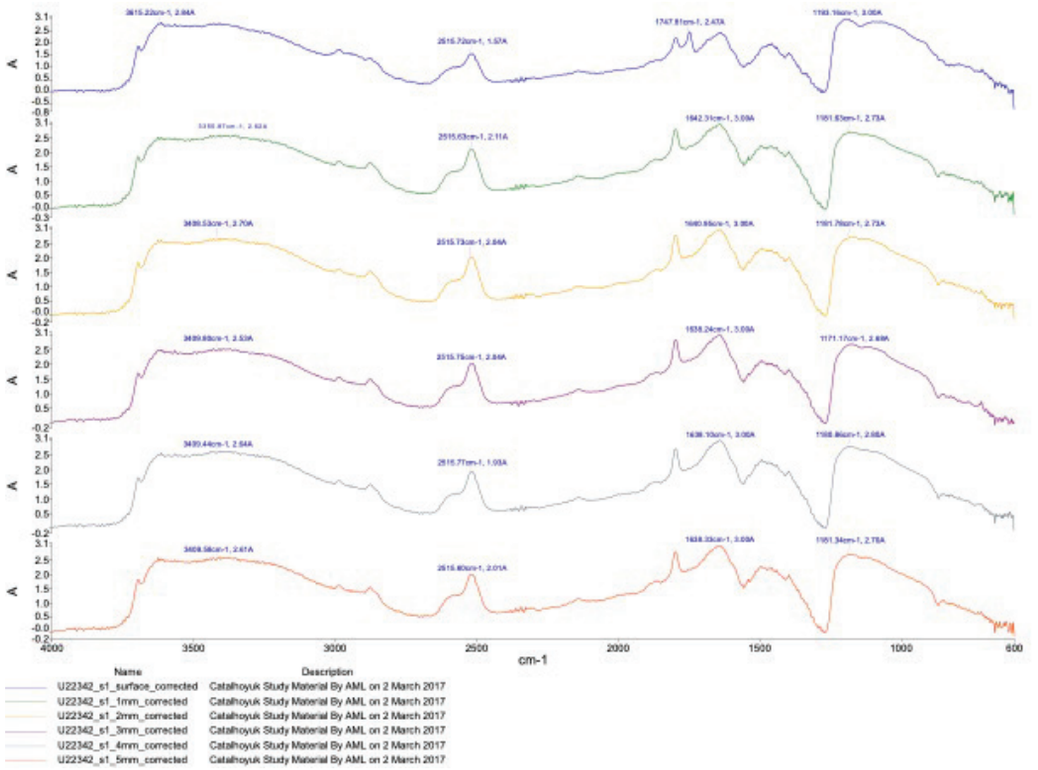


FIGURE 5 Penetration map of Primal B60A in an archaeological sample from Çatalhöyük, 1 scan per mm.

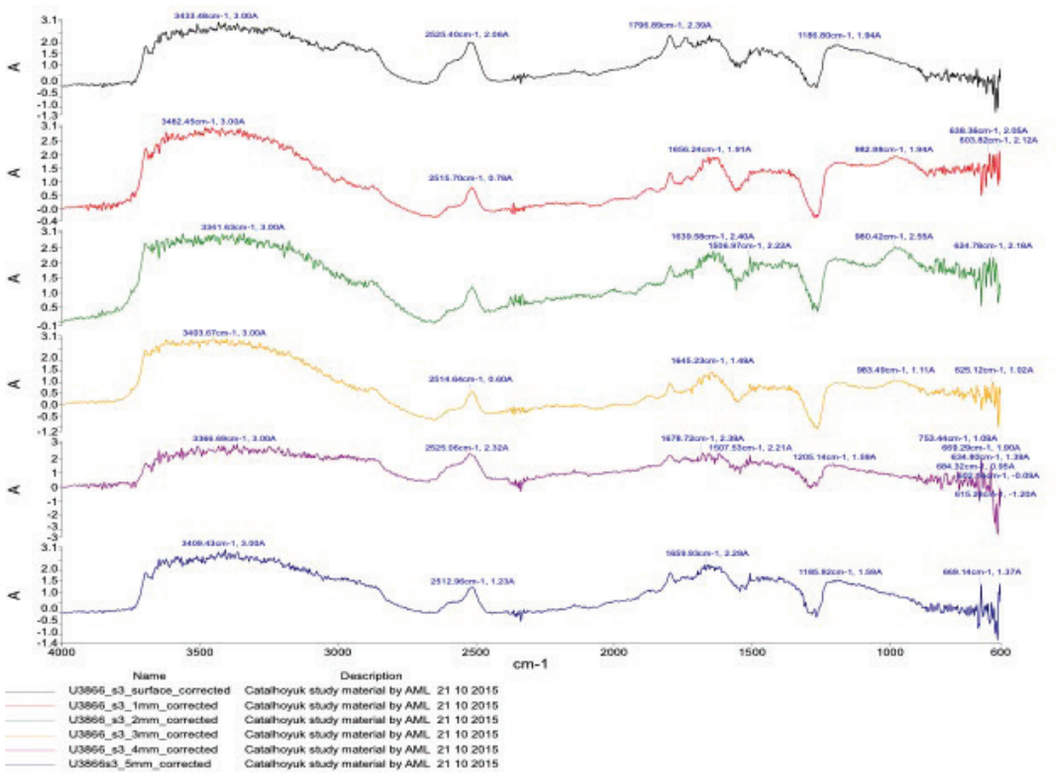


FIGURE 6 Penetration map of PVAC in an archaeological sample from Çatalhöyük, 1 scan per mm.

"idealized" consolidations and, unsurprisingly, where the polymer was introduced into the reproduction when it was formed required the highest application of force to break (table 1). However, consolidated sample groups showed no significant difference in either force or extension values at the breakpoint. Overlap between force and extension ranges at the breakpoint across all consolidated and untreated samples reveals it is not possible to state that any of the consolidation applications increase the strength of the reproductions (fig. 7). There was some evidence that environment and substrate rigidity had a more significant impact on compressive performance, though, again, overlap in the results requires further investigation.

Table 1 Average Compression FMax Descending Order of Deformation Distance (mm)

Sample group no.	Notation	Group and dilution volume v/v in deionized water (unless otherwise stated)	Average force (Newton)	Average deformation distance (mm)
1	Mix 5% PVAC	5% PVAC mixed into substrate	4590	3.4
2	Mix 5% B60A	5% B60A mixed into substrate	4780	2.9
4	B60A 15%	15% Primal B60A (3ml)	1220	1.8
3	B60A 5%	5% Primal B60A (9ml)	1080	1.8
8	40_90	40°C, 90% RH (4ml)	792	1.8
7	50_25	50°C, 25% RH (4ml)	1450	1.7
12	B44	5% Paraloid B44 (acrylic resin) w/v in acetone (5ml)	1380	1.7
10	10_25	10°C, 25% RH (4ml)	1030	1.6
6	PVAC 15%	15% PVAC (5ml)	991	1.6
9	10_75	10°C, 75% RH (4ml)	951	1.6
11	UT	Untreated	1050	1.5
5	PVAC 5%	5% PVAC (5ml)	1120	1.4

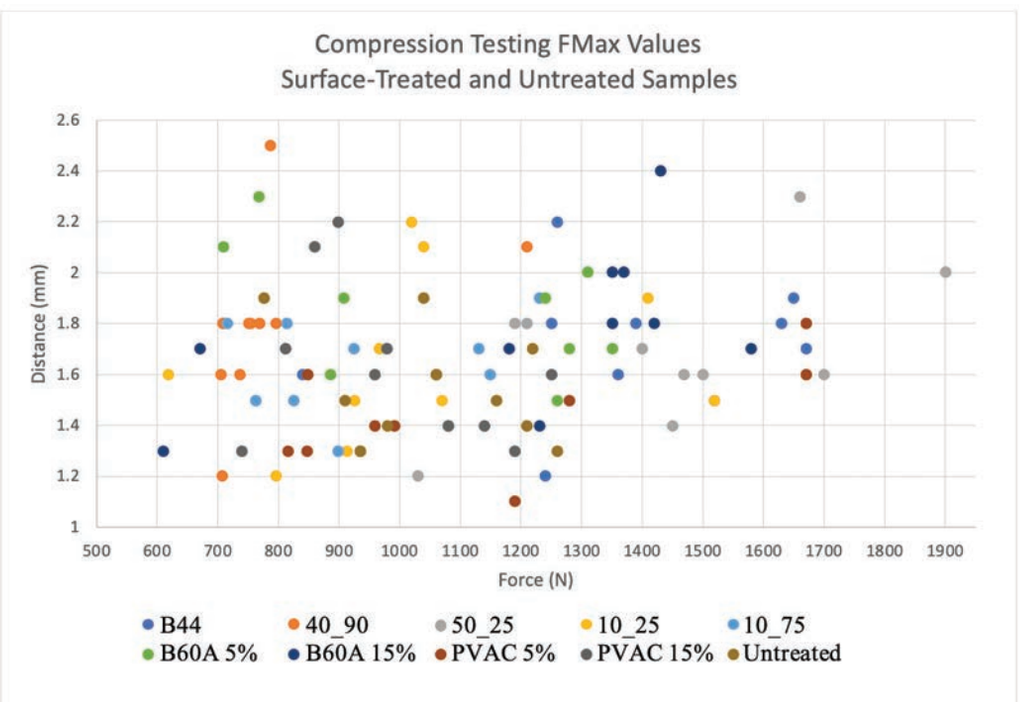


FIGURE 7 Scatterplot distribution of deformation results for the untreated and consolidated samples compressed by the UTM, dLmax distance over Fmax measurement.

Conclusion

Ultimately, some of the results of this study were anticipated as research carried out by Koob, Rogers, and Sams (1990) suggests that the viscosity of acrylic emulsions is too high for successful penetration of earthen substrates. The work by Coffman, Selwitz, and Agnew (1990) demonstrates that one of the problems encountered after the application of consolidant to earthen substrates is the formation of a consolidant-rich outer film on the face of adobe masonry. Film formation may cause accelerated deterioration of the adobe by inducing the separation of the treated outer layer from the untreated inner core (Illampas, Ioannou, and Charmpis 2011). In the case of Çatalhöyük, the lack of penetrative consolidation coupled with polymer use in widely fluctuating environmental conditions led to treatments failing.

Conservation management planning at Çatalhöyük has had to remain both flexible and consistent, a balance of research goals, heritage management, and questions of authenticity in a shifting political climate. Shelter construction has caused an overall shift in the conservation approach, moving from treatments solely based on the archaeological substrate to treatments based on the climate surrounding the in situ archaeology. The insight from this study underpinned the development of new treatment strategies and allows evidence-based planning for the future survival of the site.

Heritage conservation does not occur in an idealized and standardized manner. The composition and condition of archaeological materials is highly variable, with knock-on implications for the predictability of treatments. In situ, or field, conservation adds a further level of complexity for the conservator who is likely to have a limited ability to control the environmental conditions and may experience difficulties of access and a wealth of other practical constraints. A multidisciplinary approach allows for the effective implementation of conservation measures, including prioritization of activities and funding, but must be cyclically reviewed.

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Holistic Conservation on an Iron Age Archaeological Site in the United Arab Emirates: Hili 2, Al Ain, Abu Dhabi

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Abstract: *Hili 2 is an earthen Iron Age archaeological site comprising fifteen buildings that was discovered approximately forty years ago under the sand dunes next to one of the oases of Al Ain, in the United Arab Emirates. It is among the best-preserved remains of an Iron Age settlement in the region and is part of the World Heritage Site serial property known as the Cultural Sites of Al Ain, inscribed in 2011. Several campaigns of targeted curative conservation repairs were undertaken in the past by the Department of Culture and Tourism–Abu Dhabi (DCT). From 2017 to 2019 the DCT, in partnership with CRAterre, implemented a holistic project that responded to both international standards and local requirements. This was also an opportunity for multidisciplinary collaboration between conservators, archaeologists, structural engineers, architects, materials scientists, and traditional craftspeople. The work led to further discoveries and a deeper understanding of the site. Curative conservation measures of the archaeological structures are presented, together with the preventive conservation interventions and a new interpretation of the very unusual building technique of Hili 2.*

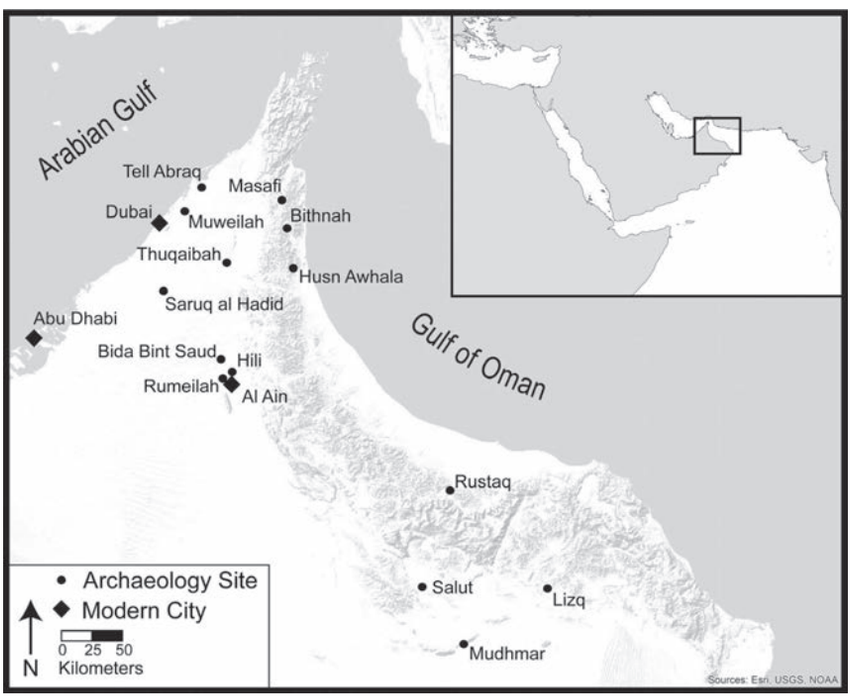
Resumen: *Hili 2 es un sitio arqueológico de tierra de la Edad de Hierro que se compone de quince edificios; se descubrió hace alrededor de cuarenta años, oculto debajo de las dunas de arena, junto a uno de los oasis de Al Ain en los Emiratos Árabes Unidos. Es una de las ruinas mejor conservadas de un asentamiento de la Edad de Hierro en la región y forma parte del conjunto seriado declarado Patrimonio de la Humanidad "Sitios culturales de Al Ain", en 2011. En el pasado, el Departamento de Cultura y Turismo (DCT) de Abu Dabi llevó adelante varias campañas de reparaciones curativas específicas. De 2017 a 2019, bajo la dirección del DCT y en asociación con CRAterre, se implementó un proyecto holístico que siguió tanto los estándares internacionales como los locales. Asimismo, esta oportunidad hizo posible la colaboración multidisciplinaria entre conservadores, ingenieros estructurales, arquitectos, científicos de materiales y artesanos tradicionales. Gracias a este trabajo, se hicieron más descubrimientos y se alcanzó una comprensión más profunda del sitio. Aquí se detallan las medidas de conservación curativas de las estructuras arqueológicas, junto con las intervenciones de conservación preventiva y una nueva interpretación de la técnica de construcción muy poco frecuente de Hili 2.*

Keywords: Iron Age archaeological site, earthen World Heritage Site, curative conservation, preventive conservation

Introduction

Hili 2 is an exceptional earthen archaeological site located in Al Ain in the United Arab Emirates (fig. 1). Al Ain is composed of several oases, and archaeological research has found evidence for several thousand years of occupation. In 2011, the Cultural Sites of Al Ain (including Hili 2) were inscribed on the UNESCO World Heritage List as a serial property.[1] First excavated in the 1970s (ur-Rahman 1978/9), Hili 2 is an Iron Age II (ca. 1100–600 BCE) settlement composed of at least fifteen mud brick structures, some of which have walls preserved to a height of 2 meters (Karacic et al. 2019, 2020).

The Department of Antiquities and Tourism in Al Ain conducted the initial excavations in 1976, exposing several earthen buildings (Al Tikriti 2001) (see fig. 1). Conservation interventions have been undertaken to consolidate the remains of the architecture since its discovery. In 2010, conservation



(a)



(b)

FIGURE 1 (a) Hili archaeological site in Al Ain (UAE) after the excavations in 2001. Map: Archive, Esri, USGS, NOAA, S. Karacic, © DCT Abu Dhabi; and (b) Aerial photo of the site. Archive © DCT Abu Dhabi.

efforts were reorganized under the Department of Culture and Tourism–Abu Dhabi (DCT).[2] In subsequent years, DCT conducted emergency interventions to maintain and consolidate the site; however, the need to address general challenges, resulting from decades of exposure without a proper holistic conservation plan, was identified.

Project Background

In 2017, DCT launched a holistic conservation project for Hili 2 in partnership with CRAterre, the International Center for Earth Construction, based in Grenoble, France, with the aim to conserve, protect, and present the site to the public. A conservation management plan was first drawn up. This included collating all existing information on the site, recording and documenting the site's current condition and challenges, and assessing the values of the site. Stakeholder consultations were also conducted to validate the significance of the assessments, a conservation vision, and the policies and strategies for the long-term conservation, management, and presentation of the site.

The detailed recording and condition assessment allowed stakeholders and the contractor (CRAterre) to identify and map specific deterioration mechanisms. The site, having remained exposed to the elements and without a regular maintenance program since its excavation, exhibited decay and collapse. Aeolian accumulation of sediments, which is likely to have begun as early as the first millennium BCE (Karacic et al. 2020), filled the rooms of the structures and arrested much of the erosion, stabilizing the remains and creating a hill in the landscape (Gandreau, Sadozaï, and Moriset 2021). Rainfall in the region, although sporadic, has increased in volume and intensity in the last decade. Clay was washed from the exposed excavated features, modifying the inner structure of the earthen material that had hardened into an impermeable crust on the horizontal surfaces. This caused water to stagnate at the bases of walls, leading to direct damage in those locations and modifying the overall topography of the site (Sadozaï 2018) (fig. 2).

To solve these issues, the general strategy for the conservation project found a balanced approach between structural stabilization of the buildings, managing sitewide drainage, and enhancing the site. The overall philosophy focused on minimal intervention, acknowledging the archaeologists' priorities, and presenting the site through interpretive mediation (pamphlets, descriptive signage, and an educational kit on earth as a construction material). Intervention planning and implementation were based on DCT's established and well-documented process, on trials and experiments undertaken by CRAterre to determine the effectiveness and feasibility of the proposed interventions, and on stakeholder consultation with DCT's conservation and archaeology teams.

Planning the Implementation

The project was implemented over a period of thirty weeks of fieldwork conducted between October 2018 and September 2019. The team included four international experts from

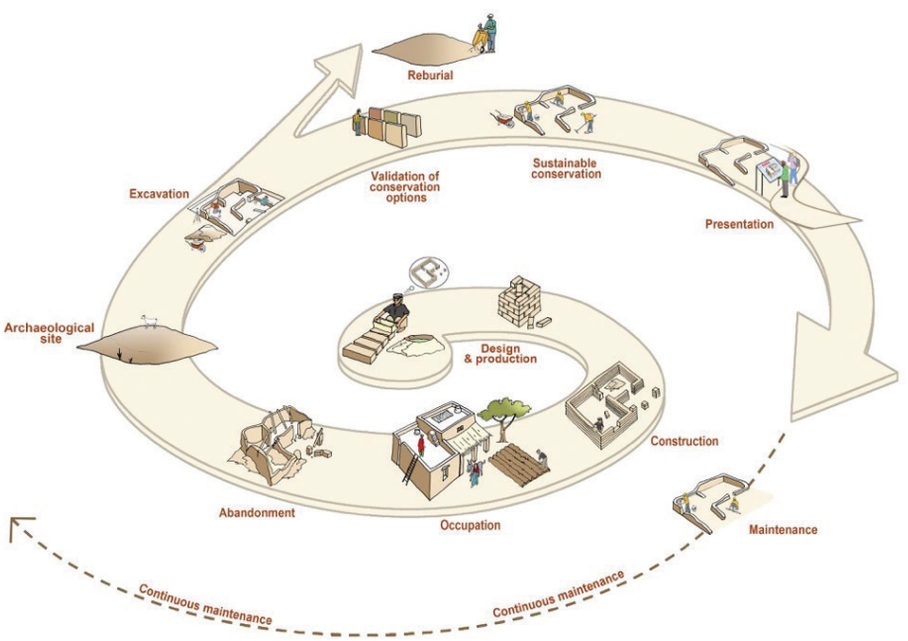


FIGURE 2 Life cycle of Hili 2 archaeological site over the last 3000 years. Illustration: C. Sadozaï, S. Moriset © CRAterre.

CRAterre and six decision makers, nine advisers, and a crew of twenty craftspeople mobilized by DCT's staff.

The project relied on DCT's resources and knowledge. This included specialized craftspeople who have been trained since 2005 in the highest standards of earthen construction and conservation methods, including mud brick production, earthen mortar mixing, and plastering techniques. CRAterre's expertise helped to improve these conservation practices and introduced innovations that were adapted to the Hili 2 context, such as experiments with the reburial of archaeological features. Previously, a layer of geotextile was put over the remains and covered by loose and clean desert sand. New processes included backfilling areas with a new sediment covered with another layer of geotextile that were then plastered with three coats of render. After an accelerated erosion simulation, this area was reexcavated and showed no sign of moisture around the reburied wall, which was not the case with the loose sand technique.

The soil was a key question during the feasibility phase of this project. DCT had been using a green-colored soil that was recovered years ago to mold mud bricks and prepare render mixes. This soil, which is now limited in quantity, has a good grain size distribution, contains 8% clay, and is slightly cohesive, inactive, and not expansive. Another yellow-colored soil was recently found in abundant quantities and was tested for better sustainability. This soil, which contains more silts and only 4% clay, is much more cohesive and active (fig. 3).

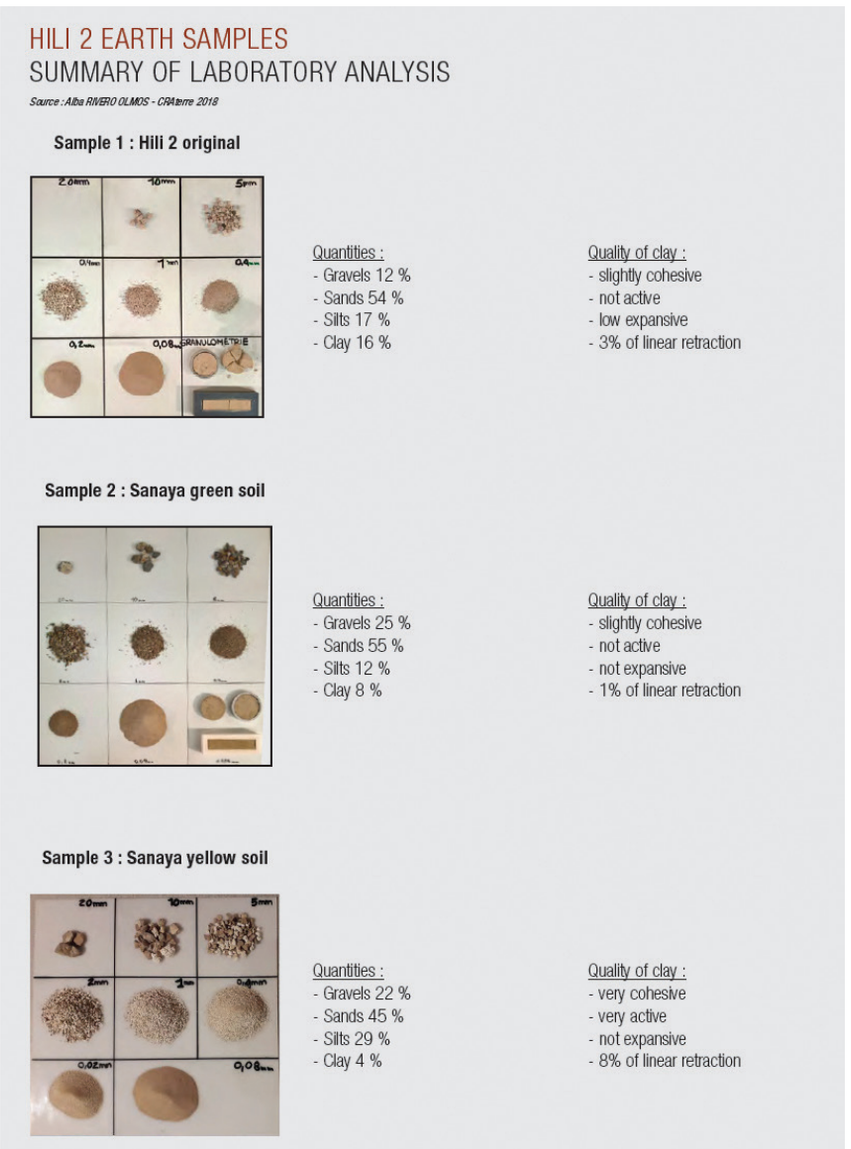


FIGURE 3 Grain size distribution and analysis of Hili 2 earth samples. Photos: A. Rivero, © DCT Abu Dhabi/CRAterre.

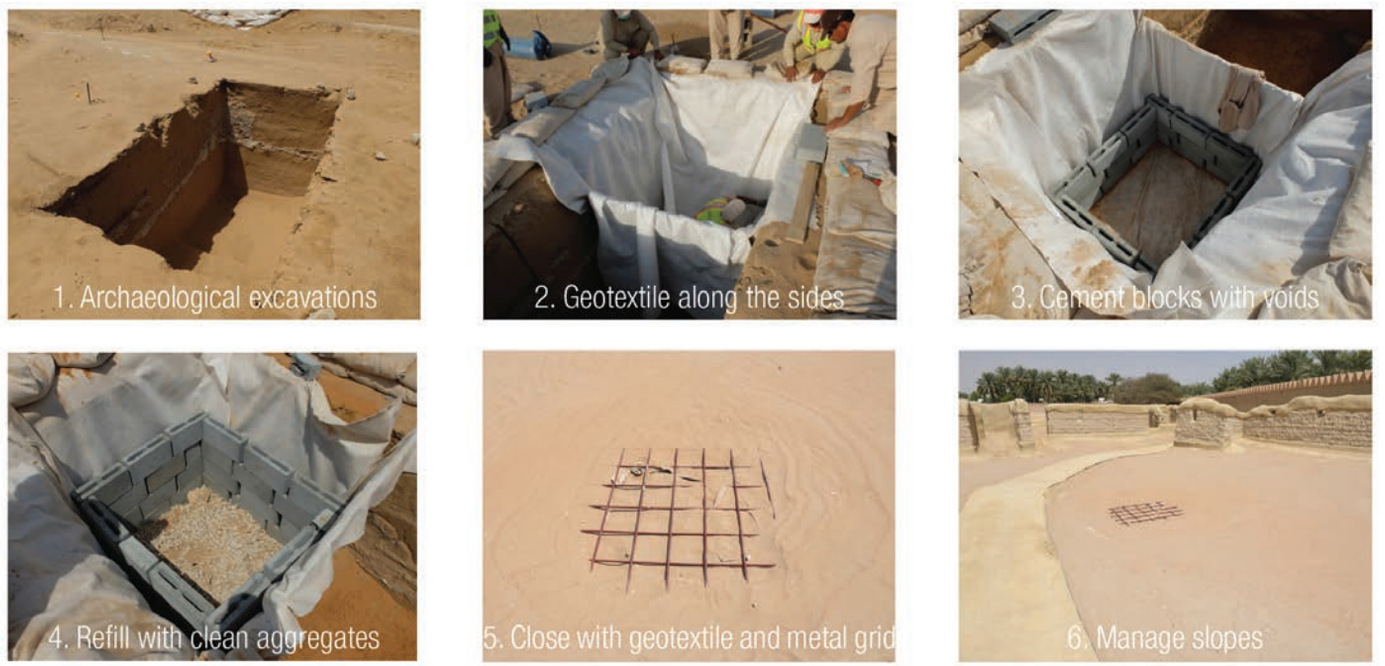


FIGURE 4 Drain sump process implemented on Hili 2. Photos: C. Sadozaï, © DCT Abu Dhabi/CRAterre.

This is quite interesting because the clay sticks better to the wall instead of being washed out, accumulating in a crust on the floor. As a result, the yellow soil was preferred for the renders at Hili 2, while the green soil was used for mud bricks.

Drainage techniques were also tested, including proposing the use of a drain sump in the areas where steep slopes could not be modified. Experiments showed that a 1.3 m^3 sump with voids could absorb a quantity of 765 L in a very short time without overflow. The implemented technique favored square sumps excavated by DCT's archaeologists; the sides of these sumps were then lined with a layer of geotextile that was reinforced by cement blocks laid without mortar for stability. Voids were left between the blocks to let the water disperse into the sandy substrate. The sump was then filled with stones and gravel in a range of sizes, and one more layer of geotextile was installed on top of the sumps with a metal grid for easy cleaning (fig. 4).

Conservation Techniques

Sacrificial layers of earthen renders were applied to satisfy the technical needs of the site while also presenting the building techniques of the Iron Age. Certain zones were left unrendered to expose the original building techniques as "windows to the past." The lowest area of the site, where pooling water threatened the structural stability of the walls, was infilled and drained by a sump while the general topography of the site was modified to direct the flow of water into key areas (fig. 5).

Specific conservation strategies were developed for each structure, taking into consideration previous excavations, erosion patterns, scientific and archaeological values, and presentation needs. A strong protocol was defined (fig. 6). Recessed features such as *tanoors* (ancient ovens or hearths) and basins that were excavated in the course of the project but were poorly preserved were reburied under compacted soil and sacrificial renders (Sadozaï 2020b). The best-preserved structures required only undercut repairs and capping while most of the structures were entirely plastered. Walls that had collapsed in 2017 were reinstated when adequate documentation existed (fig. 7). Where necessary, a thin layer of clay slurry was spray-applied preliminarily to consolidate the surfaces. The final composition of sacrificial earthen renders (Mixes 1 to 3) and floor stabilization material (Mix 4) is shown in table 1.

The final visual appearance of the structures, after the application of the sacrificial layers, was important for the stakeholders. Green-colored clay was added in the last layer (Mix 3) and applied by hand in an effort to closely match the

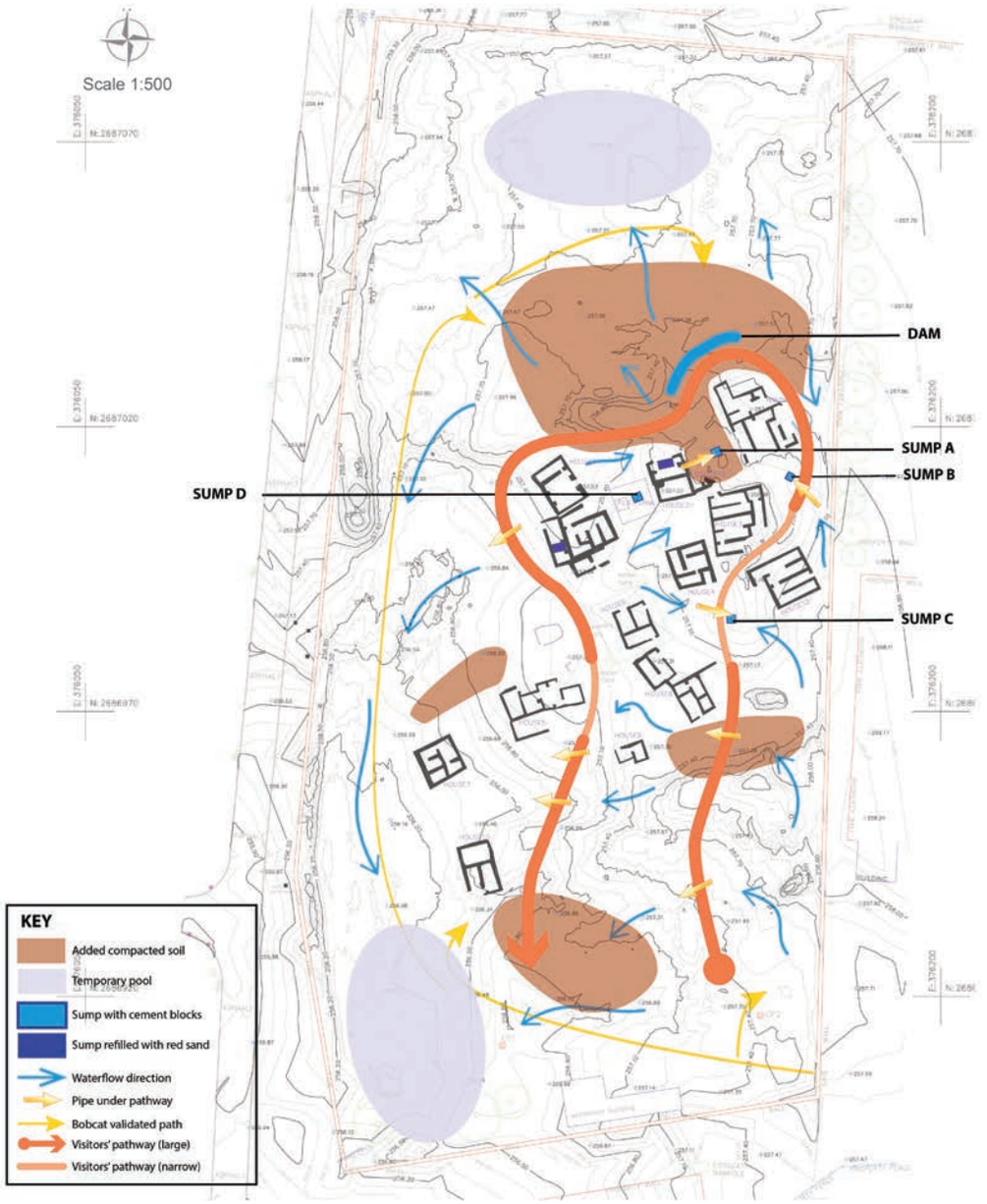


FIGURE 5 Overall drainage strategies for Hili 2. Drawing: C. Sadozaï, © DCT Abu Dhabi/CRAterre.

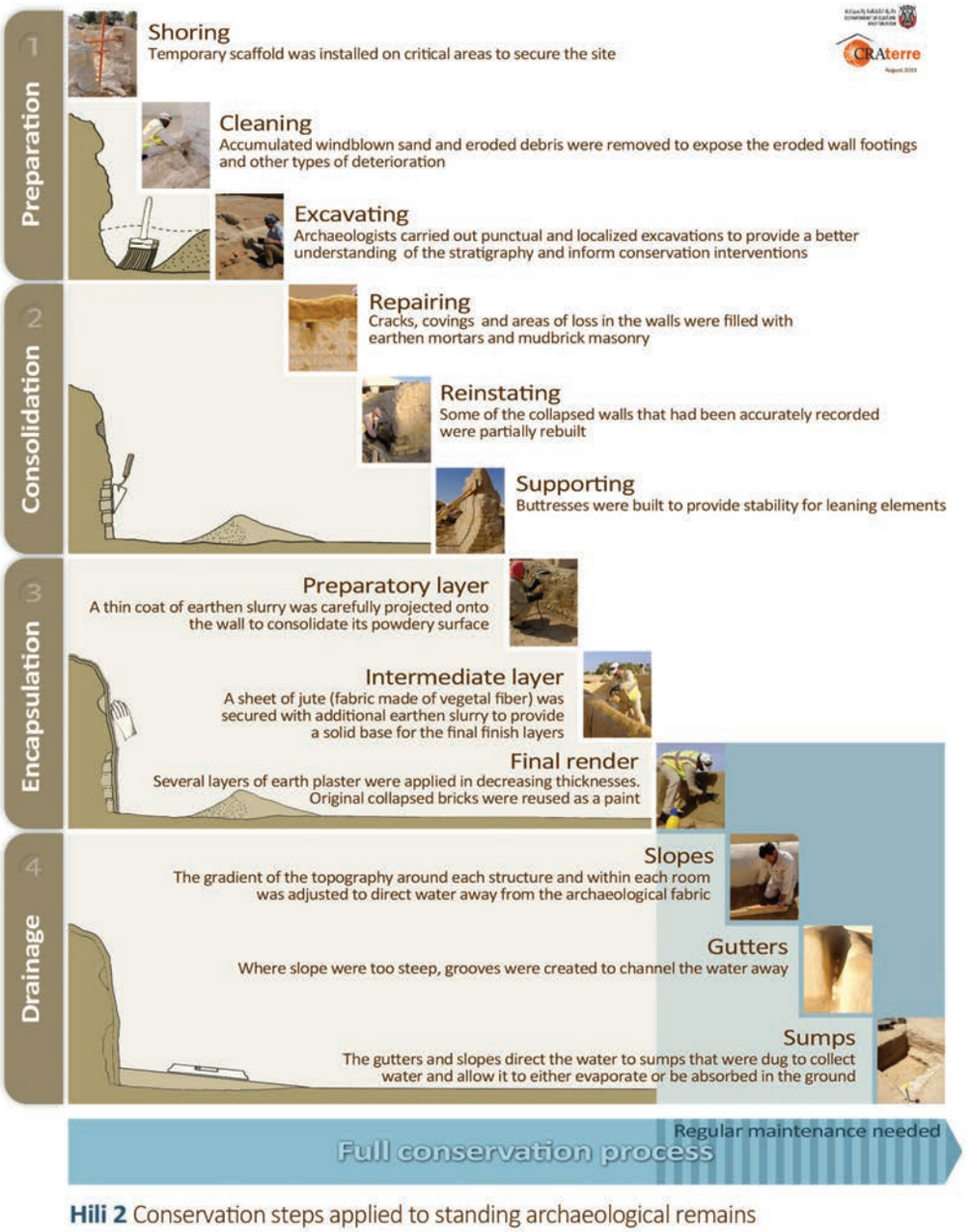
color and texture of the walls when they were first excavated. A slurry made from crushed, collapsed original bricks was applied to the walls that were not completely plastered with sacrificial layers. Holes and cracks were also filled with this mixture.

Discussions on Earthen Architecture Revealed by the Conservation Process

Targeted investigations were an important aspect of this project, and a team of archaeologists worked together with the conservators during the entire process. Because their remains would have been potentially disturbed by the conservation process, twenty-six areas were opened over the course of twenty-two weeks. These excavations revealed interesting elements of the original building technique.

First, three different types of clay were identified, each used for a specific component:

- A slightly reddish, fine soil was molded into large, thin mud bricks, with vegetal temper and dimensions varying between 40 and 55 × 35 × 8 cm;



Hili 2 Conservation steps applied to standing archaeological remains

FIGURE 6 Conservation interventions protocol for Hili 2. Illustration: C. Sadozaï, S. Moriset, © DCT Abu Dhabi/CRAterre.

- A green and more sandy soil was used as a mortar for vertical and horizontal joints;
- White nodules of what seemed to be the composition of the final layer of the original render were found all around the site and have been since described in the literature (Al Tikriti 2001).

None of the three extraction sources was identified.

The buildings were erected directly on the sandy substrate, as was observed in two trenches dug prior to the implementation phase (at the foot of Structures 10 and 12) and confirmed later, with investigations between Structures 3 and 4. The foundation system is an alternation of earthen materials: (1) a thick course (without a straight face, but rather with a belly) whose vertical separation was without mortar, a technique that could be akin to hand-shaped modules or cob;

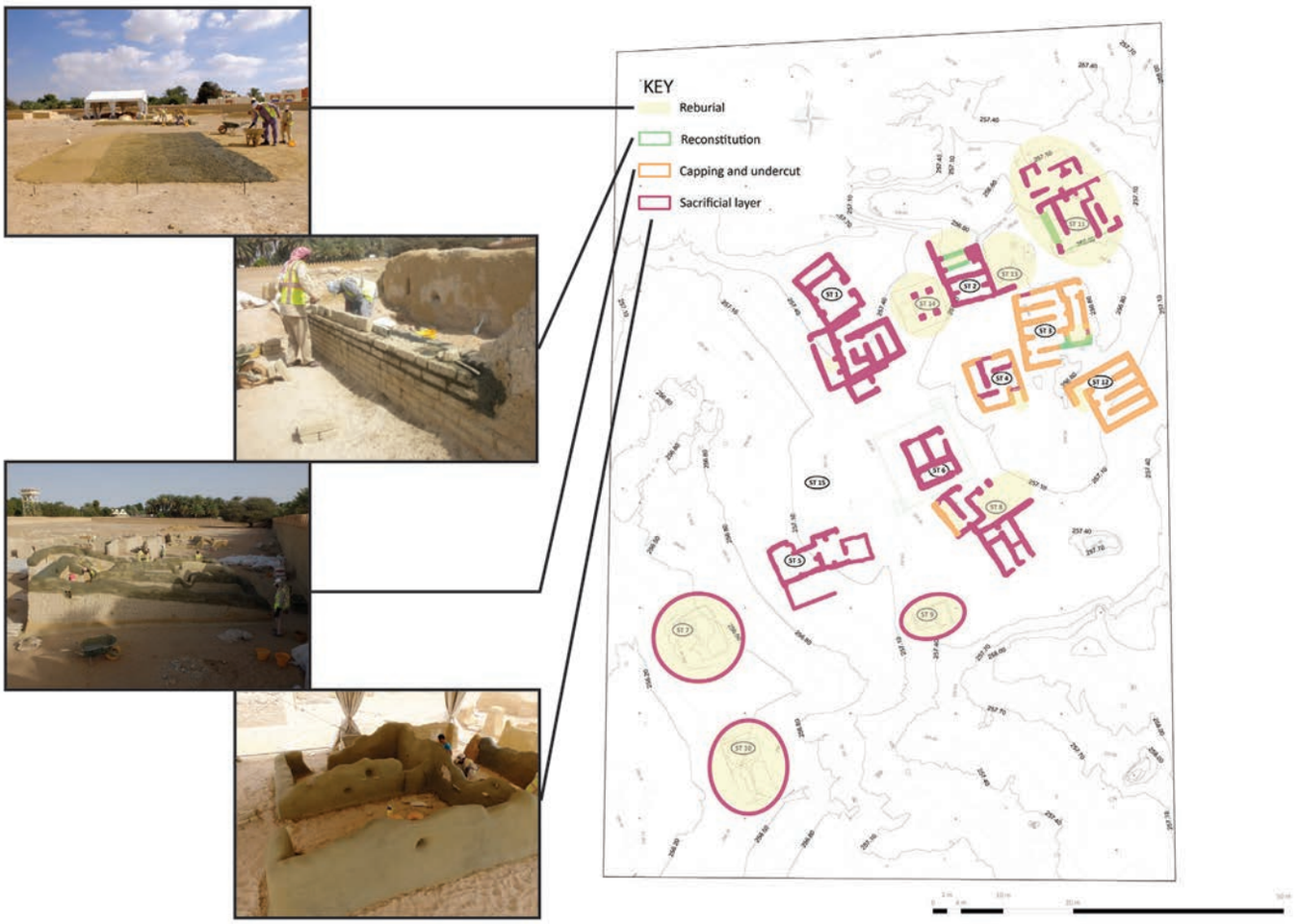


FIGURE 7 Conservation techniques implemented in Hili 2. Drawing and photos: C. Sadozaï, © DCT Abu Dhabi/CRAterre.

Table 1 Composition of the Earthen Sacrificial Renders Implemented at Hili 2

Mix 1	3 vol.* yellow soil + 1 vol. straw
Mix 2	3 vol. yellow soil + 1 vol. black sand + 1 vol. straw
Mix 3	1.5 vol. yellow soil sieved + 1.5 vol. green soil + 1 vol. black sand + 0.5 vol. straw
Mix 4	1 vol. yellow soil sieved + 2 vol. red sand

*volume

and (2) a thinner layer with a flat surface and joints that look like molded bricks (fig. 8). Only one trench, on the northern wall of Structure 2, showed another (earthen platform) system (Karacic et al. 2019).

Alternating layers of thin reddish mud bricks separated by thicker (measuring twice the height of the bricks, between 12 and 15 cm) layers of mortar are also visible on the erected wall. A new interpretation could consider the original technique of construction of Hili 2 as a kind of hybrid of mud brick masonry and cob construction. The cob technique is observed by the thickness of the mortar layer in the masonry. The very regular vertical cracks are evidence of shrinkage cracks made during the drying process, which is confirmed by the absence of mortar in the vertical joints. What was the process and why use a combination of two techniques instead of just one?

The production of mud bricks required a large amount of space, water, and people to mold, unmold, shift, and store the dried bricks in a sheltered area. The vegetal temper needed to dry before use, so it would have been collected a season before manufacturing. The need for a large amount of water suggests



FIGURE 8 Foundation system found on the northern wall of Structure 12, Hili 2. Photo: F. Gutierrez, © DCT Abu Dhabi.

that the production area was close to a well or a collecting basin, or another possibility would be that the manufacturing was done during the rainy season. Considering the arid Iron Age climate of Hili 2 and the evidence of mastered water management (i.e., the *falaj* system of irrigation described in Magee [2014] and Al Tikriti [2002]), the first scenario is more probable.

Further study of the construction techniques evidenced on site and the identification of materials has led to a reflection and better understanding of the material production, construction process, and social organization at Hili 2 (Karacic et al. 2019).

Conclusion

This comprehensive project was based on a multidisciplinary collaboration that resulted in innovations based on experimentation and various technical compromises that met the different stakeholders' requirements. The project not only deepened the knowledge of a very complex and unusual building technique from the Iron Age but also demonstrated that a different and innovative approach is possible for the conservation of earthen archaeological sites.

The different methods tested in Hili 2 have advanced conservation of this type of construction and have opened a discussion on the use of sacrificial coatings on exposed archaeological sites, the manipulation of topography as drainage system, and the role that aesthetics plays in the preservation and presentation of an archaeological site.

Finally, the conservation of Hili 2 showcases the scientific value and potential of this site, opening future possibilities for further research on construction material (micromorphological) and soil analysis. Other areas of study could include investigations to locate the original extraction quarry and research into potential parallels with other sites of the same period such as Rumeilah, Hili 14, and Hili 17.

Notes

1 https://whc.unesco.org/en/list/1343/.

2 Under UNESCO's recommendation to manage and protect the cultural heritage of the emirate, the Abu Dhabi Authority for Culture & Heritage (ADACH) was created in 2005. In 2012, ADACH merged with the Abu Dhabi Tourism Authority (ADTA) and the Cultural Division of the Tourism Development and Investment Company (TDIC) to form Abu Dhabi Tourism and Culture Authority (TCA). Finally, in 2018, TCA became the Department of Culture and Tourism–Abu Dhabi (DCT).

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Moisture Monitoring and the Use of Rhoplex-Amended Brick Veneers: A Pilot Study of Test Walls at Pecos National Historical Park, New Mexico, USA

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Abstract: *In 2014 Pecos National Historical Park began a pilot program to examine the use of Rhoplex-amended adobe veneers to protect the remnants of seventeenth- and eighteenth-century adobe walls at the Spanish colonial mission site. Park staff installed volumetric moisture and soil water potential sensors within two test walls that mimic the preservation techniques used to protect original adobe walls. One test wall uses Rhoplex-amended veneers, while the other consists of all unamended materials. Results from 2014 to 2019 suggest that the amended brick veneers resist moisture intrusion when the tops (caps) of the walls are crack free. When cracks in the cap develop, they are wider and remain open longer than in the unamended veneer cap, and moisture is more gravity-driven along preferential pathways. Fewer cracks formed in the unamended veneer cap, and they appear to heal or fill in over time. Infiltration in the unamended veneer was rare and often more diffuse, leading to more generalized moisture focused on capillarity and distributed over a wider area, thus taking longer for the wall interior to dry out. The more open cracks and the lack of self-healing properties in the amended cap may allow for faster drying of the interior than the self-healing cracks in the unamended cap. The results clearly show the positive effects of proper cap maintenance and application of shelter coats, since less infiltration occurred after shelter coat application. A hybrid approach using an amended veneer with unamended capping materials may be the best option for protecting the park's fragile adobe wall remnants, but more testing is needed.*

Resumen: *En 2014, el Parque Histórico Nacional de Pecos comenzó un programa piloto para examinar el uso de chapas de adobes estabilizados con el aditivo marca Rhoplex para proteger los restos alterados de muros de adobe del siglo xvii y xviii en el sitio de la misión colonial española. Los integrantes del personal del parque instalaron sensores para detectar humedad volumétrica y potencial hídrico del suelo en dos muros de prueba que imitan las técnicas de preservación utilizadas para proteger los muros de adobe originales. En uno de los muros de prueba se emplearon chapas de adobes estabilizados con Rhoplex, mientras que en el otro se usaron adobes sin estabilizar. Los resultados de 2014 a 2019 sugieren que los revestimientos con adobe estabilizado resisten la intrusión de humedad siempre y cuando las cabeceras de los muros no estén agrietadas. Cuando aparecen grietas en las cabeceras, son más anchas y permanecen abiertas durante más tiempo que en la cabecera con chapas de adobes sin estabilizar, y la humedad se extiende por gravedad en mayor medida en vías preferenciales. Se formaron menos grietas en la cabecera del muro con adobes sin estabilizar y parecen cerrarse o rellenarse con el tiempo. La infiltración en el revestimiento sin estabilizar fue inusual y más difusa, lo que generó una humedad más generalizada, enfocada en la capilaridad y distribuida sobre un área más grande. Esto hizo que el interior del muro tardara más en secarse. Las grietas más abiertas y la falta de propiedades de autorreparación en la cabecera estabilizada pueden permitir que el interior se seque más rápido que las grietas que pueden cerrarse por sí solas en la cabecera sin estabilizar. Los resultados muestran claramente los efectos positivos del mantenimiento adecuado de las cabeceras y la aplicación de capas protectoras, ya que hubo menos infiltración después de su aplicación. Un enfoque híbrido que emplea una chapa estabilizada con materiales de cabecera sin estabilizar puede ser la mejor opción para proteger los frágiles restos de muros de adobe del parque, pero se necesitan más pruebas.*

Keywords: adobe, amended, caps, encapsulation, moisture, monitoring, test walls, veneers

Background and Purpose

The extant seventeenth- to eighteenth-century Spanish colonial mission at Pecos National Historical Park (NHP), located 35 miles east of Santa Fe, consists of the adobe remnants of a large church and associated priests' quarters (convento), storerooms, and corrals covering 1.4 acres.[1] North of the mission complex are the remains of the Ancestral Pueblo village of Pecos, also called Pǽkilâ.[2] By the 1500s this stone masonry village housed up to 2000 people. The adobe church was first excavated and stabilized in 1915, but remnants of the convento adobe walls were not exposed until 1969. Today, the park conserves over 2500 linear feet of original adobe walls.

Since 1915, wall sections varying from 1 to 30 ft. high have been protected by encapsulating fragile original adobe walls using new adobe veneers with brick and mud plaster caps. Sometimes mud shelter coats have been applied over the veneers. Local dirt sources with similar composition as the original materials have been used to make bricks and mortar on-site. Both unamended and amended materials have been used over several decades of experimentation. Currently, the park uses small quantities of Rhoplex E-330 to create a more durable brick veneer that can withstand harsh winters and high-intensity monsoon rainfall events typical of northern New Mexico. The life span of veneers averages ten to fifteen years and varies by orientation or aspect.

Pecos NHP is one of the only locations in North America preserving historic adobe ruins through encapsulation using new adobe veneers. Using two test walls, the park is examining our encapsulation and preservation methods and materials, partially by evaluating moisture intrusion with embedded moisture and soil water potential sensors. The project is a pilot study comparing veneers using Rhoplex E-330 amended bricks with unamended veneers. In this paper we present the initial results from 2014 to 2019.

Methods

Pecos NHP, in cooperation with Cornerstones Community Partnerships, constructed two test walls in the summer of 2014 (TW1 and TW2). Both test walls consist of an unamended adobe wall core (one wythe thick) representing the original historic adobe walls (fig. 1). The methods and materials used for encapsulating both test walls using brick veneers are the same as those used by park staff to protect the original Spanish colonial adobe wall remnants. Both wall cores were covered in an unamended mud plaster separation coat approximately 0.25 in. thick. TW1 used our current preservation materials and



FIGURE 1 Construction of Test Wall 2 in 2014. The core mimics original walls and is protected by a veneer and cap using amended bricks. Photo: © National Park Service.

mixes, with the brick veneer constructed of adobes and mud mortar amended with Rhoplex E-330 (5.6 water:1 Rhoplex). TW2 consists of all unamended materials, and the mud used for the bricks was soaked for several hours to hydrate the clays. Both test walls have caps (wall top) consisting of two courses of brick/mortar and a mud plaster shelter coat at maximum thickness of 0.5 in.

Sensors were installed within the adobe wall core to monitor the penetration of moisture through the veneer and into the core of the test walls. Each test wall has two volumetric water content (VWC) sensors and two soil water potential (SWP) sensors, with each pair located in the upper and lower parts of the wall (fig. 2). The sensors were installed in the unamended core of the test walls following veneer



FIGURE 2 Location of paired VWC and SWP sensors (yellow circles) in Test Wall 1. Photo: © National Park Service.

encapsulation at depths of 11–13 in. After the sensors were installed, the holes were sealed with unamended mortar (Moss, Filippone, and Lingo 2017).

Volumetric Water Content (VWC)

VWC is a measurement of soil moisture and is the ratio of water volume to soil volume (m^3/m^3). VWC is monitored at thirty-minute intervals using Decagon EC-5 sensors. The sampling volume for the VWC sensors is 0.3 L (300 cm^3 ~1 ¼ cup). The calibration of the VWC sensors deteriorates as the surrounding matrix increases in proportion of sand to the silt-clay fraction, and also with increasing electrical conductivity of the water solution. The VWC sensors were not calibrated with the mortar or brick material used in the test walls, which is a weakness of this study.

Dielectric permittivity is the basis for the EC-5 VWC measurement. Temperature-related variability is introduced to the measurements during the year as a result. As a general rule, when the four VWC sensors in the two walls track together in terms of trends and rate of change, temperature is believed to be the primary driver. When individual sensors illustrate rapid responses following precipitation events, and when the four sensors are not tracking together, moisture, not temperature, is the driver of those changes. The VWC sensors do not function below freezing (fig. 3).

Soil Water Potential (SWP)

SWP is a measure of the energy status of a unit of water relative to a reference state. In unsaturated soils, SWP results are from the sum of numerous forces acting on the water including, but not limited to, gravity, the adsorptive attraction of solid surfaces (soil particles) for water (adhesion) (Jury, Gardner, and Gardner 1991), and capillary forces, which result from the cohesive attraction of water molecules to each other that are responsible for surface tension. Other factors that affect SWP to a lesser extent are not taken into consideration here. In unsaturated soils, SWP is negative and is also expressed as positive tension. As soils dry, SWP becomes increasingly negative as tension becomes greater.

SWP is monitored using Decagon MPS-6 sensors, with a sampling frequency of two hours. The Decagon MPS-6 measures matric potential, which is the sum of capillary and adsorptive forces acting on soil water. SWP data are displayed here as soil water tension, using the unit cm H_2O. The permanent wilting point (PWP: 15306 cm H_2O tension) is adopted as a reference point for extremely dry conditions. The soil water tension figures include the gravity (elevation) force added to

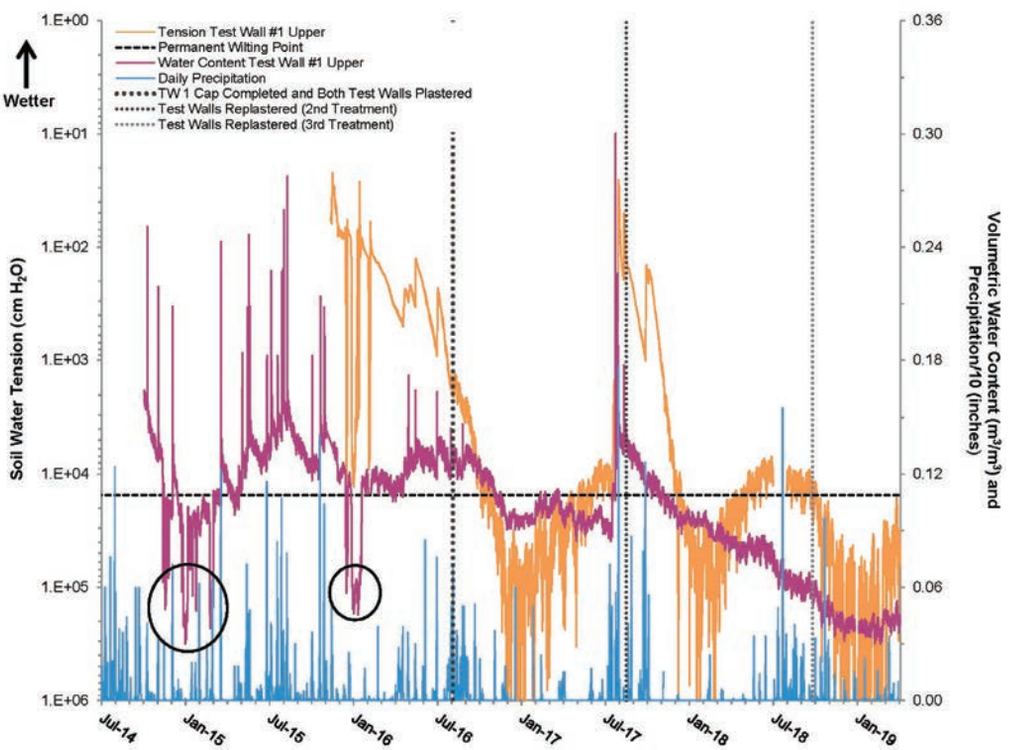


FIGURE 3 Test Wall 1, upper sensors, VWC content, SWP, and precipitation. Before 2016 the cap and first plastering were not completed. Circled areas show the effects of freezing before the cap was completed. Major cap and plaster treatments are shown as dotted lines (month/year shown on horizontal axis). Illustration: © National Park Service.

the measured SWP, using the elevation of the lower sensors as the reference elevation.

The relationship between VWC and SWP in unsaturated, porous materials is expressed as the moisture characteristic curve. Moisture characteristic curves for the ceramic discs show that, due to the nonlinearity of the water content to water potential relationship, small changes in moisture content result in increasingly exaggerated fluctuations in water potential as conditions become drier.

The Decagon MPS-6 sensor is very accurate over a range of 92 to 1020 cm H_2O and has demonstrated good accuracy to the PWP. When temperatures fall below freezing, the SWP sensors do not function. Some of the data suggest incomplete contact between one or more of the SWP sensors and the mortar, especially when the soil is dry. This results in a delay in the sensor reaching equilibrium with the surrounding material.

Precipitation

Precipitation was monitored using three different stations. The KNMROWE3 station is located approximately 1.9 miles south of the park and provided daily precipitation readings through December 2016. A Davis Station was installed near the test walls in March 2017. The Davis Station records rain amount, peak rain intensity, and temperature every thirty minutes; however, some periods of data have been lost due to mechanical issues. The NOAA Cooperative Observer Network (COOP) Station #296676 is also located at the park; however, since precipitation is manually measured during work hours, there are inconsistencies. The precipitation data from the three stations are combined in the graphs that follow.

TW1 (Amended Veneer)–VWC Prior to Capping (10/3/2014–7/14/2016)

The TW1 upper VWC sensor was installed a few inches below the wall top on 10/3/2014. A complete cap and a mud plaster shelter coat on the brick veneer was not fully completed until 8/5/2016. The record of precipitation and infiltration from 10/3/2014 to 7/14/2016 demonstrates how moisture can penetrate veneers through the top when brick or mud caps are not intact. During that time period, 145 days had recorded precipitation, ranging from 0.01 to 1.40 in. (median of 0.08 in.). Thirty of the precipitation events caused moisture to infiltrate into the core (see fig. 3).

Before the TW1 cap was completed, the VWC sensor often responded immediately to infiltration and VWC peaked within 0.5–6 hours. There was an increase in VWC associated with each precipitation event. The amount of precipitation resulting in infiltration in TW1 appears to be smaller during summer monsoon events (June to September). Monsoon precipitation under 0.15 in. did not infiltrate to the depth of the VWC sensors, while all monsoon events over 0.22 in. resulted in infiltration, with one notable exception. The one outlier is a 0.85 in. event recorded at the KNMROWE3 station during June. While that station is only 2 miles from the park, this storm event appears to have been isolated, and actual precipitation at Pecos NHP was less.

TW1–After Cap Completed (2/20/2016–4/4/2019)

Until the TW1 cap was completed, the upper VWC and SWP sensors responded to some precipitation events by registering rapid increases due to infiltrating moisture. Following the completion of the TW1 cap in August 2016, the frequency of infiltration events decreased. The VWC sensor recorded moisture infiltration for three weeks after the cap and mud plaster shelter coat was completed. The coat dried out by October 2016, when the SWP sensor indicated the wall interior reached PWP (see fig. 3). This lapse in drying after shelter coat application may mark the time it took for the interior to reach equilibrium. Table 1 shows the variability in VWC for both TW1 and TW2 following application of mud shelter coats.

Table 1 Volumetric Water Content (VWC) Test Walls after Three Plaster Treatments, 2016–2019

	Test Wall #1 Upper (m^3/m^3)	Test Wall #1 Lower (m^3/m^3)	Test Wall #2 Upper (m^3/m^3)	Test Wall #2 Lower (m^3/m^3)
After all sensors were installed and after 1st plastering treatment (2/10/2016 – 8/17/2017)				
Maximum VWC	0.300	0.198	0.175	0.140
Minimum VWC	0.085	0.125	0.111	0.087
Range	0.216	0.073	0.064	0.052
Average	0.113	0.158	0.141	0.114
Between the 2nd and 3rd plastering treatments (8/18/2017 – 9/25/2018)				
Maximum VWC	0.140	0.142	0.138	0.112
Minimum VWC	0.053	0.109	0.097	0.080
Range	0.087	0.033	0.041	0.032
Average	0.090	0.125	0.121	0.095
After the 3rd plastering treatment through the end of the reporting period (9/26/2018 – 4/4/2019)				
Maximum VWC	0.064	0.122	0.167	0.094
Minimum VWC	0.026	0.090	0.087	0.069
Range	0.038	0.033	0.079	0.025
Average	0.042	0.102	0.108	0.078

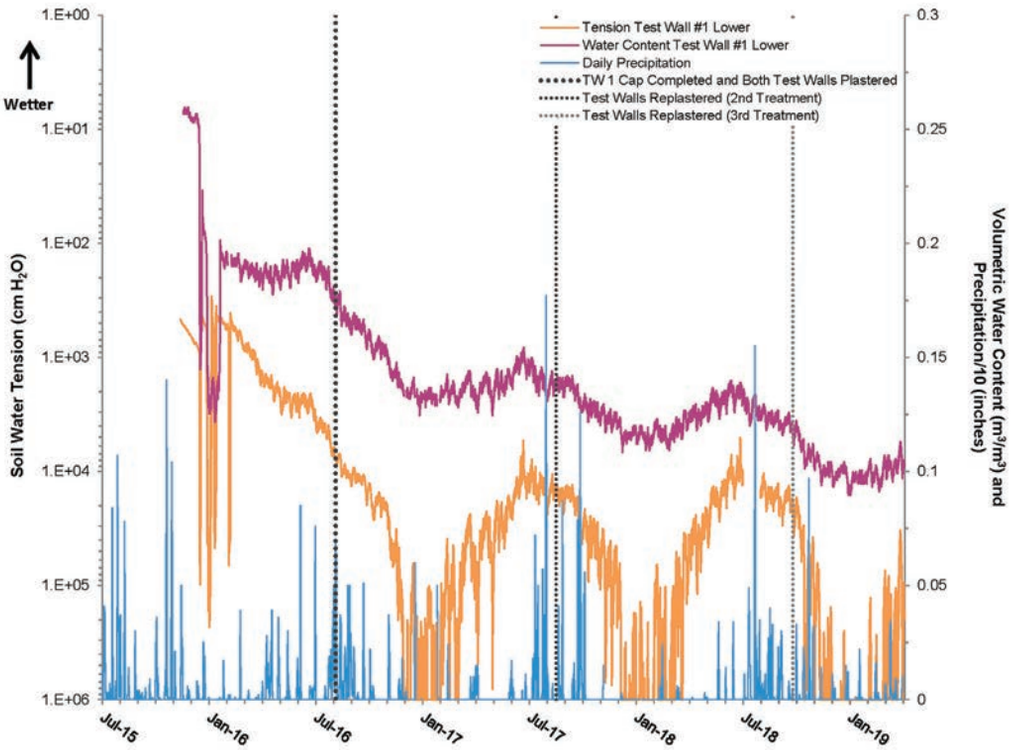


FIGURE 4 Test Wall 1, lower sensors, precipitation, and preservation treatments (2015–2019). Illustration: © National Park Service.

The rapid response of the TW1 upper sensors following precipitation in summer 2017, a year after completion of the cap and shelter coat, indicates gravity-dominated flow in a fractured (or cracked) porous material. The response of the upper VWC and SWP sensor to precipitation events over the three-year period is similar to the responses to infiltration prior to the cap completion on TW1, suggesting that deterioration of the plaster shelter coat and cracks in the mud mortar cap allowed moisture to enter until repairs were completed (see fig. 7a). Shelter coats appear to provide maximum protection for about one year. The TW1 and TW2 lower VWC and SWP sensors do not show evidence of infiltration of moisture (figs. 4, 6).

TW2 (Unamended Veneer) (2/20/2016–4/1/2019)

Following construction of TW2, the upper SWP sensors show the wall dried slowly, reaching the PWP by March 2016 (fig. 5). Since that time, the SWP sensor registered moisture above the PWP only twice: February to April 2017 and December 2018 to February 2019. Both periods demonstrate a gradual wetting and drying pattern and do not show an immediate response to precipitation, but instead indicate significant delays in SWP increases following rain and snowfall events, some of which were concurrent with several days of freezing temperatures.

Data from the upper VWC sensor show gradually increasing moisture while SWP was elevated. During both periods VWC continued to increase after the SWP sensor indicated that the wall interior dried to the PWP. During the 2017 period VWC peaked on June 17, indicating less than a 0.04 m^3/m^3 increase in VWC over the 2017 period. After 2017, the TW2 upper VWC sensor demonstrated a general downward trend until November 2018. Between November 2018 and March 2019, the VWC increased, marking the failure of the mud plaster shelter coat. The observed pattern between VWC and SWP may relate to slowly melting snow during winter and freeze/thaw cycles. The 2018/2019 winter at Pecos NHP was generally colder than normal, with mean monthly maximum air temperatures 1.2–3.2°C below normal. This may have caused increased freeze/thaw cycles after rain and snow events, which could have widened and deepened minor cracks.

Conclusion

The infiltration signals at TW1 and TW2 show very different characteristics. Moisture migration in TW1 (amended) appears to be focused and gravity-driven along cracks, similar to what may be observed in a fractured material with low

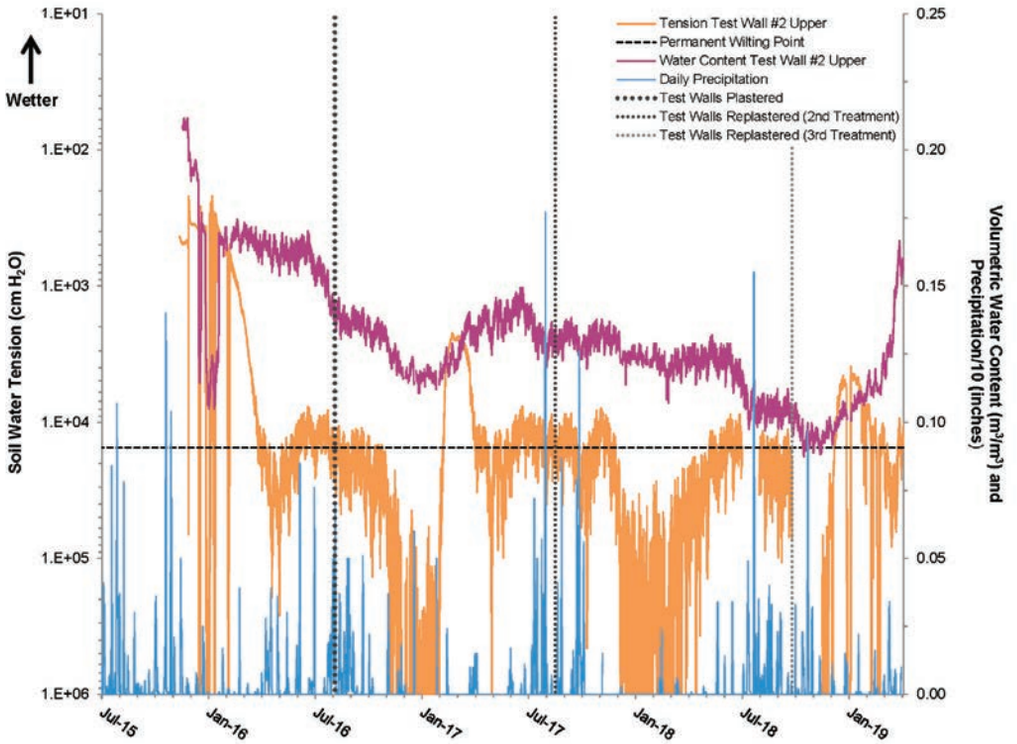


FIGURE 5 Test Wall 2, upper sensors, precipitation, and preservation treatments (2015–2019). Illustration: © National Park Service.

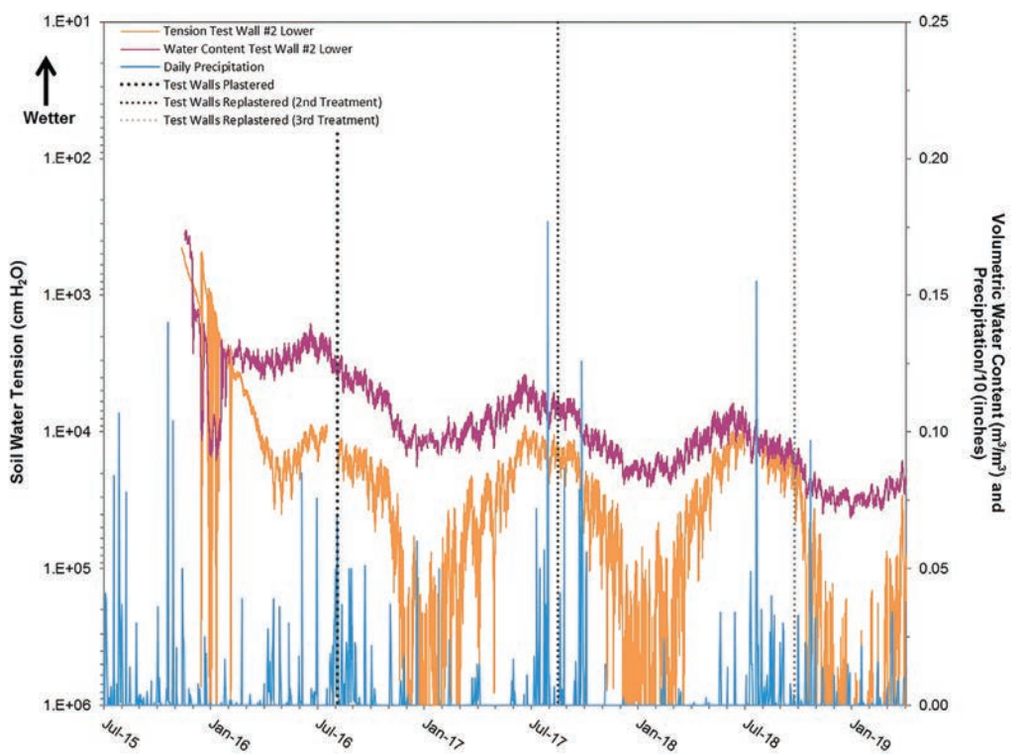


FIGURE 6 Test Wall 2, lower sensors, precipitation, and preservation treatments (2015–2019). Illustration: © National Park Service.

porosity or capillarity. Sometimes both the upper VWC and SWP sensors responded to precipitation and other times only one would indicate infiltration. This is attributed to the separation distance between the two sensors and localized nature of preferential flow within the damaged plaster and mud cap. It is not clear if water moves through the amended bricks or is only moving through cracks in the amended mortar. The veneers require a robust cap and plaster coat to prevent water infiltration to the core. Once a breach occurs in the amended vertical wall plaster or mud cap of TW1, infiltration is either rapid but does not appear to propagate to depth within the unamended adobe core mimicking the historic original walls, or it may stay in the veneer. TW2 infiltration events result in more diffuse wetting.

TW2 (unamended) data indicate only two infiltration periods of gradual wetting during which conditions remained substantially drier than the infiltration events recorded in TW1. Compared to the same events observed in TW1, the moisture in TW2 remained elevated for longer periods of time before slowly returning to the prewetting state. These characteristics indicate the dominance of capillary forces in the unamended materials of TW2, which when wetted enhance the potential for lateral migration of water surfaces into the interior and distribute moisture over a larger volume. Both infiltration events recorded by the TW2 upper sensors occurred in late fall and winter, when temperatures are often below freezing and snow may contribute to sustained wetting. The TW1 infiltration events occurred during summer or early fall when temperatures are higher and the rate of drying is expected to be faster.

Crack formation in the test wall caps, veneers, or shelter coats is probably a key factor in the rate and depth of moisture penetration. The TW1 cracks may have increased potential for focused vertical infiltration of moisture from the wall cap along preferential pathways. At times TW1 cracks could be correlated with intense monsoon storms and hail damage. However, photos from August 2017 suggest the pattern of cap cracking may also relate to shrinking and thick application of the mud coat covering cap bricks (fig. 7).

The TW2 cracks formed in winter may be a result of freeze/thaw cycles damaging the mud layer of the cap. The TW2 cracks appeared shallow, preventing moisture from quickly penetrating to the adobe core and maintaining the dominance of capillary forces (see fig. 7b). It is also possible that the unamended adobe has a greater capacity to fill cracks as they form. This self-healing quality of cracks in natural unamended mud may be a significant factor to consider in future preservation treatments. Additional monitoring and analysis are necessary to determine whether the seasonal differences in cracking and moisture infiltration between the test walls are inherent to the characteristics of the amended and unamended materials, related to conditions at the time of plastering, or caused by other factors such as application techniques.



FIGURE 7 (a) Cap/top of Test Wall 1 after plastering and (b) cap/top of Test Wall 2 before replastering (August 2017, second treatment). Photos: © National Park Service.

Recommendations

Based on the results, the park is considering using a hybrid veneer, with amended bricks and mortar for the sides and unamended materials for caps. A cap using unamended materials appears to crack less and be more resilient through self-correction, while a vertical veneer composed of amended bricks exhibits less surface erosion and little horizontal infiltration. We are also considering the use of a somewhat coarser-grained plaster separation coat between the original adobe core and the veneer. Under unsaturated conditions, hydraulic conductivity of finer-grained materials such as silts and clays tends to be greater than coarser-grained materials with more sand. Coating the original adobe wall with a coarser-grained (sandy) plaster coat could create a capillary barrier that inhibits moisture infiltration to the inner core. Prevention of moisture infiltration at the surface using plaster shelter coats is the preferable approach, and the test wall results demonstrate the effectiveness of plaster



FIGURE 8 Condition of both test walls, August 2019. Test Wall 1 (amended) on left. Photo: © National Park Service.

coats. However, the park currently considers exposed adobe bricks as essential for interpreting adobe construction to the public. The park is no longer maintaining the test walls, but we are monitoring their deterioration and collapse (fig. 8). To gain an understanding of the final stages of deterioration, Light Detection and Ranging (LiDAR) scanning is being completed each year with monthly repeat photography. Materials analysis is also being pursued to better understand how monitoring results relate to material properties, and we are using the results from the pilot study to develop a new test wall design.

Notes

1 For pictures and more information on the park and the Pecos Mission, visit https://www.nps.gov/peco/index.htm.

2 Pǽkilâ (the place above the water) is the Towa name of the site shared by Pecos descendants now residing at the modern-day Pueblo of Jemez. In 1838, the last remaining Pecos people joined their brethren at Jemez.

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Intervenciones para la conservación sostenible de La Palangana, Kaminaljuyu, Guatemala

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Resumen: *El sitio prehispánico de Kaminaljuyu, Guatemala, es un conjunto de valor patrimonial inestimable por las evidencias históricas mayas que conserva, por su extensión y por haberse construido con tierra. A consecuencia del desarrollo urbano, se ha perdido gran parte de su integridad, y solamente perviven algunas estructuras, entre las que destacan los conjuntos llamados La Palangana y Acrópolis, construidos durante el periodo Clásico Temprano y ubicados actualmente en el Parque Arqueológico Kaminaljuyu. Las primeras investigaciones de esta zona se hicieron en 1926, y desde 1960 se llevaron a cabo trabajos del Instituto de Antropología e Historia y la Universidad Estatal de Pensilvania que revelaron grandes secciones del conjunto. Desafortunadamente, estas excavaciones quedaron expuestas, lo que impactó en su conservación y complicó la lectura e interpretación de la composición original del edificio. Por ello, en 2018 se inició, en La Palangana, un programa de intervención con materiales locales y técnicas tradicionales para su recuperación volumétrica. Los criterios de preservación buscaron completar faltantes para su consolidación y mejor comprensión por parte de los visitantes. Para lograrlo, se usaron sistemas constructivos compatibles de tierra, pero buscando su notoriedad visual a corta distancia. Como el sitio se construyó con bloques amorfos de "talpetate", recubiertos con tierra y cal, los huecos ocasionados por investigaciones arqueológicas pasadas que habían quedado expuestos se rellenaron con adobes y tierra amasada compactada. Las mezclas fueron similares a las originales, pero se compensaron con arena para que su resistencia fuera menor a la de los componentes históricos a fin de que los agregados funcionaran como secciones "de sacrificio". Este artículo expone los estudios preliminares, las medidas tomadas durante los pasados dos años y el resultado final con respecto a la percepción y conservación del sitio.*

Abstract: *The pre-Columbian site of Kaminaljuyu, in the central highlands of Guatemala, is a settlement of priceless heritage value due to its long history of occupation that began around 1000 BCE and continued into 1200 CE. The settlement had over 200 earthen buildings, and its integrity has been lost due to the development of Guatemala City over the ancient site. Two main complexes—known as the Acropolis and Palangana—were built in the Classic period and remain inside the Parque Arqueológico Kaminaljuyu. The first excavations began in 1926 and continued through the 1940s and 1970s by the Carnegie Institution of Washington, the Instituto de Antropología e Historia, and Pennsylvania State University. Unfortunately, the surfaces of these buildings were left exposed, impacting their conservation and complicating the interpretation of the original architecture. To clarify and protect the Palangana structures, an intervention program began in 2018 using local materials and traditional techniques. The conservation criteria sought to fill in gaps, consolidate findings, and offer a comprehensive understanding for park visitors. Compatible earthen construction systems were used for this work, aiming to increase the site's visual impact at close range. Because the structures were built with amorphous blocks of talpatate whose surfaces were smoothed with a mixture of clay and lime, past archaeological excavations were filled with adobe and compacted earth. Using similar pre-Columbian materials, sand was added to repair aggregates so they would function as sacrificial sections with decreased durability. This article presents the preliminary studies, the interventions done during the last two years, and the final results regarding both current knowledge and the conservation of the site.*

Palabras clave: consolidación, reversibilidad, tierra estabilizada, cal, puzolanización

Introducción

La conservación del patrimonio arqueológico edificado con tierra involucra múltiples complicaciones derivadas tanto de su materialidad como de las afectaciones de su permanencia en el subsuelo por siglos. Pero adicionalmente se presenta la problemática que resulta de la serie de excavaciones que los vestigios han sufrido en los años de su exploración arqueológica y de la apertura a la visita pública, que se vuelven detonantes de factores de deterioro con imprevisibles consecuencias.

A lo largo de la historia de la arqueología, los criterios de exploración han ido evolucionando, y los estudios hechos en fechas recientes cada vez son más respetuosos del futuro de los vestigios y del manejo sostenible de los recursos para su conservación y restauración. Cuando se trata de obras de tierra, se sabe que los minutos inmediatos a su apertura resultan trascendentales, puesto que los cambios en el nivel de humedad de los hallazgos los pueden desintegrar. Es por ello que cada día mejoran las prácticas caracterizadas por la colaboración interdisciplinar entre arqueólogos y conservadores.

Desafortunadamente, estos procesos no siempre fueron así. Durante varias décadas la manera en que se realizaban las excavaciones no contaba con los conocimientos asociados a la conservación patrimonial ni con la suficiente información sobre el comportamiento y vulnerabilidad de la tierra utilizada como material constructivo. La apertura de trincheras, la eliminación de etapas constructivas, los cortes de terreno con perfiles pronunciados y la falta de previsión de las posibles afectaciones climatológicas como la lluvia, el viento y los cambios de las condiciones de humedad ambiental, han generado importantes pérdidas en el patrimonio y la dificultad de contar con una adecuada lectura de los vestigios.

Un ejemplo de este proceso se encuentra en el Parque Arqueológico Kaminaljuyu (fig. 1), específicamente, en el

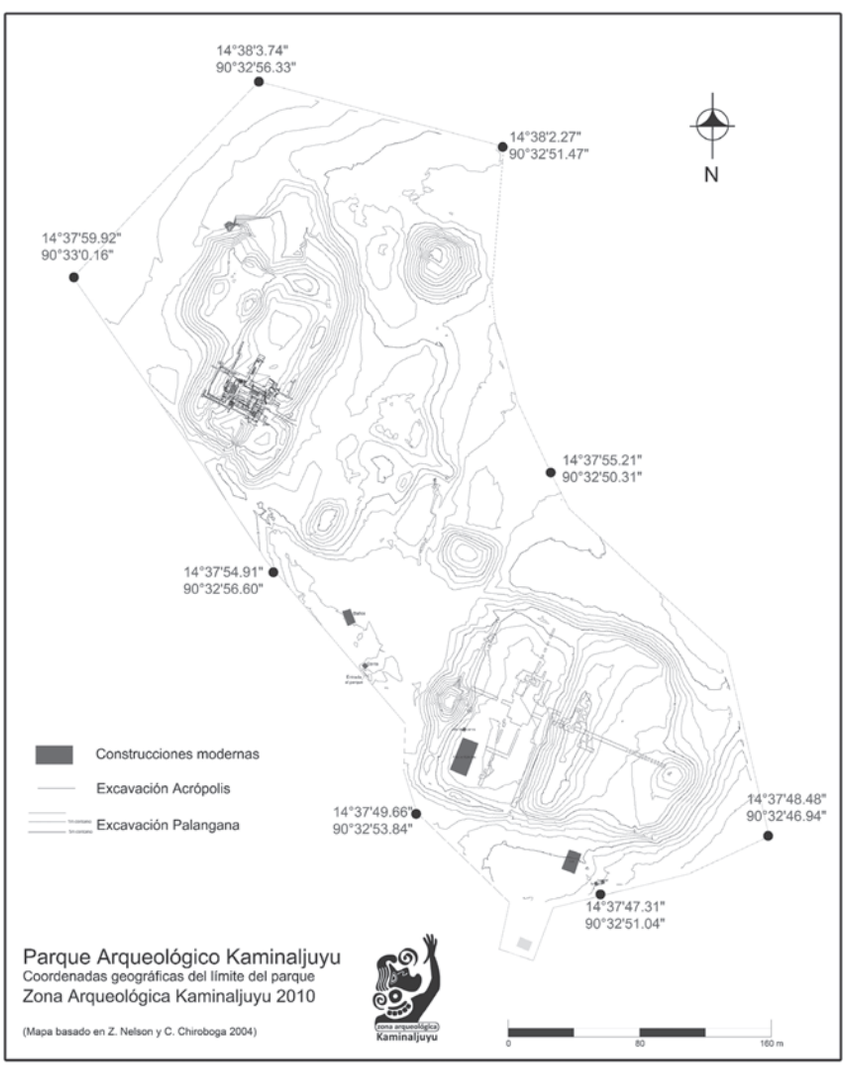


FIGURA 1 Mapa del Parque Arqueológico Kaminaljuyu. Dibujo: Proyecto Zona Arqueológica Kaminaljuyu, IDAEH, 2019.

conjunto conocido como La Palangana, en el centro de la actual ciudad de Guatemala, que ha sido estudiado desde principios del siglo XX, con lo que se ha conseguido valiosa información sobre las sociedades prehispánicas que lo habitaron al menos desde hace 2200 años.

La zona arqueológica incluía cientos de estructuras realizadas con tierra, en combinación con rocas volcánicas y bloques de "talpetate", que es un tipo de suelo consolidado en forma natural que se utilizaba como mampostería asentada con lodo. Pero el abandono de la zona ocurrido probablemente en el periodo Posclásico (1300 d. C.) detonó su paulatino deterioro. Luego, en el siglo XVIII, a raíz del traslado de la capital y la fundación de la ciudad de Guatemala, gran parte de los montículos fueron fuertemente afectados porque se usaron como cantera de materia prima de construcción (Arroyo, Conde y Sarazúa 2016). Finalmente, entre 1980 y 1990, con el crecimiento desmedido de la ciudad, los restos arqueológicos se perdieron casi por completo (Schávelzon 1993; Crasborn 2000), aunque se consiguió salvar una parte de la antigua zona patrimonial gracias a la generación de un parque donde se preservan los restos que se analizan en el presente texto.

El conjunto de La Palangana fue explorado mediante procedimientos de excavación que incluyeron la eliminación indiscriminada de algunas secciones de etapas constructivas recientes para reconocer las preexistentes (fig. 2), así como la realización de diversas zanjas que dejaron al descubierto los núcleos de las estructuras, con lo que, además de dificultar la percepción integral del sitio por parte de los visitantes, las condiciones climatológicas progresivamente fueron destruyendo los vestigios.



FIGURA 2 Vista general de la zona de trabajo. Fotografía: Bárbara Arroyo, 2019.

Ante esta situación, las últimas acciones de intervención que se decidió implementar tuvieron como objetivo central la consolidación de los elementos estructurales que se encontraban inestables y, además, el relleno de trincheras y oquedades que dificultaban la comprensión de la sucesión de etapas constructivas de origen prehispánico, que son parte de sus valores más significativos.

Antecedentes

La Palangana es un conjunto arquitectónico ubicado en el sector norte de Kaminaljuyu, donde hoy se encuentra el parque arqueológico. Este espacio tuvo su origen en el periodo Preclásico (300 a. C.), cuando era una plaza abierta, delimitada por los Montículos "C-II-12" en su frente oeste y "C-II-13" en el límite este. Todos los edificios del conjunto fueron construidos con tierra, bloques de talpetate, arena y otros materiales locales. En el periodo Clásico (350–550 d. C.) se eleva la sección al este y se construye la plaza superior. El montículo "C-II-14" separa la plaza inferior de la superior (fig. 3).

Este edificio fue excavado por varios investigadores, incluyendo al propietario de los terrenos que, en la primera parte del siglo XX, conformaban la finca Miraflores, además de Samuel Lothrop y Manuel Gamio (Álvarez y Arroyo 2018). Posteriormente, el inspector del Instituto de Antropología e Historia Gustavo Espinoza desarrolló investigaciones que condujeron al descubrimiento de una tumba del Clásico con una cámara funeraria compuesta por monumentos del periodo Preclásico que habían sido reutilizados. Desafortunadamente, esta tumba no fue adecuadamente reportada, y se conoce poco sobre ella.

En la década de 1970, exploradores de la Universidad Estatal de Pensilvania llevaron a cabo investigaciones en la Estructura "E" (Cheek 1977), un edificio construido durante el Clásico Temprano al estilo teotihuacano, con un patio frontal de fachadas y perfiles con componentes en talud-tablero (fig. 3). Este edificio fue ampliamente excavado y protegido por un techo de lámina previsto como un recurso provisional, pero que se mantuvo por varios años.

Lamentablemente, las excavaciones nunca fueron rellenadas y su exposición a los efectos climáticos impactó la conservación del conjunto. El techo de lámina no tuvo mantenimiento y fue reemplazado en 2018.

A partir de la construcción de la nueva cubierta, se habilitó un espacio más amplio que permitió llevar a cabo acciones de conservación y reconstitución de volúmenes a fin de ofrecer al visitante una visión comprensible de la forma del conjunto.

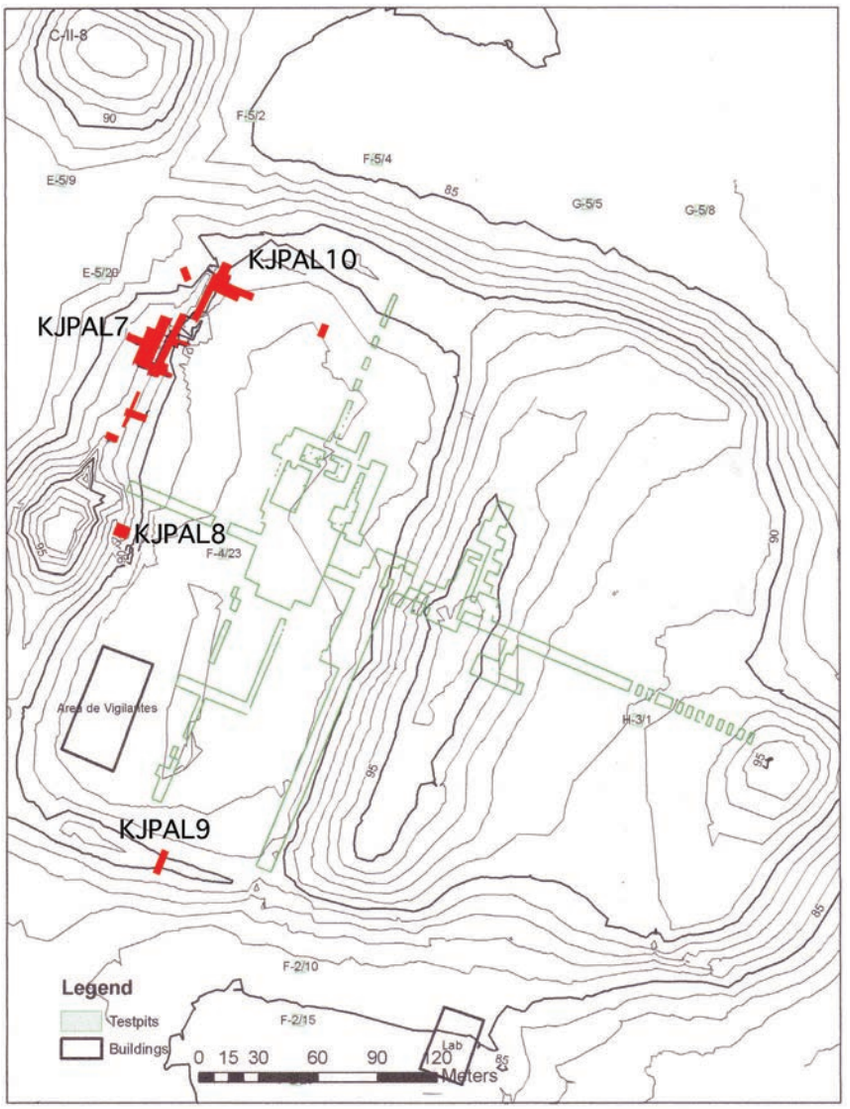


FIGURA 3 Mapa de La Palangana. Dibujo: Proyecto Zona Arqueológica Kaminaljuyu, IDAEH, 2019.

Debido a las múltiples intervenciones arqueológicas, varias secciones fueron cortadas, y era difícil su lectura. Esto hizo necesaria la reconstitución de volúmenes para destacar la continuidad de la forma exterior del edificio, además de rellenar trincheras de excavaciones para nivelar superficies.

Procedimiento

Una vez que el conjunto de La Palangana fue documentado con gran precisión, se procedió a la identificación de las áreas prioritarias a intervenir, con el fin de optimizar el trabajo y de diseñar el uso de sistemas constructivos apropiados para cada componente.

Entre los principales criterios de diseño de la intervención que decidieron de manera conjunta los profesionales a cargo del sitio, destacaba la idea de actuar en las secciones exteriores del edificio para ofrecer claridad sobre su volumetría a los visitantes, que regularmente perciben los vestigios desde la periferia.

Los criterios de intervención tomaron como premisa la línea de acción que se conoce como conservación sostenible del patrimonio, que, entre otros aspectos, procura la mínima intervención, la re-tratabilidad, el empleo de materiales de bajo impacto ambiental y de técnicas constructivas tradicionales, así como la incorporación de artesanos locales (Guerrero 2015).

Esta perspectiva considera que los bienes históricos no pueden ser entendidos ni preservados de manera inconexa a su entorno natural y social, de modo que resulta indispensable el rescate y puesta en práctica de estrategias constructivas que tradicionalmente han formado parte del patrimonio

biocultural (Toledo y Barrera-Bassols 2008). La forma convencional en la que se restauran los inmuebles requiere ser replanteada para evitar el agotamiento de recursos naturales, el dispendio de materiales innecesarios y el manejo de substancias nocivas para la salud de quienes las aplican o habitan los espacios intervenidos. La mayor parte de las obras realizadas sobre el patrimonio cultural durante el siglo XX se caracterizaron por usar componentes constructivos que cada día resultan más escasos, o bien por la aplicación de nuevos materiales para consolidar los restos existentes con substancias de origen industrial que generan una profunda huella ecológica y que no tienen una reversibilidad comprobada.

Así, la conservación sostenible se centra, por una parte, en la aplicación de los conocimientos y materiales derivados de las tradiciones vernáculas, y, por otra, en los hallazgos de la arquitectura bioclimática y la bioconstrucción (Guerrero 2021).

Para actuar en las ruinas de La Palangana se llevaron a cabo rellenos y complementos mediante el uso de la misma materia prima original, pero transformada en diferentes procedimientos constructivos. De este modo, se garantizaba la adecuada compatibilidad de los componentes, pero se dejaba clara evidencia de ser complementos realizados en el siglo XXI. Se procuraba dotar de continuidad visual a los restos que presentaban faltantes, de manera que, a la distancia, pudiera comprenderse su volumetría, pero sin llevar a engaños a través de la creación de "falsos históricos". No se pretendía "borrar" las evidencias de las intervenciones realizadas en otros momentos de exploración porque éstas también forman parte de la historia de las investigaciones arqueológicas en el sitio.

Otros de los aspectos que se consideraron prioritarios en la intervención desde la perspectiva de la sostenibilidad estaban vinculados con la durabilidad de las obras y con la accesibilidad de su ejecución, para que los trabajos de mantenimiento preventivo que se tengan que hacer en el futuro los efectúe el propio personal del sitio empleando técnicas de fácil aprendizaje, herramientas de sencilla adquisición y componentes de tierra. Bajo estas premisas, en marzo de 2019 se realizaron ensayos de caracterización de los materiales a partir de los estudios que, desde hacía tiempo, venía llevando a cabo el equipo de arqueología del sitio. Se efectuaron diferentes pruebas a fin de disponer de una tierra con granulometría similar a la de los materiales originales, pero buscando la manera de hacerla ligeramente más arenosa para conseguir su reversibilidad, en caso de que se decidiera explorar el edificio a futuro. Asimismo, esta condición permitía contar con componentes con mayor porosidad que ayudaran a eliminar más fácil y rápidamente el vapor de agua y evitar de ese modo el desarrollo de vegetación y fauna nociva, así como de eflorescencias salinas.

Se pudo observar que la tierra local (talpetate triturado) mezclada con arena gruesa de origen volcánico (pumita) y un bajo porcentaje de cal (5 % en peso seco) permitía desarrollar componentes constructivos muy resistentes, pero que conservaban la textura y color de los vestigios originales.

Con estos recursos se procedió a realizar los rellenos, en los cuales se emplearon varias capas. Primero se colocó arena suelta para evitar que se adhiriera la intervención permanentemente al sustrato arqueológico; luego se integraron adobes que se habían realizado previamente, asentándolos con mortero de tierra local, y finalmente, un recubrimiento elaborado con la mezcla experimentada de tierra, cal y arena de pumita. El empleo de la cal, además de dar mayor resistencia ante la humedad, desarrolla reacciones puzolánicas con el material de origen volcánico, incrementando su durabilidad.

Se optó por el empleo de adobes porque se trata de componentes que no existieron en la época prehispánica en el sitio, de manera que se hacían más reconocibles los tratamientos actuales. Estos adobes se fabricaron con material descartado de las excavaciones, de modo que se trataba de la misma tierra original de rellenos de edificios prehispánicos.

El recubrimiento de tierra estabilizada se aplicó mediante una estrategia a la que se ha denominado Tierra Amasada y Compactada (TAC), que se realiza incorporando capas sucesivas de material mezclado y modelado en forma de esferas. Estos amasijos se colocan en la superficie y se compactan paulatinamente con una herramienta de madera hasta que desaparecen sus formas esféricas y se consigue tener una capa sólidamente densificada (fig. 4). Antes de que seque por completo el material, se humedece y se procede a colocar la siguiente capa que se compactará del mismo modo; el procedimiento se repite las veces que sean necesarias hasta recuperar el perfil requerido (Guerrero 2020).

Mientras se elevaban las hiladas de adobes insertos, se iba agregando arena seca entre estas piezas y los vestigios originales para conformar un puente. Este relleno servirá para reconocer las intervenciones contemporáneas si se llevaran a cabo futuras excavaciones, además de funcionar como "junta constructiva" ante la incidencia de sismos, que son frecuentes en la región (fig. 5). De este modo, se garantiza que, en caso de presentarse fallas, los elementos agregados y las superficies "de sacrificio" sean los que se dañen, sin afectar los componentes patrimoniales.



FIGURA 4 Técnica de Tierra Amasada y Compactada (TAC) utilizada en La Palangana. Fotografía: Bárbara Arroyo, 2019.

Conclusiones

La incorporación de la sostenibilidad en las intervenciones de conservación destinadas al patrimonio arqueológico es un proceso relativamente reciente que requiere ser evaluado conforme se cuente con resultados de mediano plazo.

Las condiciones socioculturales, económicas y ecológicas por las que atraviesa una parte importante de los países en los que se encuentra un número significativo de sitios con arquitectura de tierra en el mundo, obligan a pensar en la necesidad de optimizar los recursos disponibles y generar la menor huella ecológica posible.

Además del apego a los lineamientos de conservación imperantes, que procuran el respeto a la integridad y autenticidad de los vestigios a partir de la mínima intervención, y el criterio de la re-tratabilidad de las acciones efectuadas, se ha vuelto imperativo el manejo de recursos locales, mano de obra de las propias comunidades vecinas a los sitios y la reducción al mínimo del uso de substancias de origen industrializado.

La permanencia de tradiciones constructivas locales son la mejor evidencia de sostenibilidad con la que se cuenta, por lo que resulta crucial su estudio y puesta en valor.

Las actividades desarrolladas en 2019 en el conjunto de La Palangana, en Kaminaljuyu, Guatemala, son una muestra de la posibilidad de llevar adelante procesos en los que se ha conseguido de manera muy económica recuperar la volumetría de un espacio de gran valor patrimonial para permitir su disfrute por las generaciones futuras (fig. 6). Además, al intervenir estructuras antiguas con estas estrategias, se ofrece al



FIGURA 5 Relleno con arena confinada dentro de adobes para recuperar el nivel original. Fotografía: Bárbara Arroyo, 2019.



FIGURA 6 Recuperación volumétrica de una de las esquinas del Edificio "E" de La Palangana. Fotografía: Bárbara Arroyo, 2019.

visitante una perspectiva más completa y comprensible de la conformación original de su composición.

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Cross-Disciplinary Approach Using Asphalt Emulsion for the Preservation of Earthen Architecture Heritage: The Case of La Joya, Veracruz, a Classic Period Site on the Mexican Gulf Coast (2004–2020)

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Abstract: *Cross-disciplinary approaches to the study and preservation of earthen architecture are still scarce in Mexico, reserved primarily for archaeological (Mogollón culture) and historical sites in the north. Only recently has there been increasing awareness of the earthen heritage of the Mesoamerican cultural area. This paper addresses the combined research and preservation programs carried out between 2004 and 2020 at the first millennium CE site of La Joya on the Veracruz Gulf Coast by archaeologists, conservation specialists, biologists, chemists, and engineers from the National Autonomous University of Mexico (UNAM) and the Center for Scientific Research in Yucatán (CICY), with funding from UNAM and Mexico's National Council for Science and Technology (CONACyT). The paper presents a synthesis of the results of the different analytical techniques applied to the archaeological samples (texture, mechanical properties, mineralogy, elemental analysis by XRF, clay identification by XRD, micromorphology, and chemical analysis of organic extracts with FTIR, NMR, GC-MS in scan and SIM mode, and IRMS) and evaluates the performance of the strategies used to preserve the extant vestige of the site's pyramid (geotextiles, vinyl polymers and hydrofugants, slaked lime, vernacular plant-derived polymers, water-based asphalt emulsion, and bitumen dissolved in oil). Archaeological evidence shows that bitumen from locally available petroleum seeps was used in the past to stabilize construction and that commercial water-based asphalt emulsions in very low percentages (1%) are viable options for the preservation of clay-rich earthen constructions in humid tropical environments.*

Resumen: *Los estudios interdisciplinarios de intervención y preservación de arquitectura de tierra son aún escasos en México, habiendo sido realizados principalmente en sitios del norte del país, tanto arqueológicos (de la cultura Mogollón) como históricos; sólo recientemente hay una mayor atención a sitios patrimoniales del área cultural mesoamericana. La presente contribución se centra en los programas paralelos de estudio y preservación realizados entre 2004 y 2020 en el sitio arqueológico veracruzano de La Joya, en el Golfo de México—datado hacia el primer milenio de nuestra era– por arqueólogos, restauradores, biólogos, químicos e ingenieros de la Universidad Nacional Autónoma de México (UNAM) y del Centro de Investigación Científica de Yucatán (CICY), con financiamiento de la UNAM y del Consejo Nacional de Ciencia y Tecnología de México (CONACyT). En este artículo se presentan los resultados de las técnicas aplicadas a muestras constructivas arqueológicas (textura, propiedades mecánicas, mineralogía, composición elemental por FRX, identificación de arcillas por DRX, micromorfología y estudios de química orgánica por FTIR, RMN, CG-EM e IRMS) y se evalúa el desempeño de las estrategias probadas para la preservación de los vestigios existentes de la pirámide del sitio (geotextiles, polímeros vinílicos e hidrofugantes, cal hidratada, emulsiones orgánicas de uso vernáculo, emulsión asfáltica a base de agua y bitumen disuelto en aceite). Las evidencias arqueológicas muestran que el bitumen de afloramientos locales de petróleo fue antiguamente utilizado para estabilizar la construcción y que, la emulsión asfáltica comercial a base de agua en porcentajes muy bajos (1%), es una opción viable para la preservación de construcciones ricas en arcillas ubicadas en ambientes de trópico húmedo.*

Keywords: humid tropics, archaeology, bitumen, organic stabilizer, XRD, micromorphology, GC-MS, IRMS

Introduction

This paper summarizes the 2004–2020 project at La Joya, Veracruz, a Classic period Mesoamerican site on the Mexican Gulf Coast that began as archaeological research to study the building sequence and the function of the monumental compound. The discovery of well-preserved remains led the authorities to require the preservation of the pyramid's exposed substructure, dated 200 CE. Therefore, in 2009, parallel programs were launched to analyze construction samples and to carry out a series of laboratory and on-site experiments to develop a valid strategy to protect the vestige. The first of these programs revealed that bitumen was present in the archaeological construction samples, suggesting its use as a stabilizer. Based on this evidence, and on the previous use of asphalt emulsions in conservation of earthen architecture, experiments compared the performance of an asphalt emulsion to lime and organic polymers used in vernacular architecture. Due to this obvious effectiveness of the pre-Columbian technology, as reflected by the 1000-year building sequence at the site, the pyramid was covered with a sacrificial layer of earth with 5% asphalt emulsion that performed well during the five years of monitoring. Yet, authorities finally decided not to open the site to the public and requested reburial, a procedure I briefly describe in this paper. The main contribution of this project is that bitumen was used 2000 years ago in earthen construction and that its application for preservation is justified and effective. This should lead to the reconsideration of the use of asphalt emulsion as a viable preservation strategy for architectural heritage in a humid tropical setting.

The La Joya Site: Archaeological Data

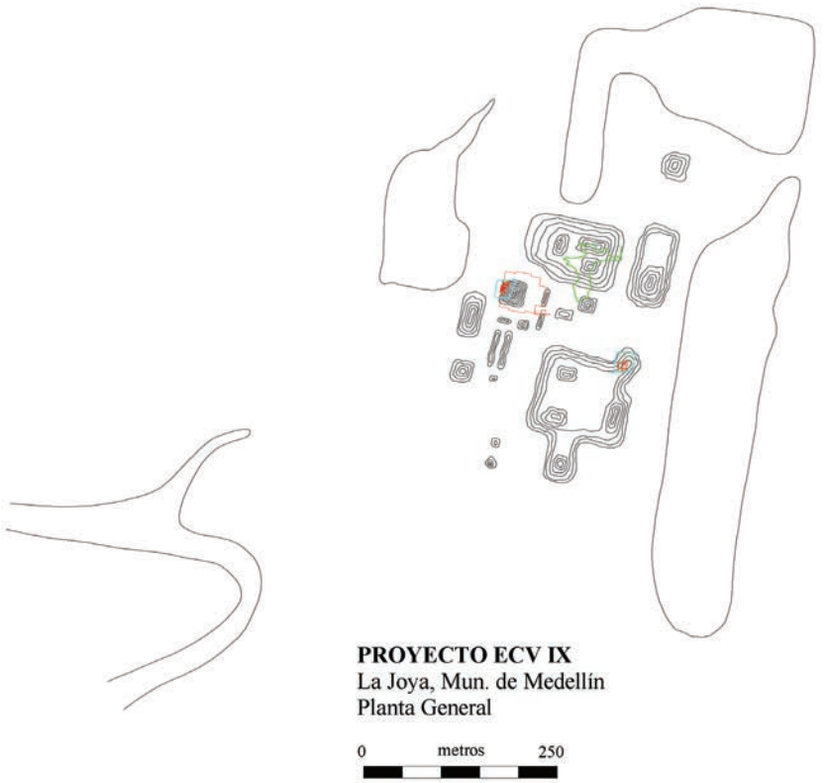
Monumental pre-Columbian architecture on the coastal plains of the central and southern Gulf Coast, between the Actopan and the Usumacinta Rivers, is predominantly made of earth (with earthen plasters) in spite of the humid tropical environment that includes alternating dry strong winds in the winter and heavy rainfall in the summer (1500–4000 mm annual average). Among these, La Joya arose as the capital of a small state around 200 BCE to 1 BCE, starting a building sequence of six stages, until its abandonment in 1000 CE. By 700 CE it had reached a volume of 244,500 m^3 of earthen construction, surrounded by three artificial water reservoirs (Daneels 2016) (fig. 1).

By 2004 only parts of the pyramid and the two palaces (North Platform and East Platform) were extant. The pyramid had two construction stages: the most recent, dated 700 CE, was 50 × 50 m and 25 m high (according to Escalona Ramos's 1937 croquis) and the earlier, dated to 200 CE, whose footing contour was revealed in 2008, was reconstructed as measuring 45 × 45 m and 11 m high, with eleven tiers and four staircases. However, only the lower part of the west staircase and adjoining sectors of six tiers were extant in elevation (in all, about 4% of the building) (fig. 2). The basal platforms were made of structured fills (Daneels, Love, and Ávalos Beltran 2018) and the buildings on top were made of mud brick; all surfaces, interior and exterior, were covered with well-compacted clay plasters. Substructures presented excellent conservation, without evidence of sagging or water damage, but these degraded rapidly after excavation, particularly during rains. This led the team to infer the use of an organic stabilizer that protected the construction while in use but degraded over time after the abandonment of the site.

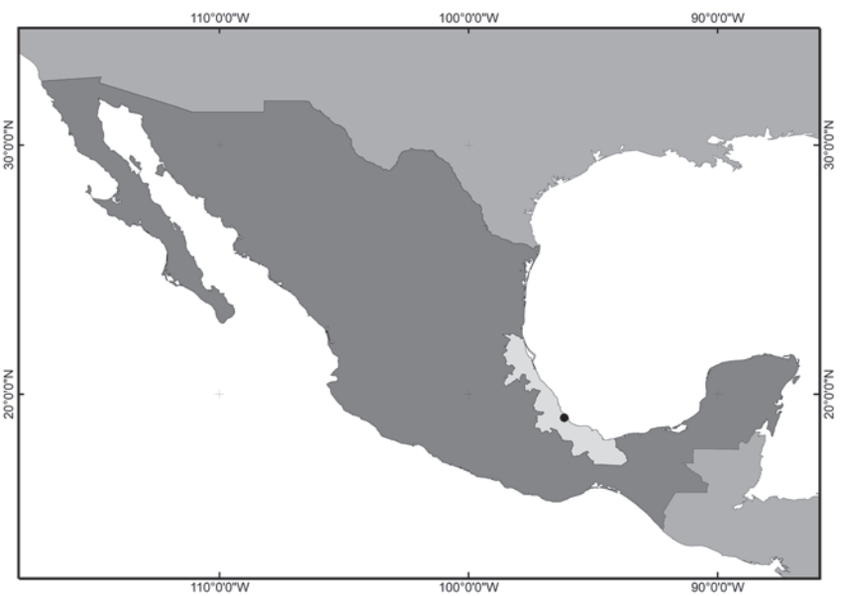
Construction Sample Analysis

The first series of studies was standard: petrography, texture, Atterberg limits, X-ray fluorescence (XRF), and mechanical properties (porosity, resistance to compression) of mud bricks, plasters, and floors. X-ray diffraction (XRD) of the clay fraction indicated the presence of smectites and halloysites. The mineralogy is consistent with fluvial deposition of volcanic sediments coming from the Pico de Orizaba volcano, where both the Jamapa and the Cotaxtla Rivers originate. The unexpected results were the dominance of the fine fraction, always >50% and up to 60–75% in the plasters, and the high resistance to compression, averaging 2.35 MPa (Daneels and Guerrero 2011). These results again led to the inference of an organic additive.

The search for organic additives in construction samples started with Fourier transform infrared spectrometry (FTIR): the results did not match with *Opuntia* sp. mucilage, a traditional stabilizer, but with bitumen paint on archaeological ceramics. The next stage was extracting organic residue from the samples and analyzing them by ^{1}H Nuclear Magnetic Resonance (^{1}H NMR): this showed a clear presence of hydrocarbons (Kita, Daneels, and de Vivar 2013). The opportunistic use of a petroleum-derived additive was possible because of the presence of natural petroleum seeps on the Mexican Gulf Coast and the antecedent use of asphalt emulsion as an effective stabilizer in earthen architecture between the 1940s and the 1990s (Barrow 2009; Oliver 2000). The residues were processed by gas chromatography–mass spectrometry (GC-MS), comparing extracts from construction samples, archaeological



(a)

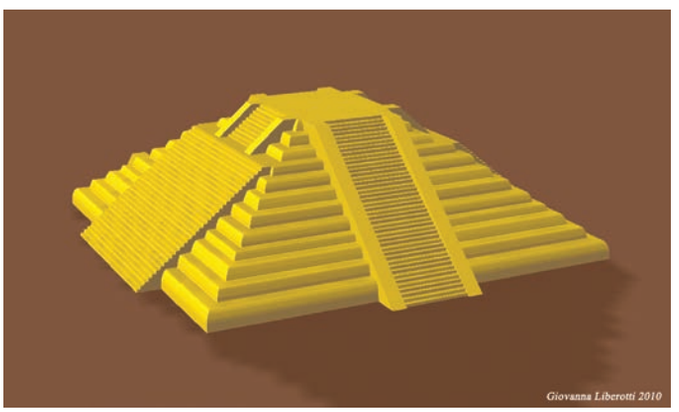


(b)

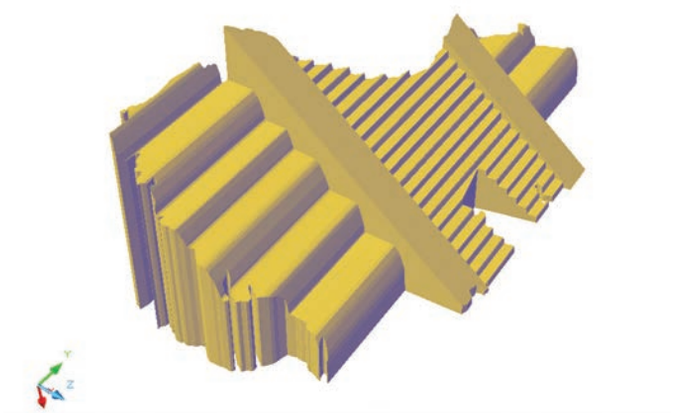
FIGURE 1 (a) Map of La Joya, with extant sectors of the pyramid, North Platform, and East Platform in green outline. The mound contours in black outline are from a 1937 croquis, the green outlines show the extant sectors, and the blue outlines show the sectors reserved by INAH. Map by Annick Daneels, contour lines of mounds redrawn from Escalona Ramos 1937; and (b) location of La Joya in the state of Veracruz, Mexico, on the Gulf Coast. Location map by A. M. Pérez Diosdado.



(a)



(b)



(c)

FIGURE 2 (a) La Joya pyramid: extant sector of staircase of west facade of 200 CE substructure, (b) 3D reconstruction of pyramid based on contour line of footing, and (c) 3D rendering of extant sector of facade. Photo of west facade of pyramid by Annick Daneels, May 2008, 3D reconstructions by Giovanna Liberotti.

bitumen paint, and paleosoils. The results show that there is asphalt in the construction samples, matching local seep profiles 30 km upriver, but that it does not appear in paleosoils (thus discarding natural contamination) (Daneels et al. 2020). This demonstrates that bitumen was added in construction mixes, at least in adobes and floor plasters, showing that the La Joya builders had already developed a technology that would be rediscovered in the twentieth century.

Experimental Program

Between 2012 and 2015, Yuko Kita carried out an experimental program of test walls and test blocks, using the composition of the archaeological mud brick (local earth of smectite/halloysite clay and loam, no sand added, 30% chopped grass in volume) to compare the in situ performance of different additives: petroleum products, slaked lime, and plant mucilage used as additives in Central America (*Sida* sp. and *Guazuma ulmifolia*) (Kita and Daneels 2015). All amendments using the heavy fraction of petroleum (bitumen dissolved in corn or linseed oil and commercial asphaltic emulsion) performed well at all concentrations (1%, 2%, 4%, 6%, and 8%), with perceptible darkening only in the samples amended with bitumen dissolved in corn oil (Daneels and Kita 2018). These series all performed better than the other additives, up to the last monitoring in July 2021 (fig. 3).

In parallel, Rolando Ríos has carried out laboratory tests on the same series of experimental blocks since 2015, comparing their mechanical performance in compression, elongation, and artificial weathering tests. Results are soon to come out as J. Pereza Góngora's doctoral thesis, but the experimental blocks amended with as little as 1% petroleum are significantly improved.

Preservation of the Pyramid

The National Institute of Anthropology and History (INAH) required the preservation of the pyramid's vestige at La Joya in 2008. Roofing over was discarded as an option due to the height and orientation of the vestige, which would have made the roof extremely vulnerable to winter winds and also because it would completely hide the facade. Therefore, the proposal was to cover the original with geotextile and a sacrificial coating to respect the original visual impact of the building. Daneels and Piña (2013) synthetized the four interventions carried out between 2009 and 2013, including the construction of mud brick walls to protect the fill of the pyramid exposed to the north and east,



(a)



(b)



(c)



(d)

FIGURE 3 In situ test walls and experimental blocks with asphalt emulsion: (a) test wall with 1% emulsion when made, March 2013, (b) test wall eight years later, in July 2021, (c) blocks when made, April 2015, from front to back, with 1%, 2%, 4%, 6%, and 8%, and (d) the same blocks in July 2021. Photos: Annick Daneels.

as well as a ramp in front of the vestige. The whole vestige was covered with thick geotextile (PET 270 gr/m²) and the application of a 2 cm thick layer of unamended earth topped by a coating with chopped grass, WACKER vinyl polymer VINNAPAS 5044N (0.75% v/v) and SILRES POWDER D (0.3% v/v) (fig. 4). The strategy revealed inconveniences: the polymers gave the sacrificial layer a rigidity and impermeability that increased internal humidity due to capillary rise, causing surface crumbling of the fill sector, as well as the growth of a biofilm on the surface of the amended coat.

Based on the experimental program developed since 2012 by Kita, a new strategy was proposed in 2013 and accepted by INAH authorities: the walls were made of brick that was mortared with an earth/slaked lime mix, the geotextile over



FIGURE 4 First intervention of the pyramid with vinyl polymer and hydrofugants. Photo: Annick Daneels.

the fill sector to the north and east was replaced by a thinner one (PET 200 gr/m²), and the coating was of earth amended with 5% commercial water-based asphalt emulsion (COMEX Impertop A) (figs. 5, 6). The latter was also applied in thin layers over the west facade after mechanically removing the biofilm on the vinyl polymer amended layer.

This strategy allowed proper evaporation and controlled biofilm, insect, and weed invasion (Kita and Daneels 2015). With only a yearly application of a thin layer of earth amended with 5% asphalt emulsion, the vestige was stable until 2018 (fig. 7), when central INAH authorities finally requested reburial, in spite of the interest expressed by municipal authorities and the local delegation of INAH to open the site to the public. The reburial consisted of applying a 30 cm layer of unamended coating over the whole vestige, thicker in areas where contours had to be softened in view of applying a *Stenotaphrum secundatum* grass cover. The latter was placed over a geotextile layer of



FIGURE 5 The pyramid's west facade, protected by ramp and conical talus, covered with sacrificial layer amended with 5% asphalt emulsion. Photo: Annick Daneels.

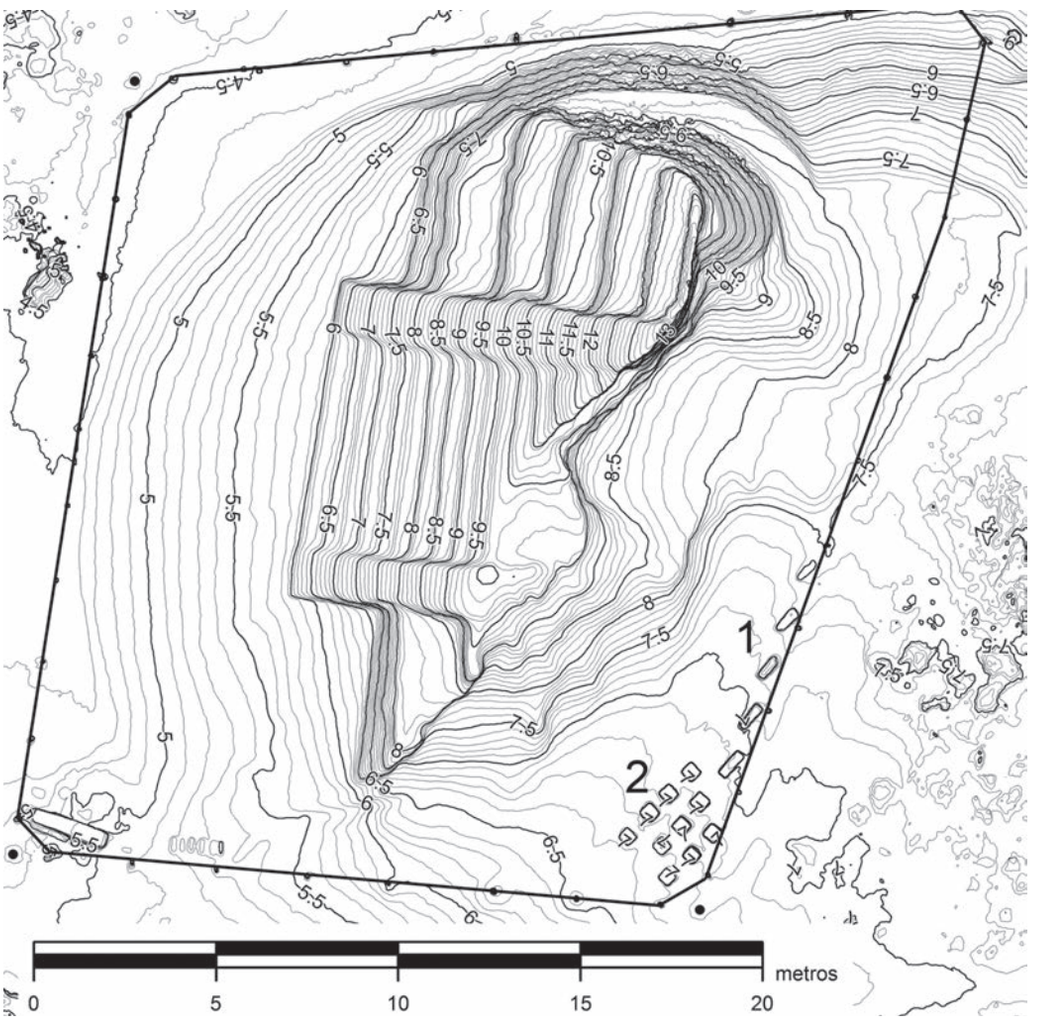


FIGURE 6 Topographic map of the pyramid after the construction of protective talus in northern and northeastern sectors, with ramp in front. Topographic rendering based on photogrammetric survey, January 2016. Guillermo Acosta Ochoa, drone handler, Gerardo Jiménez, rendering.



FIGURE 7 The pyramid's west facade after a five-year monitoring, having applied only yearly slurries amended with 5% asphalt emulsion on the existing sacrificial layer. Photo: Annick Daneels.

200 gr/m² (reburial design by Annick Daneels and Fernando Guerrero). Monitoring from 2019 to 2021 shows an adequate firmness of the core and a satisfactory establishment of the grass cover, albeit rivaled by the invasion of local shallow-rooted weeds of the Fabaceae family: *Rhynchosia* sp. and *Desmodium scorpiurus*, but they serve the same function as the grass (fig. 8).

Conclusion

The La Joya project is unique in Mexico for the systematic study of archaeological earthen materials and construction techniques that were coupled to a preservation program of exposed earthen architecture in a humid tropical setting and based on the use of pre-Columbian technology. The chemical analyses of archaeological mud bricks and plasters from the site proved that petroleum derivatives obtained from local seeps were intentionally added as stabilizers. This justified the proposal of using coatings amended with asphalt emulsion as part of the preservation strategy. In situ experiments as well as laboratory tests of mechanical performance showed that concentrations as low as 1% are effective to stabilize earth, with the added advantages of making the surface water resistant without encapsulating and controlling burrowing insects, weed, and biofilm invasion. This led to the decision to cover the pyramid with a sacrificial layer amended with 5% asphalt, showing no noticeable darkening of the surface and requiring only a yearly low-cost maintenance; the layer was monitored for five years and performed well—only administrative reasons led to reburial. Thus, although the use of asphalt emulsion in heritage conservation was gradually abandoned after the 1990s, the La Joya results suggest it definitely deserves to be reconsidered.



(a)



(b)

FIGURE 8 (a) The pyramid after reburial, 2018, and (b) after 2.5 years of reburial. Photo: Annick Daneels.

Acknowledgments, Materials, and Suppliers

The archaeological research at La Joya, as well as the laboratory analysis on its construction samples, were carried out with the permission of the Consejo de Arqueología del Instituto Nacional de Antropología e Historia. The funding for both programs was provided by the Universidad Nacional Autónoma de México (UNAM): PAPIIT IN305503, IN405009, IN300812, IN400816, and the Instituto de Investigaciones Antropológicas, as well as by CONACyT grants FI 90636 and CB2015-254328.

The materials used in the preservation program were provided courtesy of Wacker Chemie AG-Mexico (www.wacker.com; VINNAPAS 5044N, SILRES POWDER D), the raw bitumen was acquired at a Veracruz hardware store, petroleum and linseed oil in drugstores, canola and corn oil at the local supermarket, and Impertop A from a COMEX dealer.

At the Instituto de Investigaciones Antropológicas at UNAM, Manuel Reyes did porosity analysis, Cristina Adriano carried out the macrofossil identification of grass stalks used in roofing, and Emilio Ibarra supervised Angélica Pérez in the palynological analysis of soils, construction samples, and surfaces. Miguel Canseco and Alfredo Maciel of the Instituto de Materiales did the first FTIR and compression analysis. At the Instituto de Química, Alfonso Romo de Vivar of the Laboratorio de Productos Naturales supervised the extraction and separation of the organic residues by Yuko Kita, Areli Linares, and Laura Chávez and their FTIR and MNR analysis, and GC-MS was done by Marisol Reyes, Everardo Tapia, and Mayra León at the LANCIC. At the Institute of Geology, Pedro Morales, Edith Cienfuegos, and Francisco Otero did the IRMS, Patricia Girón the total samples by XRF and XRD, Teresa Pi the XRD of fine fraction, and Sergey Sedov and Jaime Díaz assisted Marta Mateu, Thania García, Salvador Piña, and Hugo Fernández in the micromorphological study of thin sections. At the Centro de Investigación Científica de Yucatán, Rolando Ríos supervised the analysis of mechanical properties of experimental mud bricks reproducing the pre-Columbian manufacture process.

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Caracterización de distintos elementos constructivos y su proceso de elaboración mediante la micromorfología: Estudio aplicado a arquitectura prehispánica de tierra en Mesoamérica

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***Resumen**: El presente artículo muestra cómo la micromorfología de suelos apoya el estudio de los restos arqueológicos de arquitectura construida en tierra; ella permite inferir: (1) la procedencia de las materias primas por las características que identifican las fuentes locales de material; (2) el proceso de elaboración de la mezcla constructiva para saber si se combinaron tierras de diversas procedencias, si se añadieron desgrasantes minerales o vegetales, y cuánta agua se usó; y (3) su puesta en obra y el grado de compactación y alisado por la forma y orientación de los componentes. El estudio se basa en el análisis microscópico de láminas delgadas de muestras orientadas conforme a su posición en la construcción; esto ha permitido caracterizar hasta ahora adobes, revoques de muros y pisos, así como cob. Este trabajo deriva de una investigación realizada entre 2019 y 2021, en la Universidad Nacional Autónoma de México (UNAM), en el marco del proyecto CONACyT CB2015-254328, sobre casi 100 muestras de distintos elementos constructivos: muros, bajareques, revoques y pisos de 14 sitios arqueológicos de Mesoamérica de los periodos Preclásico y Clásico, situados tanto en zonas semiáridas como de trópico húmedo. A fin de ilustrar el procedimiento, se presentan ejemplos de dos fragmentos de adobes, dos de revoques y dos de adobes experimentales del sitio de La Joya, Veracruz, México, comparándolos con muestras de otros sitios. Esto evidencia cómo la micromorfología ayuda a la correcta identificación de las técnicas constructivas, una información que es básica para la adecuada preservación del patrimonio construido con tierra.*

***Abstract:** This paper shows how soil micromorphology supports the study of archaeological earthen architecture. It allows us to infer (1) the provenience of raw materials according to the characteristic features of local soils; (2) the manufacturing process, indicating whether earth from several sources was mixed, whether mineral or vegetal tempers were added, and how much water was used; and (3) construction features and the degree of compaction using the shape and orientation of the components. This study is based on the microscopic analysis of thin sections of samples cut according to their position in the construction, allowing us to characterize mud bricks, renders (from walls and floors), and cob. The research was carried out between 2019 and 2021 at the Universidad Nacional Autónoma de México (UNAM), within the framework of the CONACyT CB2015-254328 project, on almost one hundred samples of different types of walls, daub, plasters, and floors from fourteen Mesoamerican sites that date to the Preclassic and Classic periods, located in both semiarid and humid areas. To illustrate the procedure, we present examples of two mud bricks, two renders, and two experimental mud bricks from the archaeological site of La Joya, Veracruz, Mexico, and compare them to samples from the other sites. Our study shows that micromorphology is useful for correctly identifying construction techniques, basic information that is necessary for the adequate preservation of earthen heritage.*

Palabras clave: construcción en tierra, geoarqueología, rasgos tecnológicos, México

Introducción

El uso de la tierra en diversas tradiciones constructivas de Mesoamérica es poco conocido, a pesar de haber prevalecido desde el segundo milenio antes de Cristo como un material aplicado tanto para viviendas temporales como para edificios monumentales. Estas técnicas, materiales y formas de edificación son escasamente reconocidas en el registro arqueológico debido a la poca formación profesional en esta identificación. En las últimas tres décadas, se ha visto un aumento en estudios multidisciplinarios, la mayoría orientados a la composición y propiedades mecánicas de los materiales. Aquí se presentará una técnica complementaria: la micromorfología de suelos, que tiene antecedentes en Europa pero es pionera para Mesoamérica y que no sólo informa sobre la materia prima, sino también sobre sus procesos de manufactura y deterioro. Este trabajo deriva de una investigación sobre muestras de adobe, tierra amasada (*cob*) y revoques de 14 sitios arqueológicos de Mesoamérica desarrollada por los autores en la UNAM, en el marco del proyecto CONACyT CB2015-254328. Para este artículo, nos enfocaremos en adobes y revoques de muros del sitio La Joya, en Veracruz, comparadas con muestras de adobes experimentales y arqueológicas de la compilación que el proyecto maneja, para demostrar cómo la micromorfología permite reconocer los procesos de manufactura.

Universo de estudio

Las muestras principales consistentes en dos adobes de muro, dos revoques y dos adobes experimentales (Cuadro 1) proceden de La Joya, sitio arqueológico ubicado en la planicie costera del Golfo de México, en un ambiente de trópico húmedo, y ocupado entre 100 a. C. y 1000 d. C.; consiste en arquitectura de tierra monumental, con material obtenido de tres bancos locales: tierra limosa de las terrazas aluviales, arena de paleodunas y tierra con arcillas expansivas, tanto de horizontes B de paleodunas como de gleyes de estanques de agua artificiales (fig. 1). Aunque la combinación de condiciones climáticas y materia prima podría parecer adversa a la construcción con tierra, no fue un inconveniente para un programa de edificación monumental que permaneció por más de un milenio (Daneels y Guerrero 2011).

Los basamentos fueron logrados alternando capas de rellenos de texturas distintas; los elementos de acceso y de acabado se hacían con tierra amasada (modelada); las habitaciones y muros divisorios eran de adobe; y los techos planos

Cuadro 1 Descripción micromorfológica de las muestras analizadas (las claves de muestra proceden del proyecto y del estudio de Piña 2021; para términos específicos micromorfológicos aplicados a la arquitectura en tierra, ver Mateu y Daneels 2020).

	Porosidad y microestructura	**Componentes minerales principales**	**Componentes antropológicos y orgánicos**	**Edaforrasgos**
Adobe M1 (6A)	15 % porosidad con distribución heterogénea: poros de empaquetamiento y alguna cavidad, vesículas y poros de molde. Microestructura masiva.	40 % fracción gruesa: predominan arenas subredondeadas (y alguna subangular) con distribución homogénea (arenas finas y medianas de 0.085 a 0.3 mm). Fracción fina: color marrón-anaranjado (PPL) y en XPL fábrica de birrefringencia indiferenciada. Distribución relacional quito-porfírica (en alguna zona casi no hay fracción fina).	Fragmentos de cerámica (a-1), fragmentos pequeños de carbón (a-1) y hueso (a-1).	– Nódulos pequeños negros de ox(hidr) Fe/Mn (0.1 a 0.2 mm) (aa). – Pápulas amarillas y anaranjadas redondeadas pequeñas (alrededor de 0.1 mm) (a). – Agregados de sedimentos redondeados de 1.5 mm (a*). – Alineaciones de material fino.
Adobe M4 (2188)	20 % porosidad: fisuras y vesículas, alguna cavidad (bioturbación), muy pocos finos poros de molde. Microestructura masiva.	25 % fracción gruesa: arenas subangulares y subredondeadas, distribución homogénea (arenas finas 0.1 a 0.25 mm y algunas arenas gruesas de 0.5 a 0.7 mm). Fracción fina: clara en PPL y en XPL baja birrefringencia (tendencia a fábrica de birrefringencia granoestriada). Distribución relacional porfírica cerrada.	Fragmento pequeño de cerámica (a-1).	– Nódulos negros, redondeados pequeños (de 0.1 a 0.5 mm) (aa) e impregnaciones rojo oscuro ox(hidr) Fe/Mn (a). – Pápulas amarillas y anaranjadas redondeadas (entre 0.25 y 0.3 mm) (a). – Agregados sedimentarios irregulares de 1.6 a 2.6 mm largo (a). – Bioturbación.

Cuadro 1 (*continúa*)

	Porosidad y microestructura	Componentes minerales principales	Componentes antropológicos y orgánicos	Edaforrasgos
Revoque M10	25 % porosidad: fisuras y vesículas (alguna cavidad). Microestructura masiva con tendencia a laminar.	30 % fracción gruesa: arenas subangulares y subredondeadas (arenas finas y medianas de 0.1 a 0.5 mm). Fracción fina: clara en PPL y con baja birrefringencia en XPL (fábrica de birrefringencia granoestriada). Distribución relacional porfírica cerrada.	No.	– Nódulos negros (redondos pequeños de alrededor de 0.2 mm) (aa) e impregnaciones rojizas de ox(hidr) Fe/Mn. – Pápulas amarillas y naranjas (0.075 a 0.14 mm) (a). – Agregados sedimentarios irregulares (de 0.5 o 1 mm) (a*).
Revoque M11	20 % porosidad: fisuras y vesículas (algún poro de molde). Microestructura masiva con tendencia a laminar.	25 % fracción gruesa: arenas subredondeadas y algunas subangulares (menos proporción de arenas que la anterior) (arenas finas y medianas de 0.075 a 0.3 mm). Fracción fina clara en PPL y con baja birrefringencia en XPL (fábrica de birrefringencia granoestriada). Distribución relacional porfírica cerrada.	Fragmentos pequeños de hueso (a-1) y carbón (a-1).	– Nódulos negros redondeados pequeños (0.07 mm) (aa) e impregnaciones marrones-rojizas (0.45 mm) de ox(hidr) Fe/Mn. – Pápulas amarillas y anaranjadas (0.063 a 0.08 mm) (a). – Agregados sedimentarios redondeados (0.96 mm) (a*).
Adobe Experimental 1 (molde)	15 % porosidad: cavidades, vesículas y fisuras. Microestructura masiva.	20 % fracción gruesa: arenas subredondeadas a subangulares (arenas finas de 0.9 a 0.35 mm y alguna arena gruesa de alrededor de 0.82 mm). Fracción fina: clara en PPL y con poca birrefringencia en XPL (fábrica de birrefringencia granoestriada). Distribución relacional porfírica de espacio doble.	Se observan los componentes vegetales aún frescos añadidos a la mezcla.	– Nódulos negros pequeños redondeados (0.07 mm) (aa) e impregnaciones (1.3 mm) de ox(hidr) (a) Fe/Mn. – Pápulas naranjas y amarillas (0.09 mm) (a).
Adobe Experimental 2 (hoyo)	10 % porosidad: cavidades, vesículas y fisuras. Microestructura masiva.	25 % fracción gruesa: arenas subredondeadas a subangulares (arenas finas y medianas de 0.1 a 0.5 mm). Fracción fina: oscura en PPL y con poca birrefringencia en XPL (fábrica de birrefringencia granoestriada). Distribución relacional porfírica de espacio doble.	Se observan los componentes vegetales aún frescos añadidos a la mezcla.	– Nódulos negros pequeños redondeados (0.1 mm) e impregnaciones oscuras (entre 0.5 y 0.82 mm) (aa) de ox(hidr) Fe/Mn. – Pápulas amarillas y naranjas (0.1 mm) (a) (alguna de 0.5 mm). – Alineaciones y agregados sedimentarios irregulares (2.26 mm largo) (a).
Adobe Teotihuacan	10 % porosidad: alguna fisura, cavidades y alguna vesícula. Microestructura masiva.	25 % fracción gruesa: la mayoría de arenas subangulares (de arenas muy finas a medianas, 0.069 a 0.35 mm), pero todo muy homogéneo, alguna arena de vidrio volcánico. Fracción fina: limosa-arcillosa con poca birrefringencia en XPL (fábrica de birrefringencia cristalítica con tendencia a indiferenciada). Distribución relacional porfírica.	Algún fragmento de carbón (a*) y de cerámica (a-1). Fitolitos en CV.	– Nódulos negros pequeños redondeados (0.1 mm) (aa) de ox(hidr) Fe/Mn. – Agregados redondeados de sedimento arcilloso (de alrededor de 2 a 5 mm) (a).
Piso Teotihuacan	15 % porosidad: fisuras, cavidades, más en la parte inferior. Microestructura con tendencia a masiva.	35 % fracción gruesa: gravillas de roca volcánica subredondeada (2 a 10 mm) y arenas finas subangulares (0.095 a 0.3 mm). Todo distribuido heterogénea y aleatoriamente. Fracción fina: limosa de colores marrones (PPL), sin birrefringencia en XPL (fábrica de birrefringencia con tendencia a indiferenciada). Distribución relacional porfírica.	Fragmentos de carbones en la parte inferior (a*). Fragmento de revoque de cal (a-1).	– Nódulos y pequeñas impregnaciones de ox(hidr) Fe-Mn (a*). – Agregados de sedimentos arcillosos redondeados (3.7 mm) (a*). – Capa de carbonato en la parte superior. – Revestimientos de finos en FG.

a: escaso <2 % (a*: 1 %; a-1: un solo caso); aa: ocasional 2–5 %; aaa: mucho 5–10 %; aaaa: abundante 10–20 %; aaaaa: muy abundante >20 % (estimación semicuantitativa de abundancia según Macphail y Goldberg 2018, 93).

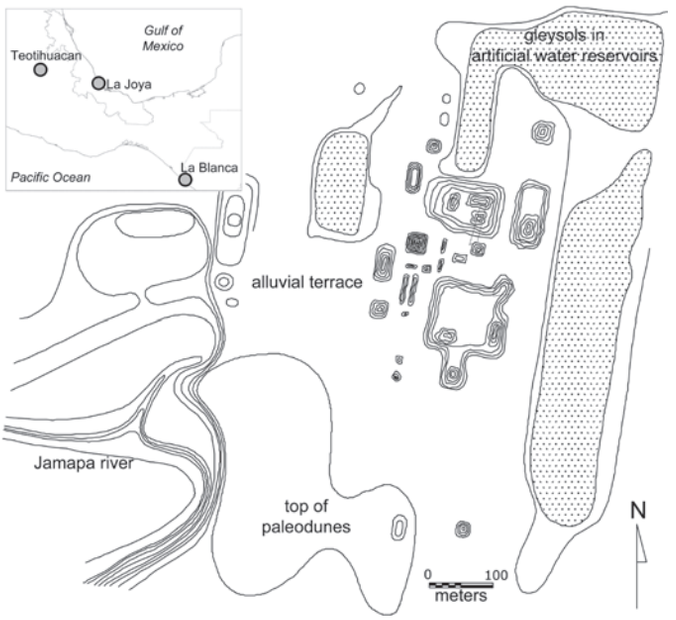


FIGURA 1 Mapa del sitio arqueológico de La Joya. Dibujo: A. Daneels, usando información de Escalona Ramos 1937. Recuadro: Localización de los sitios mencionados. Dibujo: G. Jiménez.

presentaban una estructura de madera y carrizos cubierta por una capa de tierra amasada. Todas las superficies recibían revoques realizados con delgadas capas de tierra mezclada con material vegetal finamente picado que se aplicaban de manera continua sobre las superficies (desde lo alto de los muros hasta pisos, escalones y alfardas) (fig. 2). Estas muestras se compararon con un adobe y un piso del conocido sitio arqueológico de Teotihuacan, Estado de México (ver Cuadro 1).

Metodología

Para estudiar estos materiales y entender el proceso de construcción, la micromorfología define los distintos componentes (minerales, orgánicos, antrópicos, etc.), lo que permite inferir su posible banco de origen. El estudio de las proporciones, formas y orientación de los minerales y poros ayuda a identificar las técnicas constructivas y su forma de puesta en obra en la construcción, así como los procesos posdeposicionales (Mateu 2019).

Las muestras se extraen en campo, manteniendo su orientación original y registrando su posición en la estructura y la identificación de su cara exterior. En el laboratorio se procede a la elaboración de las láminas delgadas cortadas de manera perpendicular, para tener un perfil (corte transversal) del elemento arquitectónico (Mateu y Daneels 2020). Las láminas delgadas se observan con un microscopio óptico petrográfico con luz polarizada plana (PPL) y luz polarizada cruzada (XPL), y se describen e interpretan conforme a los criterios utilizados por Bullock *et al.* (1985); Courty, Goldberg y Macphail (1989); Loaiza *et al.* (2015) y Stoops (2003). De preferencia, estos estudios se comparan con muestras de paleosuelos y sedimentos locales, y se complementan con otros estudios como los de Difracción y Fluorescencia de Rayos X (Macphail y Goldberg 2018; Mateu y Daneels 2020).

Resultados y discusión

Materias primas

La determinación de componentes que forman el material (qué tipo de partículas se encuentran, su proporción y organización) nos ayuda a identificar su origen e interpretar si se mezclaron tierras de varios bancos para formar el elemento estructural. La distribución de las fracciones y su grado de homogeneidad permiten interpretar si se añadieron materiales (como gravas o gravillas) a la mezcla. En nuestro caso (ver Cuadro 1), aparecen materias primas de distintos bancos, aunque todas presentan una composición mineralógica muy similar, coherente con los suelos formados de sedimentos volcánicos de la región los cuales son abundantes en cuarzos, feldespatos del tipo de las plagioclasas, minerales ferromagnesianos (anfíboles, piroxenos y, en menor cantidad, micas) y vidrio (Daneels y Guerrero 2011; Piña y Cabadas 2018; Piña 2021). La diferencia entre las muestras arqueológicas (fig. 3) es que las que proceden de la Pirámide y de la Plataforma Norte tienen rasgos que pueden asociarse a las terrazas aluviales del sitio, mientras que las de la Plataforma Este se asocian a los horizontes de enriquecimiento arcilloso de paleoduna. Este aspecto es importante en la interpretación del sitio y complementa lo observado arqueológicamente de la secuencia de construcción (Daneels y Guerrero 2011; Piña 2021).

Rasgos de elementos constructivos: Porosidad y microestructura

La forma, orientación, proporción y distribución de poros (microestructura) indica la cantidad de agua/aire usada, así como la técnica de manufactura (Cammas 2018; Friesem, Wattez y Onfray 2017) (Cuadro 2). En estos ejemplos (ver Cuadro 1, fig. 4) el porcentaje de porosidad es similar, pero la forma de los poros y su distribución es diferencial. En los



(a) (b)

FIGURA 2 Elementos constructivos en tierra de La Joya, donde se observa la continuidad de los revoques. (a) Sobre muro de adobe y relleno, que continúa desde el muro al piso, dos etapas constructivas del talud y la plaza. (b) Muro de cob con sus revoques en dos etapas constructivas. Fotografías: A. Daneels, reproducción autorizada por el Instituto Nacional de Antropología e Historia (INAH).

adobes, tanto los arqueológicos como los experimentales, los poros son pocos y vesiculares (redondeados), remanentes de la evaporación del agua usada en cantidad justa para obtener la plasticidad de la mezcla (fig. 4c). Por otro lado, hay pocos poros cavitarios (procedentes de la bioturbación) y de empaquetamiento, que no responden a la técnica, sino al tipo de material usado, pues hay más espacio poroso en mezclas más arenosas (fig. 7c). En el caso de los revoques, encontramos más fisuras paralelas a la superficie, resultado de una aplicación distinta y la fuerza usada en su puesta en obra (fig. 4a).

Rasgos de elementos constructivos: Componentes minerales principales

En todos los materiales encontramos una selección intencional de la granulometría según las técnicas o el tipo de estructuras constructivas, a juzgar por la clasificación y distribución homogénea del material (ver Cuadro 2). En las muestras de Teotihuacan se puede ver la diferencia entre un adobe y un piso del llamado "concreto teotihuacano" (fig. 5). El primero tiene una proporción de 25 % de fracción gruesa, que se compone principalmente de arenas y alguna gravilla, y el segundo tiene una fracción gruesa del 35 %, con mayoría de gravillas

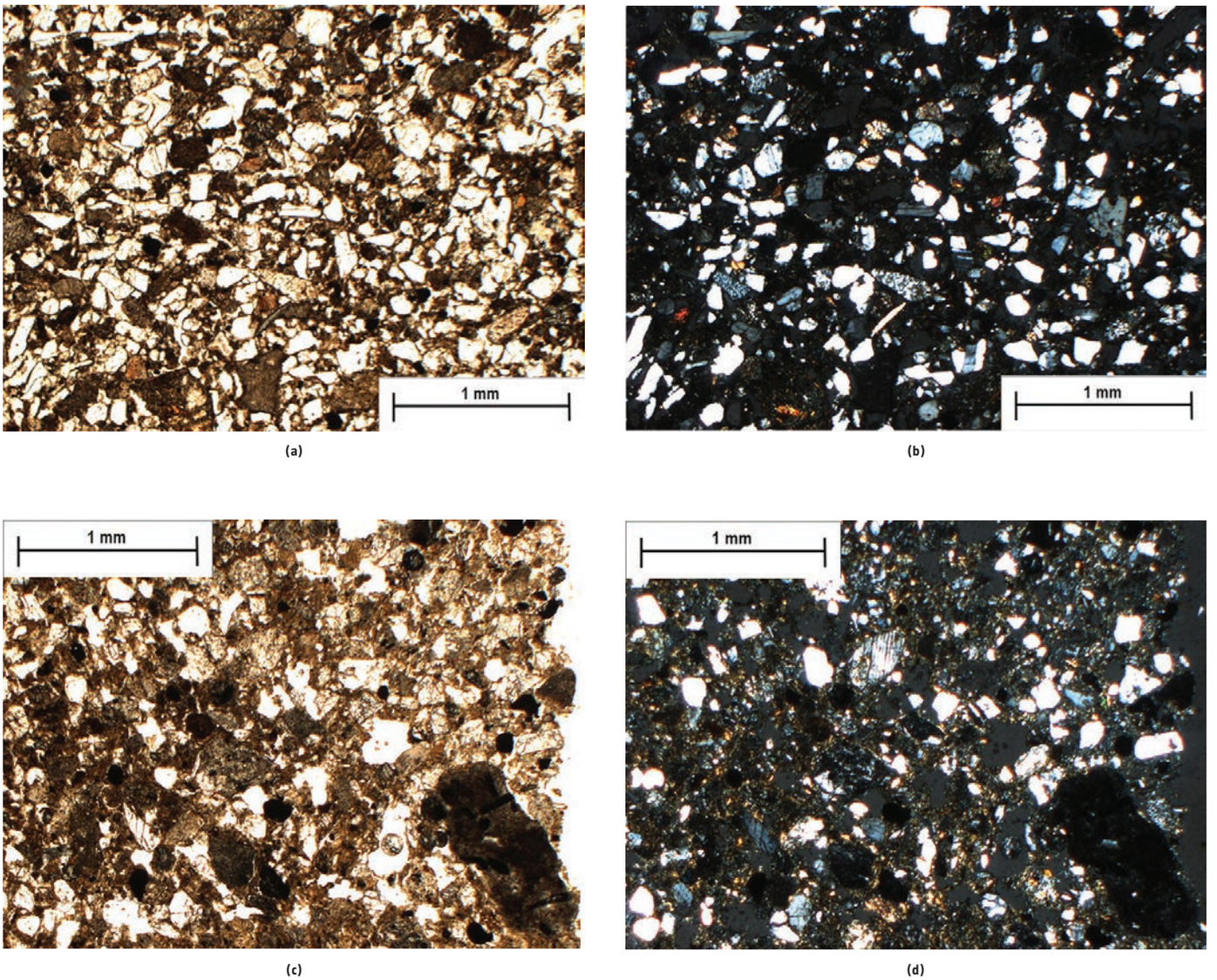


FIGURA 3 Diferencias entre las dos masas basales de los adobes. *Izquierda:* Adobe M1, muy arenoso ([a]: PPL, [b]: XPL). *Derecha:* Adobe M4, donde se observa más fracción fina ([c]: PPL, [d]: XPL). Microfotografías: M. Mateu, reproducción autorizada por el INAH.

casi sin arenas (Mateu y Daneels 2020). Por su parte, en La Joya todos los elementos tienen una granulometría similar de arenas: los constructores originales no quisieron añadir fracción más gruesa o quitaron aquellas más grandes (figs. 3 y 4).

En este punto también es importante mencionar la organización de la fracción fina. En algunas zonas encontramos una acumulación de fracción fina más oscura en formas de líneas o segmentos dentro de la masa. Aunque tales alineamientos se pueden encontrar de forma natural (Karkanas 2019), en el caso de muestras constructivas se infiere que se forman mientras la mezcla se encuentra húmeda (Friesem, Wattez y Onfray 2017; Piña 2021). A partir de la comparación con muestras experimentales, inferimos que indican fuerzas ejercidas en la elaboración y/o aplicación en húmedo de la materia prima (fig. 6).

Rasgos de elementos constructivos: Componentes añadidos

En materiales constructivos podemos encontrar, por un lado, los propiamente antrópicos (fragmentos de otras estructuras de

Cuadro 2 Comparación de las características micromorfológicas de los dos elementos constructivos estudiados: adobes y revoques

	Porosidad y microestructura	**Componentes minerales principales**	**Componentes antropológicos y orgánicos**	**Edaforrasgos**	**Grado de mezclado**	**Grado de humedad**	**Otros**
Adobe	Poca porosidad (máx. 20 %): vesículas, cavidades y poros de empaquetamiento (según los componentes y la bioturbación), poros de molde (CV). Microestructura masiva.	Granulometría bien clasificada, sin muchas diferencias de tamaño en la fracción gruesa. Entre un 25 y un 50 % de fracción gruesa (la mayoría, arenas entre finas y medianas). La fracción fina es limo-arcillosa. Normalmente, distribución relacional porfírica.	Algunos fragmentos de cerámica, fragmentos pequeños de carbón y/o hueso. Estos no son añadidos intencionalmente.	Dependerá de la masa basal y sus componentes, pero podemos encontrar: – alineaciones de material fino y agregados sedimentarios; – nódulos pequeños e impregnaciones de ox(hidr) Fe/Mn; – pápulas; – restos de bioturbación.	Regular con tendencia a bien mezclado. Aun encontramos: – agregados sedimentarios; – impregnaciones de ox(hidr) Fe/Mn; – alineaciones que proceden de las diferentes humedades del material.	Correcta. – Pocos poros vesiculares. – No muchas alineaciones.	A veces hay componentes vegetales añadidos y a veces no.
Revoque	Porosidad media (20–25 %): fisuras, vesículas (alguna cavidad). Según la masa CV. Microestructura masiva con tendencia a laminar (fisuras hacen aumentar la porosidad).	Granulometría bien clasificada, sin muchas diferencias de tamaño en la fracción gruesa. Entre un 25 y un 35 % de fracción gruesa (la mayoría, arenas finas y medianas). La fracción fina es limo-arcillosa. Normalmente, distribución relacional porfírica.	Normalmente, sin este tipo de componentes (puede que haya algún fragmento pequeño de hueso y/o carbón accidental).	Dependerá de la masa basal y sus componentes, pero podemos encontrar: – nódulos pequeños de ox(hidr) Fe/Mn; – pápulas; – restos de bioturbación.	Bien mezclado. No encontramos las evidencias anteriores (se han deshecho los agregados, impregnaciones, etc.) y es todo más homogéneo.	Correcta. Igual que los adobes.	Los componentes y la porosidad se orientan conforme a la fuerza aplicada. A veces hay componentes vegetales añadidos y a veces no. Se pueden distinguir capas superpuestas de aplicaciones secuenciales.

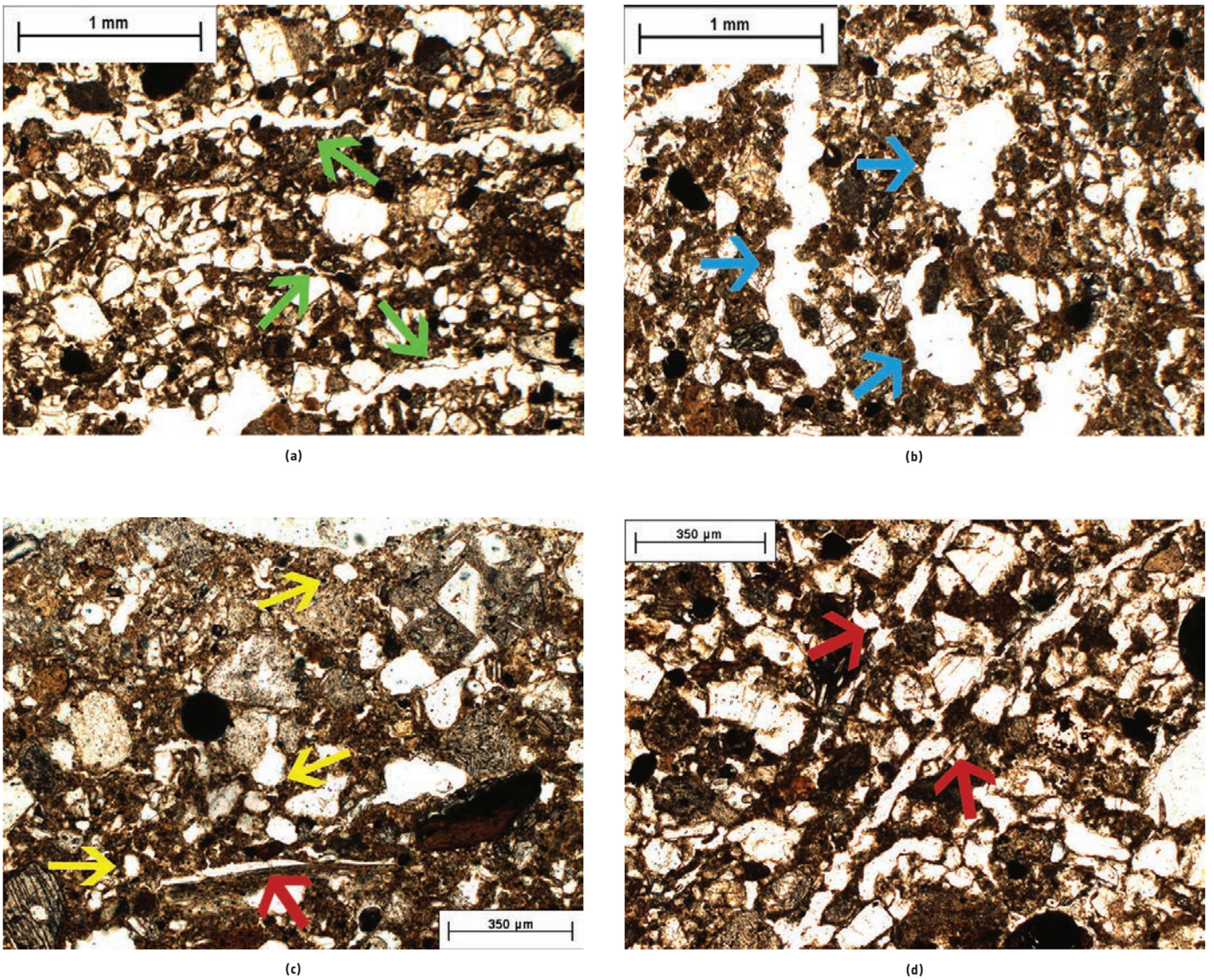


FIGURA 4 Tipos de porosidad. (a) Revoque M10 con los poros tipo fisuras horizontales y paralelos a la superficie (flechas verdes). (b) Adobe M4 con poros cavitarios alargados con tendencia a la verticalidad (flechas azules). (c) Poros de componentes vegetales (flecha roja) orientados paralelos a la parte exterior en adobe experimental en hoyo y poros vesiculares (flechas amarillas). (d) Poros de componentes vegetales en adobe M1. Todas las microfotografías en PPL. Microfotografías: M. Mateu, reproducción autorizada por el INAH.

tierra o de cerámica) y, por otro, los de origen biológico. Dentro de este último grupo podemos observar restos vegetales en forma de fitolitos (mineralización) o de carbón, y normalmente los encontramos como poros de molde (fig. 4d); también conchas, fragmentos de excrementos, etc. Para poder determinar si estos son añadidos intencionalmente o vienen con la materia prima, hay que valorar su frecuencia y distribución en la masa. Si los componentes son pequeños y esporádicos, es probable que se encontraran en la tierra o el lugar de preparación de la mezcla (figs. 7a y b).

Rasgos de elementos constructivos: Edaforrasgos

Los edaforrasgos se desarrollan por procesos edáficos naturales. Cada suelo, de acuerdo con las condiciones climáticas y de vegetación, desarrollará rasgos característicos. También pueden informar sobre procesos posdeposicionales después

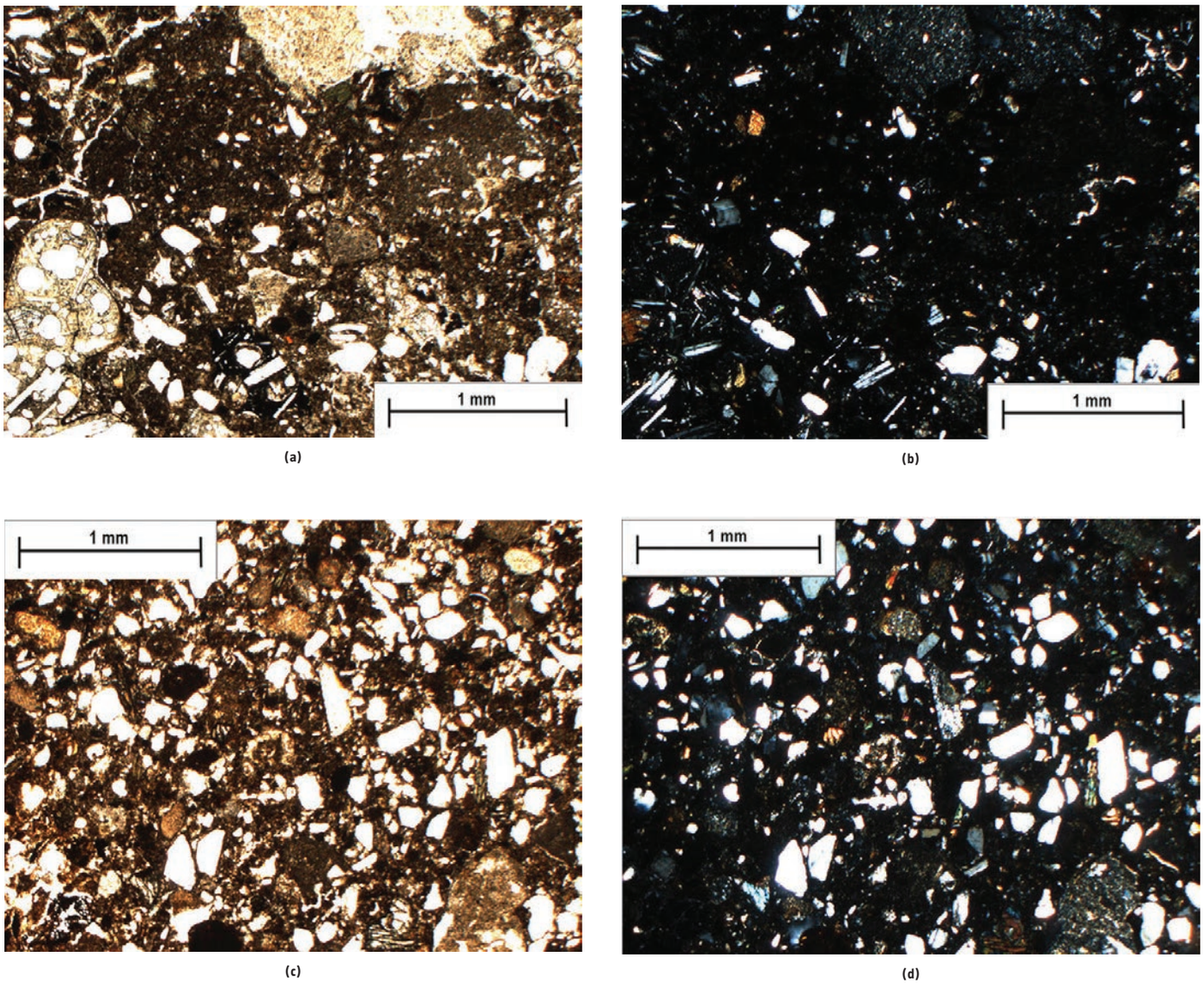
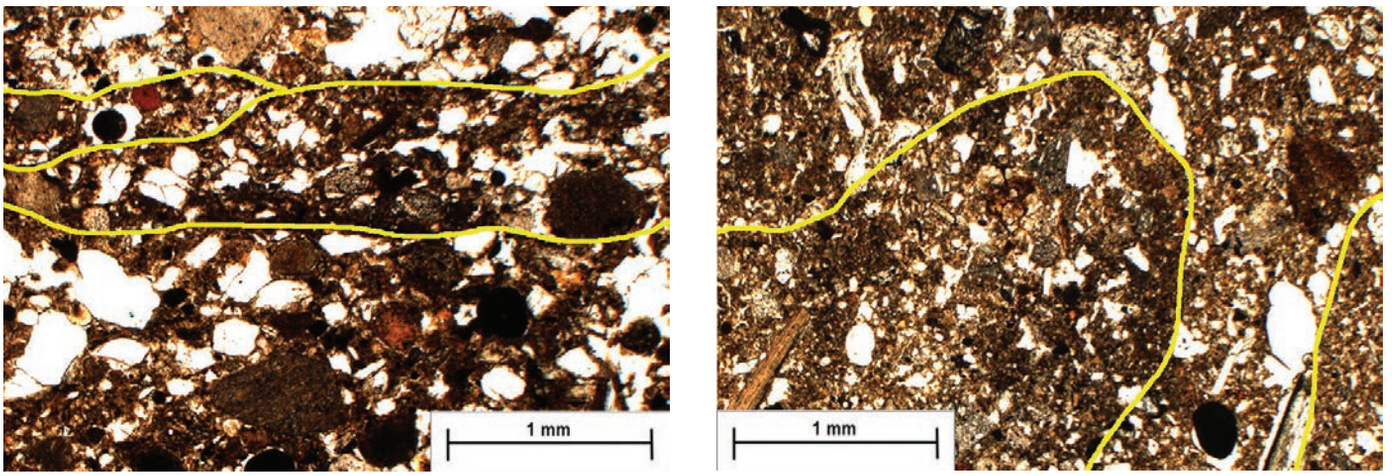


FIGURA 5 Muestras de Teotihuacan. *Izquierda*: Proyecto Plaza de las Columnas (D. Carballo). Piso donde se observan las gravillas y la matriz entre ellas ([a]: PPL, [b]: XPL). *Derecha*: Proyecto Tlajinga (D. Carballo). Adobe con una masa arenosa ([c]: PPL, [d]: XPL). Microfotografías: M. Mateu, reproducción autorizada por el INAH.

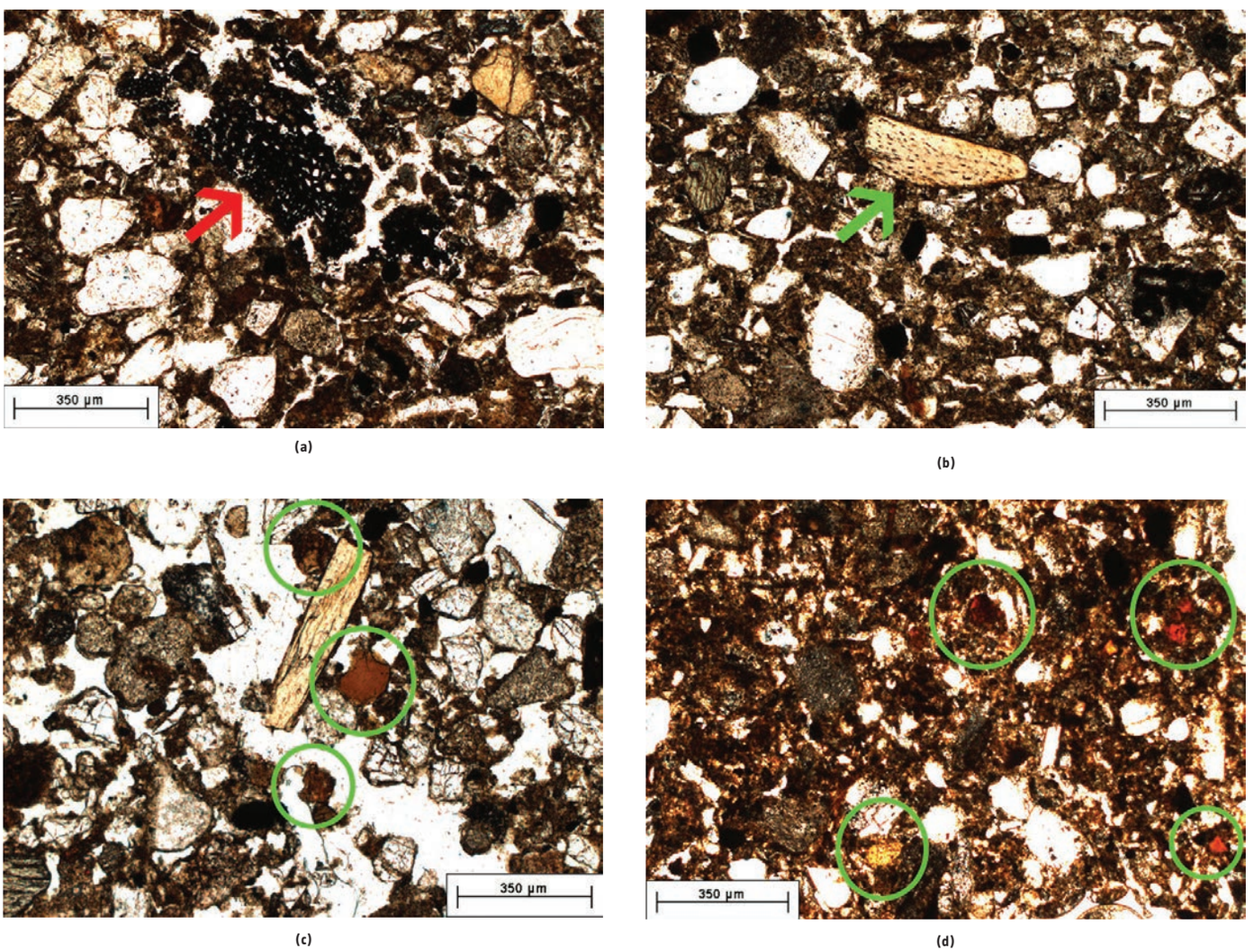
del abandono del sitio (ej. bioturbación, desagregación, etc.), que permiten estimar el grado de conservación o deterioro de distintos componentes de un edificio.

Los más relevantes son los cutanes (acumulaciones de arcillas en espacios porosos y fisuras, que se asientan conforme a procesos gravitacionales) y pápulas (cutanes fragmentados) (figs. 7c y d); estos se forman en suelos sub-superficiales con alto contenido de arcilla, que son los materiales de construcción más buscados (Piña y Cabadas 2018). Encontrar en una misma lámina cutanes o pápulas de distinto color y forma indicará que se mezclaron tierras de diferentes tipos de bancos de material, que se pueden identificar si hay, para comparación, láminas de suelos y paleosuelos del entorno del sitio. En casi todas las 100 muestras estudiadas, también hay agregados de sedimentos compuestos principalmente por una matriz limo-arcillosa (figs. 8a y b) como posible evidencia de la mezcla deliberada de dos o más suelos o sedimentos limosos (Piña y Cabadas 2018).



(a) (b)

FIGURA 6 Alineamientos de material más fino y oscuro en adobe M4 (a) y adobe experimental de molde (b) (señalados con línea amarilla sobrepuesta). Ambas en PPL. Microfotografías: M. Mateu, reproducción autorizada por el INAH.



(a) (b)

(c) (d)

FIGURA 7 *Izquierda:* Componentes de inclusión accidental: (a) Fragmento de carbón (flecha roja) en adobe M1; (b) Fragmento de hueso (flecha verde) en revoque M11. *Derecha:* Pápulas en adobe M1 (c) y adobe experimental de hoyo (d) (señalados con círculos verdes). Todas en PPL. Microfotografías: M. Mateu, reproducción autorizada por el INAH.

Los óxidos (hidróxidos) de hierro o manganeso, ox(hidr) Fe/Mn, en forma de nódulos o impregnaciones, se desarrollan normalmente por efecto de la lluvia o de la saturación de agua capilar. En todas las muestras aparecen nódulos pequeños y negros (ver Cuadro 1). En los adobes (fig. 8c y d), así como en un experimento que hicimos aplicando el Test Carazas, parece que las impregnaciones en agregados sedimentarios finos se asocian a materiales hechos con más agua (en las láminas que se hicieron del Test Carazas hay más en el estado plástico –posiciones P7, P8, P9– y el viscoso –posición P12– en el diagrama del test) (Piña *et al.* 2019).

Aspectos relacionados con la posterior conservación y restauración

El análisis micromorfológico ayuda a entender la composición y los procesos de manufactura, información de primera importancia para proponer una adecuada estrategia de preservación.

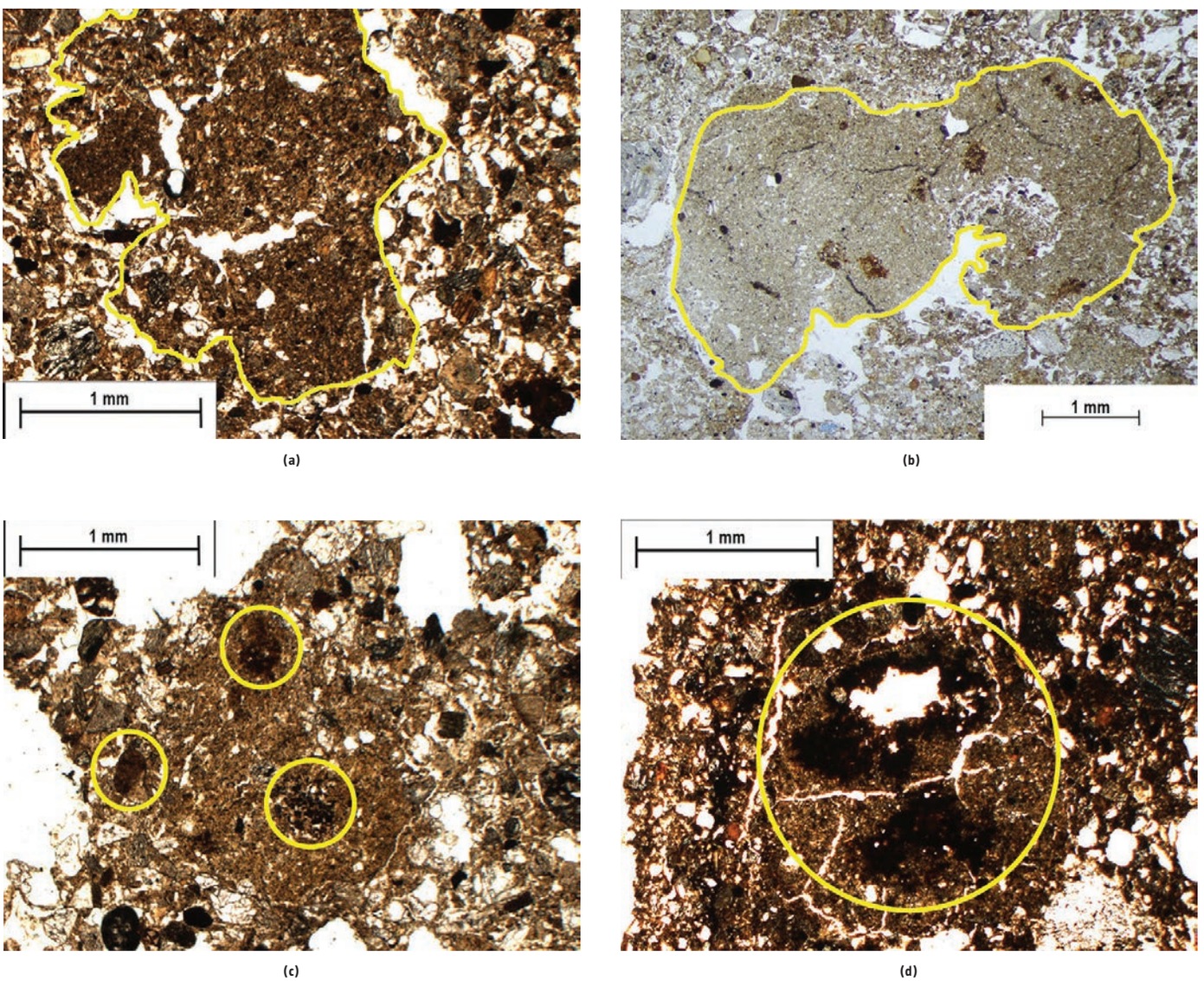


FIGURA 8 *Izquierda:* Agregados sedimentarios limo-arcillosos en adobe M4 (a) y en muestra constructiva del sitio arqueológico de La Blanca (Guatemala) (b) (el contorno marcado de color amarillo). *Derecha:* Impregnación de ox(hidr) Fe/Mn en agregados sedimentarios finos, en adobe M4 (c) (círculos amarillos) y adobe experimental en hoyo (d). Todas en PPL. Microfotografías: M. Mateu, reproducción autorizada por el INAH.

El estudio permite, además, observar a nivel microscópico los procesos de degradación mecánica (desagregación) por agua (fisuras, revestimientos de finos en poros, pérdida de material, etc.), biodeterioro por agentes como hongos, líquenes, algas, musgos, etc., o bien la presencia de sales solubles. En las muestras de La Joya, obtenidas a más de 1 m de profundidad bajo la superficie, no se presenta evidencia de deterioro, sólo un incipiente proceso de bioturbación (por raíces e insectos principalmente), que puede dañar la estructura a la larga. En el proyecto general se hallaron dos casos de estructuras realizadas con tierra amasada (*cob*), con una masa basal muy disgregada, pero que fueron encontradas a escasa profundidad estratigráfica; por ello, esta condición no se deberá tanto a la técnica como a la bioturbación.

Conclusiones

Con este breve trabajo, se quiso mostrar que la micromorfología proporciona información que no dan los demás estudios más usuales en materiales constructivos de tierra: ayuda a identificar los bancos de material y el proceso de elaboración de los diferentes elementos constructivos (ver Cuadro 2), y hasta sus técnicas de construcción. En este caso, la manufactura de los adobes fue similar en La Joya y Teotihuacan, pero la preparación de los revoques, muy distinta, refleja pautas culturales diferentes. También apoya un diagnóstico fino del grado de conservación de las estructuras. Tales informaciones son importantes para una correcta conservación y/o restauración, cuando sea necesario. De este modo, la micromorfología no sólo ayuda a entender a las sociedades del pasado que erigieron la arquitectura, su lógica de selección y preparación de materiales, las etapas sucesivas de manufactura, así como la organización social que fue requerida para su construcción, sino que contribuye al desarrollo de estrategias actuales para poder preservar este patrimonio.

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Archaeological Conservation between Excavation and Fruition: The Case of Tell Mozan, Ancient Urkesh

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Abstract: *Conservation is at the intersection of archaeology-as-excavation and archaeology-as-fruition. We have seen this at work in an extraordinary way at Tell Mozan in northeastern Syria, where war has now raged for over twelve years. Mozan is the site of ancient Urkesh, one of the very earliest cities in history. Situated in northern Syro-Mesopotamia, it has extensive mud brick architecture in both private dwellings and public buildings. From the start of the excavation, we set in place an effective protective system consisting of localized shelters that closely mirror structures' faces and the top of walls, helping to reproduce architectural volume while protecting the ancient document. Other conservation strategies in our area, such as capping and reconstruction, fell short of these two goals. The modesty of our approach has proven to be its strength: our dependence on only local resources (materials and skills) and the simplicity of the procedures have made it possible for our conservation project to continue uninterrupted throughout the ongoing war. We see conservation as publication: we make available the documents for scholars to see, exposed in their pristine conditions. Beyond scholars, and this is the second part of our paper, there is fruition at the level of the broader public. Once conserved, the site is transparent to visitors' perception, even for those least prepared for its message. Conservation offers a construct that can elicit fruition at its best. Throughout the war, Mozan has become a model of how conservation can serve not only to protect the material remains of a distant past but also to protect and foster the spirit of social cohesion and shared identity among people who find a reason for survival in this distant past.*

Resumen: *La conservación se encuentra en la intersección entre la arqueología como excavación y la arqueología como fruto. Hemos visto esto en funcionamiento de una manera extraordinaria en Tell Mozan, en el noreste de Siria, donde la guerra ha durado más de diez años. Mozan es el sitio de la antigua Urkesh, una de las ciudades más antiguas de la historia. Situado en el norte de Syro-Mesopotamia, tiene una extensa arquitectura de adobe en viviendas privadas y edificios públicos. Desde el mismo inicio de la excavación se instaló un eficaz sistema de protección, consistente en refugios localizados que se adhieren a los paramentos y a la parte superior de los muros, reproduciendo así los volúmenes arquitectónicos y protegiendo el documento antiguo. Otras estrategias de conservación en nuestra área (taponamiento y reconstrucción) no alcanzan estos dos objetivos. Además, la modestia de nuestro enfoque ha demostrado ser su fortaleza: nuestra dependencia total de los recursos locales (materiales y habilidades) y la simplicidad de los procedimientos, han hecho posible que nuestro proyecto de conservación continúe ininterrumpidamente durante la guerra en curso. Vemos la conservación como una publicación: ponemos a disposición el documento tal como se expone para que los académicos lo vean en su estado original. Más allá de los eruditos, y esta es la segunda parte de nuestro artículo, hay frutos a nivel del público en general. Una vez conservado, el sitio se abre de forma transparente a la percepción de los visitantes, incluso de los menos preparados para su mensaje. La conservación ofrece una construcción que puede producir frutos en su mejor momento. A lo largo de la guerra, Mozan se ha convertido en un modelo de cómo la conservación puede servir no solo para proteger los restos materiales antiguos, sino también para proteger y fomentar el espíritu de cohesión social e identidad compartida entre las personas que encuentran en este pasado lejano, una razón para sobrevivir.*

Keywords: mud brick conservation, archaeological conservation, site presentation, Urkesh, Syria, public archaeology, community archaeology

Introduction

Tell Mozan, in northeastern Syria, has been the object of a long-term archaeological project. Since the beginning of our work at the site in 1984, we have committed to a conservation program that has proven successful in three major ways: (1) it has effectively preserved the site's mud brick walls, proving to be eminently sustainable during twelve years of war; (2) it has shown how conservation can be seen as a form of publication; and (3) it has become the focus of an intense local community engagement. We will take up these three points in turn.

The Tell (130 ha) is the site of ancient Urkesh, one of the first cities in history, whose origin dates back to around 4000 BCE. It was an important religious center for the Hurrians, an elusive population of ancient Syro-Mesopotamia, and it achieved political importance in the third millennium. Around 2300 BCE a king named Tupkish built a palace that is the object of the conservation project we are illustrating here. In the second millennium the settlement was reduced to the role of a minor religious sanctuary, and it was abandoned around 1200 BCE. Excavations were interrupted in 2011 because of the start of the war in Syria, yet we have continued to be fully active at the site in every respect other than excavations.

Conservation as Practice: Sustainability

The technical aspects of the conservation system have been described elsewhere[1] and are briefly summarized here. Each wall is protected from the very moment of excavation (fig. 1) with a localized shelter that consists of three components. (1) An iron trellis closely follows the contours of the wall without touching it, and intrudes minimally into the floor (fig. 2). The trellis protects the original wall, reproducing it to a higher level than is present in the current archaeological record and rendering more closely a sense of the original volume. (2) The sides are covered by curtain-like burlap panels (figs. 3, 4) that can be drawn open (figs. 5, 6) to show the wall as excavated (this is the document that remains visible in its pristine status). The panels have proven an ideal protection for the walls from rain, heat, and wind, which can all be quite severe at Mozan. The fabric allows the walls to breathe and natural water absorption and drying processes to still take place.



FIGURE 2 Urkesh (Tell Mozan), Palace AP; iron trellis over walls. Photo: © IIMAS.



FIGURE 1 Urkesh (Tell Mozan), Palace AP; mud brick walls as excavated. Photo: © IIMAS.



FIGURE 3 Urkesh (Tell Mozan), Palace AP; covers on walls (stage 1). Photo: © IIMAS.



FIGURE 4 Urkesh (Tell Mozan), Palace AP; covers on walls, with colors matching different functional areas of the palace (stage 2). Photo: © IIMAS.



FIGURE 5 Urkesh (Tell Mozan), Palace AP; detail in room D1 (curtains closed). Photo: © IIMAS.

(3) The top is covered by a metal sheet that in turn is covered by mud and straw. This protects the walls from snow, another local weather factor that presents a major danger and in some years can be quite considerable.

We developed the system through a series of steps that allowed us to test various alternatives, working primarily from a commonsense approach and in close consultation with experts from both the Opificio delle Pietre Dure in Florence and the Getty Conservation Institute (GCI). Neville Agnew



FIGURE 6 Urkesh (Tell Mozan), Palace AP; detail in room D1 (curtains open). Photo: © IIMAS.

and Martha Demas from GCI, came to inspect the system thoroughly and advised us on a number of issues, two of which resulted in a long-standing publication project that we will describe in the next section.

One of the suggestions from Agnew and Demas was to use a material that was more durable than burlap and could be imported from the United States. We did purchase the material, but it turned out that sanctions prevented us from shipping it to Syria (!). This was actually a blessing in disguise: by relying entirely on local material, it was possible for us to have no interruption in the maintenance of the system during the twelve long years of war. So, in order to make the panels stronger, we reduced the panels' size and sewed heavy ribbons along the edges, giving them more stability. Also, local staff were able to repair the burlap when damage occurred using simple patching and mending techniques that served our purposes well, if at the expense of aesthetics. Put to the test by the war, sustainability has thus proven to be a great strength of our system: our total reliance on local resources (materials and skills) has made it possible for the system to remain fully functional in spite of our forced physical absence from the site.

Conservation as Publication: Document and Monument

Excavation frees culture from the grip of the earth, serving as the converse of the depositional process by which things came

to be interred. We cannot conserve a process, be it deposition or excavation, but we can and must conserve the result of that process, i.e., the emplacement of what has been deposited as it has been found. If documenting this endeavor is the archaeologist's first aim, publishing it is a concomitant goal and duty. Thus, the case can also be made that conservation is publication, for what better way to publish than to make available the document, as exposed, for scholars to see in its pristine condition?

The Urkesh model eloquently shows how this is possible, i.e., how conservation truly *is* publication, in four distinct ways. First, conservation makes it possible to have an autoptic view of the document, in our case the walls as originally excavated and as seen today when the curtains are drawn open (see fig. 6). This renders a visit to the site worthwhile for the scholar in ways that no traditional publication can serve, providing information on two levels: there are details that cannot be rendered in a photograph, and the sense of how each wall fits into its context cannot be matched by even the most thorough walk-through video. Second, we have set in place a signage system that illustrates features, with comments that go into very specific detail. We call this project *The Site as a Book*. It contains an approximate total of some 200 pages as well as clearly identified technical comments on small reading stands that we call footnotes. A casual visitor can, therefore, decide which level of detail is of interest at each sign. This signage is also implemented through a modest, but effective, approach: simple printed and laminated pages can easily be maintained and updated when new information becomes available. Third, following a suggestion by Agnew and Demas, we systematically documented the walls in two ways: with yearly photos of both faces of each wall and by taking a daily record of temperature and humidity readings adjacent to one of the walls. We thus have an unequaled record that, by now, covers twenty-two years—both photos and readings being available on our website (urkesh.org/wall-cons). We also published a critical review accompanied by a drawing of each wall that is available on our website. This was done in the last year of our physical presence at the site (2010) and a second review was just finished in winter 2022. Fourth, the Urkesh model combines the goals of conservation with those of restoration and even reconstruction, but in such a way that the monument does not impact the document.

We may say that we have two sites in one: that of the conserved walls and that of the architectural volumes. In fact, besides walls, we have also conserved important excavation sections in order to give the scholar a view of the critical layering on which our depositional inferences rest, as well as to give the casual visitor insights into technical details that are of critical importance for explaining what archaeology really does.

Conservation as Fruition: The Social Impact

We have seen that, while the localized shelters provide effective defenses against the weather and preserve the walls as document, the projection of architectural volumes approximates the aesthetic and perceptual impact of the ancient building, providing a sense of the walls as monuments. Seen from a vantage point above the palace, the building can be viewed spatially—a view the ancients never had, but one that gives the viewer an insight into the structural complexity of the building (fig. 7). This, too, should be the concern of the archaeologists, not just of experts in popularization. It is an important point: we want to convey, *qua* archaeologists, a sensitivity for the material remains that we have developed in ways an interpreter cannot faithfully reproduce. We are the native speakers, as it were, and it is as such that we must communicate with the broader public. Otherwise, the extrinsic nature of the preservation ultimately betrays the original. This can only be avoided if the fruition offered is the fruition felt.

Our project, through a number of initiatives, has maintained an exceptionally sustained degree of interest throughout the war. This is not the place to describe those efforts in detail, but they are worth briefly mentioning. They include an intense program of local visits by schools and families (fig. 8), the organization of lectures in villages in the area,



FIGURE 7 Panoramic view of palace. Photo: © IIMAS.



FIGURE 8 Urkesh (Tell Mozan), Temple BA: visitors on staircase (2016). Photo: © IIMAS.

the long-distance twinning between middle schools near Tell Mozan and those in Italy, Greece, and the US (future plans include adding schools in China and Gaza), the organization of exhibits in various parts of Syria and abroad, and the publication of additional educational materials for stakeholders and visitors. The point to be made here is that these projects are only possible because of the upstream conservation efforts. More often than not, a Mesopotamian archaeological site appears as a crater with ill-shapen stubs of mud brick architecture, when any is visible at all. How could such a desolate landscape attract any attention? Conservation must be at the core also in this regard.

The tragic travail of the war has shed unexpected light on our project. We have been present in terms of guidance and support during the twelve years of our forced absence from the site. What we developed, through the conservation methods we have presented here, was a cultural infrastructure that provided the basis for a degree of social awareness otherwise difficult to imagine. Cultural heritage can only live through its inheritors and, in our case, it is this monument of an ancient city that is dead and yet alive. Only conservation can bring about what we can truly call a miracle—the miracle of a broken tradition being reinserted in the identity of a community alive today. Our conservation effort could continue throughout this difficult period because it was so structured in purely local human and natural resources. Thus it is that Mozan has become a model of how the intersection of the two archaeologies—excavation and conservation—can serve not only to protect the material remains of a distant past but also to protect and foster the spirit of social cohesion and shared identity of communities who find their roots in this distant past and, therein, a reason for their survival.

Note

1 We refer readers to a full list of our publications, available in the E-Library on the Urkesh website: urkesh.org/eL-cons.

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PART 5

Care by and for Communities / Cuidado por y para las comunidades

The Past and Future of Adobe Heritage at Ohkay Owingeh

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Abstract: *The Pueblo tribes of the American Southwest maintain the oldest traditions of architecture in the United States. Many villages have been in their current locations since time immemorial, with several known to have been occupied for more than 1000 years. The adobe homes have undergone countless cycles of growth, contraction, and alteration. Adobe maintenance was woven into tribal traditions, and the homes were understood to be of the living earth. When a structure outlived its usefulness, it was returned to the earth and built anew. Over the last half century, US Department of Housing and Urban Development (HUD) housing initiatives and the use of portland cement have significantly increased the abandonment and deterioration of the villages. Advances in self-determination policy have recently enabled the Pueblos to develop plans to renew their villages according to their own unique heritage values. Some Pueblos are renowned for resistance to change, while others view preservation with great skepticism. This paper explores the origins, implementation, and reception of a preservation project at Ohkay Owingeh in New Mexico. The ongoing effort began in 2005 with a grant to train tribal youth and has resulted in the completion of forty-five home rehabilitations and the reintroduction of earthen plasters in the traditional village of Owe'neh Bupingeh. Using the concepts of* traditional cultural place *and* intangible heritage*, the tribe negotiated a Section 106 review that challenged the Secretary of the Interior's Standards and Guidelines for foundational concepts of authenticity and materiality. This effort demonstrates that vernacular authenticity extends beyond historic materials, that change can be accommodated, and that integrity lies in the relationship between community life and place.*

Resumen: *Las tribus Pueblo del suroeste de Estados Unidos mantienen las tradiciones arquitectónicas más antiguas del país. Muchas aldeas han estado en sus ubicaciones actuales desde tiempos inmemoriales, y se sabe que varias han estado ocupadas durante más de 1000 años. Las casas de adobe han sufrido innumerables ciclos de crecimiento, contracción y alteración. El mantenimiento del adobe estaba integrado a las tradiciones tribales, y se entendía que las casas eran de la tierra viviente. Cuando una estructura sobrevivía a su utilidad, era devuelta a la tierra y construida de nuevo. Durante el último medio siglo, los programas del Departamento de Vivienda y Desarrollo Urbano de EE.UU. (HUD) y el cemento portland han aumentado significativamente el abandono y el deterioro de las aldeas. Los avances en la política de autodeterminación han permitido recientemente a los Pueblo desarrollar planes para renovar sus aldeas de acuerdo con sus propios y únicos valores patrimoniales. Algunos pueblos son reconocidos por su resistencia al cambio, mientras que otros ven la preservación con gran escepticismo. Este artículo explora los orígenes, la implementación y la recepción de un proyecto de preservación en Ohkay Owingeh. El esfuerzo en curso comenzó en 2005 con una subvención para capacitar a jóvenes tribales y ha obtenido como resultado la ejecución de 45 rehabilitaciones de hogares y la reintroducción de enlucidos de tierra en la aldea tradicional de Owe'neh Bupingeh. Utilizando los conceptos de* lugar cultural tradicional *y* patrimonio inmaterial*, la tribu negoció una revisión de la Sección 106 que desafió los conceptos fundamentales de autenticidad y materialidad de las Normas del Secretario del Interior de los Estados Unidos. Este esfuerzo demuestra que la autenticidad vernácula se extiende más allá de los materiales históricos, que el cambio puede ser adaptado y que la integridad radica en la relación entre la vida comunitaria y el lugar.*

Keywords: Pueblo, Native American, adobe, intangible, traditional cultural place, authenticity, values, change, sovereignty, self-determination

Ohkay Owingeh is one of nineteen Native American Pueblos in New Mexico. Our people have called this area home since time immemorial. "The Place of the Strong People" (the meaning of our Tewa name) is located at the confluence of the Rio Chama and Rio Grande, forty-five minutes north of Santa Fe. Owe'neh Bupingeh is the Tewa name for the central plaza area, where people have been living for more than 700 years. *Bupingeh* translates roughly to "middle heart place" and is the term used by the Tewa-speaking Pueblos for their main plazas. At Ohkay Owingeh, the area comprises four plazas where sacred ceremonies occur. There were once well over 150 adobe homes on our plazas. Many of these homes have returned to the earth and others were combined into larger homes. By 2005, when we began this effort, less than sixty homes remained and fewer than half were occupied. Buildings were deteriorating quickly and a spider's web of power lines crisscrossed the sky over our ancient sacred place. The conditions of the homes ranged from a few fully modernized buildings to abandoned, collapsing structures that had not been homes for over fifty years (fig. 1). Many of the homes were only used during cultural celebrations and no longer held daily life.

There is a profound need for investment in the traditional villages of the Pueblo tribes, which together contain more than 3000 homes. Their deterioration is the result of a combination of inappropriate cement plasters used as exterior coatings on the traditional adobe buildings as well as new forms of housing introduced by the US Department of Housing and Urban Development (HUD) that ignored cultural and tectonic traditions, settlement patterns, and fluctuations in climate. These changes resulted in the slow degradation and partial abandonment of the villages. Poor-quality housing, significant



FIGURE 1 Homes photographed in 2005, showing a considerable range of conditions. Photos: ©Atkin Olshin Schade Architects.

overcrowding, and inadequate federal funding make explorations of new preservation models an urgent priority among all the Pueblos. The ongoing Owe'neh Bupingeh Project at Ohkay Owingeh has demonstrated one possible path for a self-determined approach to balancing architectural preservation, community needs, and cultural practices. We recognize that all traditional communities have their own unique understanding of time, space, and place. Each community deserves the opportunity to chart their own course in line with their cultural values.

When we began seventeen years ago, there were few regional models for developing a self-determined preservation plan for a living Pueblo. The Ohkay Owingeh Housing Authority began collaborating with Atkin Olshin Schade (AOS) Architects of Santa Fe in 2005 to begin understanding the physical conditions of the buildings in the village and to develop a strategy to improve them. We started with small grants from the New Mexico State Historic Preservation Office (SHPO), the National Trust for Historic Preservation, the Chamiza Foundation, and the McCune Foundation. We established a summer youth academy that employed tribal high school students who assisted the project for five summers. They learned the basics of preservation practice and surveying and generated the first accurate maps of the village in decades (fig. 2). They went home each night excited by our heritage and by the future that this project would hopefully bring. Middle-aged tribal members engaged tribal elders in oral history, and together we learned what life was like in the village prior to the government-constructed subdivisions that were deteriorating traditional life. Our first grant from the SHPO was $7,500. We have now leveraged that into more than $13 million.

The intergenerational community engagement employed in this project set out to determine a preservation approach that was first and foremost grounded in our cultural values. Through these discussions we determined that the preservation of our vernacular heritage demanded an approach that accepted the need for change rather than a focus on historical appearances. Our people determined that the primary goal of the project would be to balance preservation of the buildings and plazas with functional renovations of the homes, permitting contemporary life and cultural tradition to comfortably coexist. Preserving the buildings would not be enough—restoring daily life, laughter, and love to these spaces was more important. We hoped that these were not mutually exclusive and sought a way to do both.

One of the most important early planning efforts we made was working with tribal elders to define the extents of the traditional area. The village had been designated a historic district on the National Register of Historic Places in 1973, with a boundary that included the majority of buildings around the plazas, but failed to acknowledge the traditional-use area defined by life and seasonal observances. Looking over the new map produced by tribal youth, Herman Agoyo, a revered cultural leader, sketched out a new district bounded



FIGURE 2 Map of Owe'neh Bupingeh illustrating the level of use in 2010. Map: ©Atkin Olshin Schade Architects.



FIGURE 3 "View of San Juan Pueblo and North Plaza." Photo: John K. Hillers, 1877, © National Anthropological Archives, Smithsonian Institution (NAA INV 06344100).

on the east by the tribal cemetery, on the west by the traditional acequia (a constructed drainage ditch that continues to irrigate the nearby agricultural fields), and on the north and south by steep topographic change. Using the surveys made by the tribal youth and the new district boundary, we began mapping various qualities of the village, proving the anticipated correlation that a home that is fully used for daily life will be better maintained.

Through a grant from the National Park Service Tribal Preservation Program, we found over 400 historic images of the plaza area in twenty-two repositories, and we were able to identify the specific vantage points for over 100 of them. Many of these photos were taken by anthropologists who sought to document our culture without our permission. Some of the images depict activities that are not to be shared with outsiders. These images remain painful, but the process reappropriated these stolen views for the betterment of our community. These photos revealed a physical heritage that was organic and ever changing. The images enriched the community conversations but, interestingly, they steered the community away from a precise restoration to any particular period of time. The community recognized that the true significance of these photos was the depiction of intangible traditional life more so than precise configuration and components of tangible buildings. Nevertheless, the community used the images to identify the physical elements of construction that remain integral to this place, as well as the elements of a physical past that no longer resonate with who we are today.

We established a photographic record of each home in the village in order to understand its evolution as best we could without being restricted by it. Prior to the 1960s, the homes were intergenerational and rooms were multifunctional. Homes were not subdivided into places for living, eating, and sleeping, and there was no internal privacy. Since that period, lifestyle and domestic expectations have shifted profoundly. We realized that in order to meet our higher charge of restoring daily life, we would have to accept physical change in order to accommodate new functional uses, spatial expectations, and infrastructural demands. The interiors would need to be adjusted and the homes would need to be expanded. We determined that we needed a rehabilitation approach that would honor and respect both the past and the future.

The oldest photograph of Owe'neh Bupingeh was taken by John K. Hillers in 1877 (fig. 3). This image shows Owe'neh Bupingeh in tremendous transition. Ladders remain on many of the homes that do not have doors. Occupants scaled the ladders and descended into the home through a roof hatch. However, this oldest image also shows that many of the families had done away with the ladders and installed doors at the first floors. We reviewed these images with the community with great humility, as we knew that this place existed at least 550 years before the advent of photography. The architects asked cultural leaders if this oldest image represented "the period of significance," a time period that might guide an authentic restoration. They chuckled and said, "No, the period of significance is tomorrow." This is a profound disconnect with standard preservation practice, which is guided here in the US by the Secretary of the Interior's Standards. Our federal standards distinguish between four approaches: preservation (extending the life of what remains), rehabilitation (modernizing usage), and restoration and reconstruction, which are both about returning the appearance of a historic place back to a specific moment in time. In Pueblo culture, the homes are living members of the family. These beings live and breathe and are meant to return to the earth, just like us. The historical photos show many buildings declining with age and others in states of collapse and reconstruction. The walls are rebuilt in the same settlement pattern and often with the very same adobe and vigas. The western modality of preservation grounded in the pre-eminence of original material and limiting change is antithetical to our understanding of the natural order.

Because the construction efforts would be largely federally funded, the project would require approval of the SHPO,

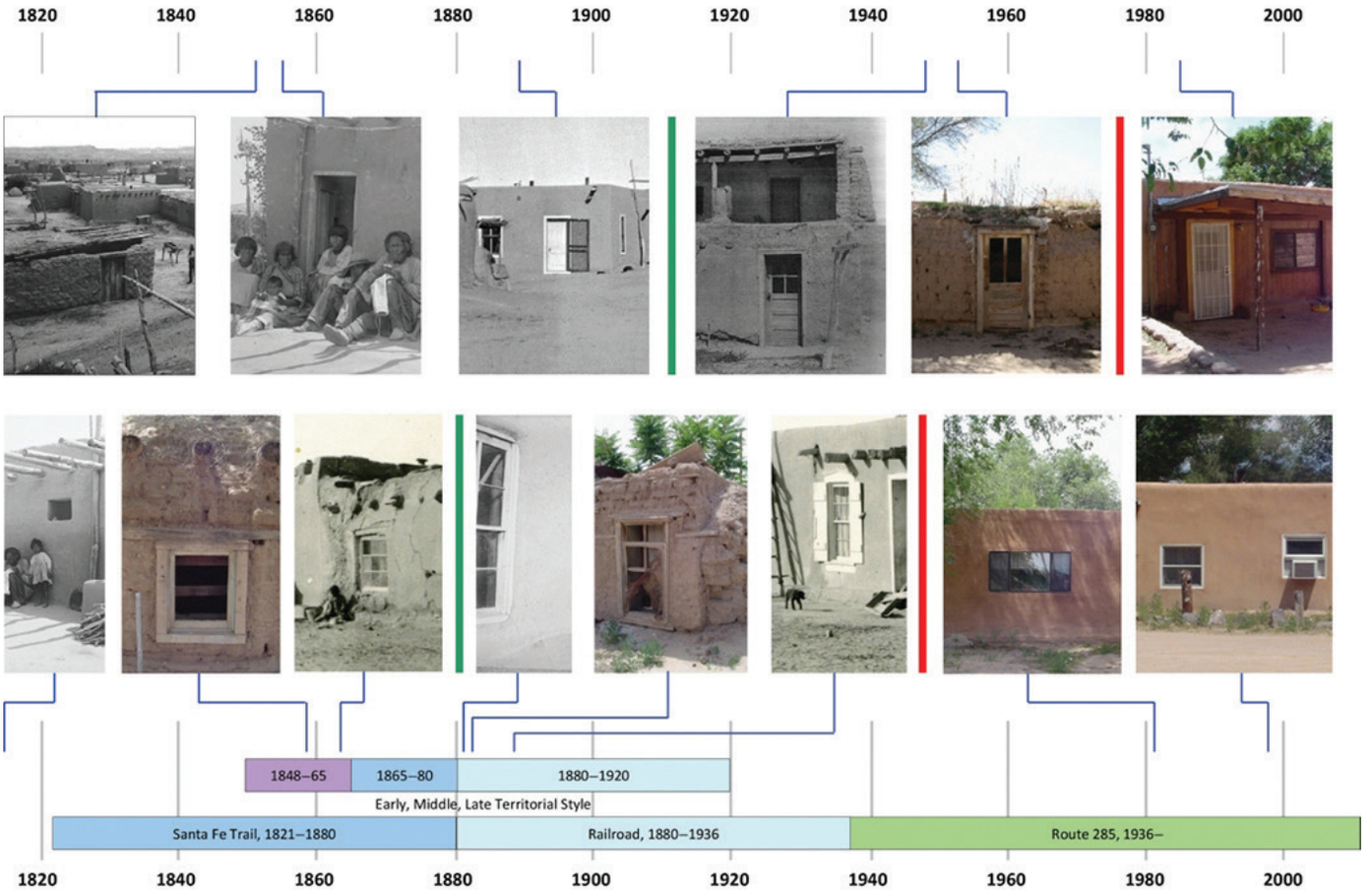


FIGURE 4 Evolution of windows and doors at Owe'neh Bupingeh. Photo collage: © Atkin Olshin Schade Architects.

for Ohkay Owingeh had not (and still has not) established a Tribal Historic Preservation Office (THPO). We knew our preservation approach would need to be comparable to one of the preservation approaches of the Secretary's standards. Through continued community conversations, AOS Architects facilitated the development of a preservation approach grounded in the values of this community and place. As part of the Section 106 process, we reviewed each standard for the four approaches to understand how these fit with the cultural values of this community. We found strong and moderate conflicts in each of the four approaches and a number of standards that were unobjectionable, but we advocated that the foundation of the preservation principles needed to originate in our culture (table 1). Our self-determined preservation principles aim to reinvigorate the physical core, reinforcing the village as both the spiritual center of the community and the center of daily life once again. Our principles reach into each of the Secretary's standards rather than just one, but the principles were carefully phrased and framed without preservation jargon. We were determined to keep what we could, make our homes livable, make it look like our place (not a generic Pueblo), and conserve our culture.

Federal funding brought many strings and complications. We successfully convinced our partners—HUD, SHPO, and the New Mexico Mortgage Finance Authority—that if we strictly followed the standards and policies of each state and federal agency, the project would not be possible without violating our cultural values. Flexibility was required. We all committed to the larger goal of returning life to this place. A programmatic agreement between the tribe and these agencies affirmed the necessity for local cultural values to be given the utmost priority. We utilized the framework of "traditional cultural place" to prioritize the perpetuation of the intangible over the preservation of the tangible.

Table 1 Development of a Preservation Approach for Ohkay Owingeh

PRESERVATION	REHABILITATION	RESTORATION	RECONSTRUCTION
1 **Appropriate Use** Use as was used, or use to maximize physical retention.	1 **Appropriate Use** Use as was used, or use to maximize physical retention.	1 **Appropriate Use** Use as was used, or use as per restoration period.	1 **Accuracy and Need** Reconstruct only where documentation minimizes conjecture and where essential to public understanding of property.
2 **Retain Character** Replacement will be avoided.	2 **Retain Character** Removal will be avoided.	2 **Retain Character** Removal of features from the restoration period will be avoided.	3 **Preserve What Remains** Preserve remaining historic materials, features, and spatial relationships.
3 **Record of Its Time** Conservation will be compatible and identifiable.	3 **Record of Its Time** False sense of historic development will be avoided, such as adding conjectural features or elements from other historic properties.	3 **Record of Its Time** Conservation of materials and features from the restoration period will be compatible and identifiable.	5 **Identification** Reconstruction will be clearly identified as a contemporary re-creation.
4 **Historic Changes** Historic changes will be retained and preserved.	4 **Historic Changes** Historic changes will be retained and preserved.	4 **Historic Changes** Materials, features, spaces, and finishes that characterize other historical periods will be documented prior to removal.	
5 **Distinct Craftsmanship** Preserve materials, features, finishes, and construction techniques.	5 **Distinct Craftsmanship** Preserve materials, features, finishes, and construction techniques.	5 **Distinct Craftsmanship** Preserve materials, features, finishes, and construction techniques.	4 **Reconstruct Craftsmanship** Duplicate materials, design, color, and texture.
6 **Minimize Replacement** Existing conditions will determine appropriate intervention. Where replacement is required, new material will match composition, design, color, and texture. Replacement requires documentary evidence.	6 **Repair or Replace?** Deterioration will be repaired rather than replaced. Where replacement is required, new material will match composition, design, color, and texture. Replacement requires documentary evidence.	6 **Replace from Restoration Period** Deterioration of features from restoration period will be repaired rather than replaced. Where replacement is required, new materials will match composition, design, color, and texture. Replacement requires documentary evidence.	
		7 **Substantiation of Replacement** Replacement of missing features from restoration period will be substantiated.	
7 **Gentle Treatment** Chemical or physical treatments, if used, will be as gentle as possible.	7 **Gentle Treatment** Chemical or physical treatments, if used, will be as gentle as possible.	8 **Gentle Treatment** Chemical or physical treatments, if used, will be as gentle as possible.	
8 **Protect Archaeology** Protect and preserve in place. Mitigate if required.	8 **Protect Archaeology** Protect and preserve in place. Mitigate if required.	9 **Protect Archaeology** Protect and preserve in place. Mitigate if required.	2 **Archaeological Investigation** Reconstruct following thorough archaeological investigation. Mitigate resources if disturbed.
	9 **Differentiation and Compatibility** New construction shall be differentiated from the old and compatible with historic materials, features, size, scale, and proportion.	10 **False History** Designs that were never executed historically will not be constructed.	6 **False History** Designs that were never executed historically will not be constructed.
	10 **Reversibility** New construction should be removable without impacting essential form and integrity.		

LEGEND

No conflict between treatment standard and Ohkay Owingeh cultural values

Moderate conflict

Strong conflict



FIGURE 5 Participants in a community mud plastering workshop. Photo: ©Tania Hammidi.



FIGURE 6 Tony Marquez of Avanyu General Contracting working on an adobe home under construction at Ohkay Owingeh. Photo: ©Minesh Bacrania Photography for *Preservation Magazine*.

The preservation plan explores the history of various building components: massing, roofs, drainage *canales* (scuppers), timber vigas, adobe walls, parapets, doors and windows, interior floors and ceilings, and landscape elements. Through our study of historical photographs, we found that doors and windows have seen the most change, evolving rapidly in the late nineteenth century through the mid-twentieth century as transportation networks exposed the people of the Southwest to other traditions, tools, and materials (fig. 4). The community determined that neither the oldest nor the newest appearances provided the necessary balance between the past and the present. The earliest windows (wind-doors) that admitted breezes but not views were no longer appropriate, nor were more recent vinyl and aluminum windows made of foreign materials. Larger, double-hung windows, often ganged in pairs, seen in photographs from the 1950s were determined to be the best balance of contemporary life with traditional building. Demands for more interior space and bedrooms resulted in returning a two-story massing not seen since the nineteenth century. Standard preservation practice frowns on combining elements from varying time periods that never coexisted, but in this case these asynchronous features are necessary.

After much discussion, community leaders elected to return to the tradition of mud-plastered adobe walls but not earthen roofs (fig. 5). The new roofs are protected by a thermoplastic polyolefin (TPO) membrane; thus we needed to join the membrane and the mud in a logical manner that eased maintenance. Whereas some western Pueblos have a tradition of ledge stone copings or overhanging roofs that help protect the mud plaster—Indigenous traditions that could have been utilized with membrane roofs—these techniques were never used here. Tribal leaders preferred to introduce a modern metal coping rather than a solution used by another nearby tribe with different material traditions. The return to traditional mud plaster tangibly connects the tribal community to these ancient homes while resurrecting the intangible traditions of seasonal maintenance.

Avanyu General Contracting, a Native woman-owned business led by Liana Sanchez of San Ildefonso Pueblo, has overseen the construction efforts (fig. 6). Avanyu worked with renowned adobe maestro Pat Taylor to hire and train local tribal members, who made up almost half the crew, and returned more than $1 million in salaries to the community. AOS Architects continued to assist in the effort through five phases of construction, updating the preservation plan with lessons learned, meeting with families to determine individual needs, designing the rehabilitations and expansions, and administering the construction contracts. The effort is truly collaborative—the Housing Authority, Tribal Council, participating families, funders, architects, and contractors have each brought their own expertise and living experiences to help shape this process and its outcomes.

Perhaps one day the plaza area will be entirely two stories—not as it once was, and not as a designed vision of our architects, but as an organic place meeting the ever-changing needs of its inhabitants (fig. 7). For the first time in many decades, the appearance of Owe'neh Bupingeh befits this unique and sacred place, while the modernized interiors provide for a safe and healthy modern life. And we have indeed



FIGURE 7 Computer rendering of potential full build-out at Owe'neh Bupingeh. Rendering: ©Atkin Olshin Schade Architects.



FIGURE 8 Tribal youth playing baseball in the plaza. Photo: ©Minesh Bacrania Photography for *Preservation Magazine.*

restored the sounds of laughter to our middle heart place (fig. 8).

We have learned many lessons along the way. Much of life has changed in the last fifty years since the village was the center of daily life. What was recently a quiet area with mostly one-person households is now full of the life, noise, and belongings of forty-five families of varying sizes. How do we balance modern life with this sacred place? The preservation plan specifically did not restrict homeowner improvements after HUD-funded construction. Thus satellite dishes are not an uncommon sight. While we were troubled by their appearance at first, we have grown to appreciate these signs of present-day life.

Regulation and enforcement of the preservation plan is a great challenge. The 2010 preservation plan has been adopted into a master land use plan, but consensus still eludes the community on the question of guidelines versus standards. Should our preservation principles be optional or mandatory? How should self-funded rehabilitation and additions be managed as compared to projects funded by the Ohkay Owingeh Housing Authority? We understand that mixed messages seem to have been sent. Most additions we have built are wood frame with cement stucco; this is first and foremost a housing project where budgets are very limited per home. We would prefer to be using adobe, but the hard reality is that while adobe was once free, it is now significantly more expensive than wood frame because of the extensive labor required. Additionally, many of our funding sources have exceptionally tight schedules and complex reporting requirements that site-made adobes greatly complicated. Other mixed messages arose from the tribe using stabilized adobe and cement plaster on recent rehabilitations of the kivas. There was no federal funding for those efforts, thus Section 106 review was not required. Many families are asking why they should have to use mud plaster when the additions and kivas did not.

Substantial investment has been made in training families in the necessary skills of mud plastering; however, these traditions are not yet being sustained by the families. There is now a new generation of adobe masons at the Pueblo who have found well-paying careers and they could be tasked with adobe maintenance moving forward, but there is a realization that mud plastering was once woven into the ceremonial cycle of this place and is the responsibility of all families. There is an old saying here: "The adobe homes are part of the family—you take care of them and they take care of you." If adobe construction is monetized and practiced by just a few and not the community as a whole, is that tradition? Is it preservation? Only time will tell. For now, we remain committed to education and encouragement, and we hope our story encourages similar traditional communities both nearby and around the globe to find their own paths to preservation.

Beyond Participation in Tribal Housing and Perpetuation of Earthen Architectural Traditions

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Abstract: *Design and preservation professionals have long advocated for the perpetuation of earthen architectural traditions in housing. This advocacy is driven by an interest in local context and labor, social and spatial justice, environmental stewardship, and the relevance of these traditions to contemporary society. Many practitioners contend with diverging paradigms of informal and formal architecture by foregrounding participatory processes, seeking lateral knowledge transfer, and expanding their professional role to facilitator. However, there has been limited evaluation of community-driven approaches. Based on the author's graduate thesis in historic preservation, this paper retheorizes participation in the perpetuation of earthen architectural traditions through a cross-sectional analysis of four case studies in tribal housing: (1) Subhouse-2, Taos Pueblo and World Monuments Fund, (2) Owe'neh Bupingeh, Ohkay Owingeh, and Atkin Olshin Schade Architects, (3) PAHA House, Acoma Pueblo and Cornerstones Community Partnerships, and (4) Lone Tree, Navajo Nation and DesignBuildBLUFF. In analyzing both the successes and shortcomings of these cases not as housing* projects *but rather as* relationships *between professionals and tribal communities, this paper identifies and challenges the dichotomies of Western and Indigenous approaches to preservation, expert-led and community-driven processes, culturally inappropriate and culturally appropriate design, contemporary and traditional lifestyles, and professional expertise and local knowledge. While the dominant discourse on participation focuses on cultivating more meaningful participation from communities, this research suggests the need to cultivate more meaningful participation from professionals, proposing an ethos of reciprocity in advancing collaborative partnerships and adaptive built environments.*

Resumen: *Desde hace mucho tiempo, los profesionales del diseño y la conservación defienden la perpetuación de las tradiciones de la arquitectura de tierra en la construcción de viviendas. El interés en el contexto y el trabajo local, la justicia social y espacial, la gestión ambiental y la importancia de estas tradiciones para la sociedad contemporánea son los aspectos que impulsan las tareas de defensa. Para lidiar con los paradigmas divergentes de la arquitectura formal e informal, muchos profesionales priorizan los procesos participativos, buscan mecanismos laterales de transferencia del conocimiento y amplían sus roles profesionales hacia el de facilitadores. Sin embargo, los enfoques impulsados por la comunidad se evaluaron de manera limitada. En este artículo, sobre la base de la tesis de posgrado de la autora acerca de la conservación histórica, se teoriza nuevamente la participación en la perpetuación de las tradiciones de la arquitectura de tierra por medio de un análisis transversal de cuatro estudios de casos sobre viviendas tribales: (1) Subhouse-2, el Pueblo de Taos y el World Monuments Fund; (2) Owe'neh Bupingeh, Ohkay Owingeh y Atkin Olshin Schade Architects; (3) la Autoridad de la Vivienda del Pueblo de Acoma (PAHA), el Pueblo de Acoma y Cornerstones Community Partnerships; y (4) Lone Tree, la Nación Navajo y DesignBuildBLUFF. Al analizar los aspectos positivos y las deficiencias de estos casos, no como* proyectos *de Vivienda sino más bien como* relaciones *entre profesionales y comunidades tribales, en este artículo se identifican y desafían las diferencias entre el enfoque occidental y el enfoque indígena en lo que respecta a la preservación, a los procesos a cargo de expertos y a aquellos impulsados por la comunidad, a los diseños culturalmente apropiados e inapropiados, a los estilos de vida contemporáneos y a los tradicionales, así*

como a la experiencia profesional frente al conocimiento local. Aunque el discurso dominante sobre la participación se centra en fomentar una mayor participación por parte de las comunidades, esta investigación demostró la necesidad de fomentar una mayor participación de los profesionales, mediante un espíritu de reciprocidad que permita promover las asociaciones de colaboración y los entornos construidos adaptables.

Keywords: tribal housing, earthen construction, earthen architectural traditions, participatory design

Introduction

Earthen architecture is predominantly vernacular, lending itself to the use of local materials, owner-occupant agency, and the exclusion of professionals. The active properties of the material demand that buildings constructed with raw earth receive diligent care and more frequent maintenance from community users for a prolonged life span, reminding us that architecture is not static but rather an evolving expression and embodiment of those who inhabit and care for it.[1] Durability is defined through a collective process of renewal, and the knowledge of these processes is often held intergenerationally within communities. As a result of their inherent place-keeping qualities, earthen building traditions have garnered the support of various design professionals who often arrive with ambitions to challenge normative modes of top-down, ends-based, object-centric design practice. In contending with the diverging paradigms of formal training and an informal building tradition, architects and preservationists have foregrounded community-centered processes, local expertise, lateral knowledge transfer, and a shift in their conventional roles from designer to design facilitator. Over the years, earthen architecture has become an arena in which both professionals and non-professionals operate, blurring the conventional boundaries between the "expert" and the "non-expert" in the built environment.

Even so, those who advocate for the use of earthen building traditions are in the minority. Disciplinary biases have profoundly influenced the built environment that we see and experience today. Colonial ideas regarding what is and is not "architecture" have placed earthen buildings in an immutable association with "primitive" and "substandard" housing, earning validation primarily through notions of "heritage" and romantic myths of preindustrial purity (Avrami 2011). Consequently, the materials—and the societies associated with them—have been continually placed in a defensive relationship with the status quo. In what architectural historian Duanfang Lu calls the "epistemological violence" of European colonial power, the relegation of "other" knowledges as prehistoric has resulted in the suppression of identities and the rapid decline of Indigenous building knowledge, a loss that has drastically altered our built environment and provoked decades of deliberation on the growing problem of placelessness (Lu 2012). The structural legacies of these injustices have caused immeasurable harm to the people whose culture and lifeways have been systematically rejected, destroyed, and erased.

Increasingly, earthen architecture advocates have made a concerted effort not only to revive earthen architectural knowledge but also to assert their contemporary relevance—particularly in recognition of the ecological and place-based qualities of earth in an increasingly homogeneous global society. Over the past several decades, research and scholarship have focused on the technical challenges of earth in meeting modern definitions of durability and strength. As a result, cement-stabilized earthen construction, such as rammed earth, has become more popular in high-end architecture, as the smooth, straight, and colorfully striated walls promise to deliver a harmonious celebration of modern and traditional ideals. But there has also been a renewed interest in earthen construction as "appropriate technology." This interest has been strongly influenced by the work of prominent architects such as Hassan Fathy (1900–1989) in Egypt, Laurie Baker (1917–2007) in India, Nader Khalili (1936–2008) in Iran and the United States, and Francis Kéré (1965–) in Burkina Faso. These architects recognized a shift away from regional architectural traditions in favor of "modern" materials such as concrete and steel as emblems of cultural and ecological devastation. They were interested in the virtues of raw earthen construction, its rediscovery as a process of ancient knowledge, and its evolution as a viable contemporary building material with social and environmental aptitude. Central to this work was the idea of community participation—characterized largely by working with local builders and employing end users in the construction process.

Four Case Studies in Tribal Housing

Despite the devastating impact of colonization on the Indigenous landscape, earthen architecture in the United States maintains a strong connection with its historical derivation from Indigenous building traditions and Pueblo architecture in the Southwest. As such, the renewed recognition of

the opportunities of building with earth in healing cultural amnesia has been explored rigorously through tribal housing projects—many of which can be characterized as a product of deeply collaborative partnerships between Indigenous communities and design and preservation professionals. For example, Taos Pueblo partnered with World Monuments Fund (WMF) in 2012 to preserve Subhouse-2, a crumbling eleven-unit dwelling at the public entrance of the historic site through paid job training programs in traditional adobe construction (fig. 1). The goal of the Taos Pueblo Preservation Program (TPPP) was to ensure continuity of tribal traditions as much as it was to bring future employment opportunities in preserving these multistoried adobe buildings to the tribal population. Around the same time, Ohkay Owingeh Housing Authority (OOHA) partnered with Atkin Olshin Schade (AOS) Architects in 2010 to renovate thirty previously vacated and deteriorating Pueblo homes with modern amenities, historical and contemporary construction methods, and traditional earthen plaster (fig. 2). The ambition of the Owe'neh Bupingeh Restoration Project was to repopulate the historical and cultural core of the Pueblo, thereby revitalizing the tribe's lost cultural traditions, including the perennial practice of remudding. Though these projects were anchored in the preservation of physical buildings, or "tangible" cultural heritage, they foregrounded the preservation of intergenerational knowledge and the practice of building with earth, or "intangible" cultural heritage, often removing original material and rebuilding with new earthen mixes, thereby testing the deeply safeguarded Western underpinnings of preservation's preoccupation with original fabric.



FIGURE 2 Structure involved in Owe'neh Bupingeh Restoration Project at Ohkay Owingeh. Photo: Atkin Olshin Schade Architects.

Collaborative tribal housing projects have also broadened the realm of "new construction" to include a preservation ethos. In 2002, the Pueblo of Acoma Housing Authority (PAHA) reached out to the nonprofit adobe restoration organization Cornerstones Community Partnerships to design and construct a model earthen home in Acomita, financed by the US Department of Housing and Urban Development (HUD), as a response to the growing need for sustainable and culturally appropriate models to affordably house the increasing number of Acoma residents moving off the mesa (fig. 3). The Traditional Housing Construction Project was part of a larger initiative that involved training a crew of tribal members



FIGURE 1 Subhouse-2 at Taos Pueblo. Photo: World Monuments Fund.



FIGURE 3 House constructed by the Pueblo of Acoma Housing Authority (PAHA). Photo: Tonia Sing Chi.



FIGURE 4 Construction of the Lone Tree house at Dennehotso. Photo: DesignBuildBLUFF.

in traditional construction through the restoration of the San Estevan del Rey Mission Church, an undertaking that would build the skilled labor force for the new PAHA house. In another new construction project between Dennehotso Chapter of Navajo Nation and the University of Utah's graduate studio DesignBuildBLUFF, a sweat equity model was employed to include new homeowners in the process of constructing their own homes in exchange for home ownership. The graduate students worked with the Dennehotso Sweat Equity Housing Program to design Lone Tree with the community client while also providing labor to build the house as part of their educational experience (fig. 4).

These projects epitomize an increasingly popular model of practice in which professionals put forth the idea of their role as facilitators of community visions, and of communities themselves as the experts of their own built environment, driving the decision-making process. Accordingly, this type of work has received near universal praise as an antidote to the bedrock of exclusionary, culturally uninformed, and elitist practices that have held center in our profession for too long. They are emblematic of our field's renewed sense of commitment to architecture as social practice and our enchantment with creatively reinterpreting dichotomies of vernacular versus modern, traditional versus contemporary, and Indigenous versus Western. The intention of this paper is not to reiterate or praise this trend toward locally driven participatory design, nor is it to discredit the ingenuity, significance, and sincerity of the work. Rather, it is to acknowledge that these case studies, selected for the merit of their intentions and their demonstration of sincere and rigorous investigation into the rules of professional engagement, are rich and robust enough to warrant a nuanced critical inquiry into both the successes and shortcomings of bridging "formal" and "informal" architecture in a settler-colonial context. What are the dynamics and ethics of professional practice when engaging pre-industrial building traditions? How do professional values and biases intersect with community values and biases in a participatory design model? How do we escape the rhetoric of community engagement and ensure that our work does not replicate top-down prescriptive processes and do more harm than good for communities?[2]

Earthen Architecture Values

These projects demonstrated many valuable lessons in community-centered design. Each was successful in preserving and constructing the building itself and employing earthen architectural traditions. However, they experienced more difficulties in expanding that success beyond the construction of the prototype, which was intended to be a vehicle for the revival of building traditions as careers within the community. In better understanding this disconnect, a cross-sectional analysis of the projects allowed for a more universal understanding of *professional* trappings over *personal* biases in decision-making processes and project outcomes.

For example, sustainability has become almost implicit within preservation rhetoric and contemporary architectural values, referencing notions of embodied energy, locality, and community connection. Earthen architecture advocates will often cite social and environmental responsibility, along with the ubiquity of the material and practice, as key motivators in perpetuating these traditions. Unfortunately, the extent to which earthen construction is practiced, on the Pueblos today is widely misconstrued—in fact, it is almost nonexistent. Rather, it exists predominantly in the high-end building construction industry for its stylistic appeal (Ted Jojola, pers. comm. 2018). Today, nearly all of the approximately twenty or so Pueblos in the United States use cement stucco and other modern materials and construction methods in lieu of earthen plaster and adobe. The significance of this fact cannot be overemphasized, as many designers and preservationists see the opportunity to work in tribal housing as a way to advance earthen building while supporting Native communities in preserving their heritage. However, as Ted Jojola, director of the Indigenous Design and Planning Institute at the University of New Mexico, reveals, "Within the Pueblos, communities no longer identify with it because they no longer understand

the ethos, or the soul of the earthen architecture" (Jojola, pers. comm. 2018). Though earthen architecture may historically reference socially sustained practices in tribal communities, the reality is that these practices are no longer sustained as such. Due to multiple social factors, including colonial mentalities, postcolonial attitudes, and the adaptability of culture, many Indigenous people prefer to live in Western-style homes (Jojola, pers. comm. 2018; Concho, pers. comm. 2018). As Zuni native Shalie Gasper points out, lifestyles and building traditions are not necessarily entwined with identity, stating that "just because they're living perhaps in a new house, or they're living in a frame house, or a mobile home, doesn't mean that who they are as people is lost; it's just a manner in which they choose to live" (Crocker, Swentzell, and Gasper 1997).

Native professionals hold a unique position as part of both the tribal community and the professional community. Many indicated their support and often deep passion for the revival of earthen building traditions, expressing their frustrations with the strong resistance displayed by the tribal communities to which they belong. When asked about her position with regards to the reintroduction of earthen building traditions at Acoma, Theresa Pasqual, former director of the Pueblo of Acoma Historic Preservation Office, responded, "If I were to look at it from a professional lens, my response would be yes as much as possible . . . let's return to the use of traditional building materials. But then if I were to look at it from a lens of a community member . . . I also know that the challenge is time. We have wage earning jobs. That takes away from the community" (Pasqual 2018). This distinction gives potency to the idea that despite our associations of earthen architecture with Indigenous communities, these traditions live powerfully in professional paradigms and value systems.

The Romance of Maintenance

Earthen building traditions have the power to evoke the "romance of maintenance," popularized internationally by buildings such as the Djenne Mosque in Mali, which emerged as a global icon through increased interest in both intangible heritage and the concept of the vernacular as profoundly cultural, climatic, and technological.[3] Unfortunately, these romantic constructions do not divulge evolving community values, the adaptability of culture, or the context of contemporary lifestyles.

In professional practice, maintenance is often given less consideration in the project scope and, therefore, less funding. This neglect is compounded with what appears to be a romantic faith that communities will return to their ways and continue to "maintain" their homes if they are just given the direction, tools, and resources to do so. The case studies provided paid or free plastering workshops for community members, with the ambition that the families would continue to remud their own homes (fig. 5). Yet, although the community members were trained in mud plastering, the ceremony surrounding the practice had been lost, making it challenging to integrate into a contemporary way of life. As Tomasita Duran, executive director of OOHA, explained, most families living in the Owe'neh Bupingeh houses are younger families who have expectations about lifestyle. With insufficient interest from tribal members, the OOHA opened plastering workdays to the public. And while they have no shortage of volunteers eager to help, many of them are outside school groups and companies who are interested in meaningful, hands-on experience in learning about Indigenous culture (Tomasita Duran, pers. comm. 2018).



FIGURE 5 Participants in a mud plastering workshop at Ohkay Owingeh (2012) for the Owe'neh Bupingeh Restoration Project. Photo: Tania Hammidi.

Skills Transfer versus Intergenerational Knowledge Transfer

In our contemporary Western society, personal identity is commonly, if not principally, bound to our mode of employment. In our move away from a subsistence economy to a monetary economy, work, and therefore financial access to professional services, is the dominant means for providing basic needs over natural resources, empirical knowledge, or localized community-oriented channels. Professionals recognize this shift by reassociating earthen construction with

employment rather than subsistence and self-reliance (as it was historically) through job training, seeing these initiatives as a way to both build capacity within communities and revive earthen building traditions. Oftentimes, however, the power of knowledge transmission in a tradition is conflated with the efficacy of employment-based skills training. This can be problematic as tradition is supported by social connections and will perpetuate outside of any economic drivers. Skills gained from job training (and therefore earthen building traditions), however, will only continue in the context of employment. As expressed by adobe conservator Edward Crocker, who has spent decades working in job training for earthen construction, "Job training in any context without a place to go when the training is done is downright evil. To provide skills, sometimes on the highest level, and then not have even an entry level job waiting destroys self-esteem and leads to all that goes along with that" (Edward Crocker, pers. comm. 2018). Education and job training are often idealized and celebrated as virtuous in their own right, yet these efforts also have the ability to cause more harm than good.

Building Trust, Knowledge Coalitions, and Reciprocity

Professionals of the built environment who work in the "living" context of earthen building traditions often take a critical position on both the primitive and elitist associations with earthen architecture.[4] They recognize that the continuation of earthen building traditions in these contexts requires ingenuity and activism. Ascribing to the idea that earthen construction can solve environmental, economic, and social problems is seductive, and oftentimes a deeper understanding of social factors is neglected, as ideals run the risk of being projected and imposed. The motivation to act with integrity and provide opportunities for cultural reconnection can at times operate as professional blinders, causing disregard for critical truths and untruths—for instance, ignoring the reality that earthen construction is no longer prevalent as a socially embedded tradition in the Pueblos in favor of corresponding, though not necessarily translatable, notions such as the ubiquity of earthen building traditions on a global scale or the historical significance of the practice. Unfortunately, the position of wanting to save traditional knowledge also comes more commonly from those who have not experienced societal injustices to their own ways of living, and professionals who advocate for the preservation of traditional buildings will often find themselves in opposition to the communities with whom they collaborate.

In the context of community-engaged design, universally praised principles such as increased user participation as a means of better alignment with community needs, skills training as a means of empowerment or preservation, and employing historically marginalized knowledge over conventionally recognized knowledge can actually have the opposite of their anticipated effect. The intention is not to discredit these principles entirely; rather, it is to cultivate awareness of the dangers of implementing them without a critical assessment of our assumptions. This is not to say we should reject professional knowledge or values, but rather that we might think of them as a means rather than an end. Rather than pitting expert-led processes against community-driven ones and trying to step outside of the professional role and into a facilitation role, it can be beneficial to instead consider new functions for professional knowledge. With the community's best interests in mind, professional integrity can be redefined as transparency of professional values. The value of professional knowledge comes in the sharing of that knowledge for empowered mutual decision making, and therefore the concept of reciprocity extends beyond an ethical obligation. It can cultivate and contribute to longer-term intergenerational project goals such as inspiring members within the community to themselves become the next generation of professionals (Pasqual 2018).

Notes

1 Raw earth refers to earth without cementitious additives.

2 This paper is based on the author's Historic Preservation Graduate thesis, "Building Reciprocity: A Grounded Theory of Participation in Tribal Housing and the Perpetuation of Earthen Architectural Traditions" (Chi 2018).

3 In reference to the chapter titled "The Romance of Maintenance" in Brand 1994, 110.

4 Here, "living" is used in reference to UNESCO's term "living heritage."

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The Ethics of Representing Stakeholders in Conservation Decision Making: Some Questions and a Probable Solution from the Himalayan Region

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Abstract: *Ladakh, in northern India, has a rich tradition of wall paintings on earthen surfaces. These wall paintings of Vajrayana Buddhism are located in temples and monasteries across the region, and most are in poor condition due to the inherent fragility of the materials and their antiquity. The damaged state of these paintings has resulted in an exponential growth in conservation projects that are trying to save them. Over the past thirty years there has been dissatisfaction in Asia with the limitations of the archaeological approach to conservation of wall paintings in religious use with regard to addressing the religious perquisites. Instead, a "living religious heritage" or a "living heritage" approach has been proposed as a viable and imperative alternative. Such an approach privileges community traditions and other intangible cultural and religious aspects over the material-centric focus of scientific conservation. However, in the remote locations common in Ladakh, stakeholders' awareness of their rights and, importantly, conservation issues is limited or absent. Under such circumstances any claim of stakeholder engagement in decision making is problematic. This paper questions the ethics of unilaterally defining stakeholder interests in conservation projects and describes a possible solution based on several workshops conducted in the Minyag region of China to develop conservation literacy. These workshops were designed specifically for the owners of homes with significant wall paintings on earthen supports in order to facilitate their participation in conservation decisions.*

Resumen: *Ladakh, al norte de la India, tiene una rica tradición de pintura mural sobre superficies de tierra. Estas manifestaciones pictóricas del budismo Vajrayāna se encuentran en templos y monasterios de toda la región, y la mayoría está en mal estado debido a su antigüedad y a la fragilidad de sus materiales. El nivel de daño de estas pinturas provocó un crecimiento exponencial de proyectos de conservación con el objetivo de salvarlas. En Asia, durante los últimos treinta años, ha existido un descontento en cuanto a las limitaciones del enfoque arqueológico de conservación de las pinturas murales en lo que respecta al tratamiento de su uso religioso. Es por eso que, como alternativa viable e imperativa, se propuso un enfoque de "patrimonio religioso vivo" o "patrimonio viviente". Este enfoque prioriza las tradiciones de la comunidad y otros aspectos culturales y religiosos intangibles sobre el enfoque de la conservación científica que se centra en lo material. Sin embargo, en los remotos lugares de Ladakh, la conciencia de las partes interesadas sobre sus derechos y, más importante aún, sobre cuestiones de conservación, es limitada o inexistente. Por lo tanto, las afirmaciones para la colaboración de las partes interesadas a la hora de tomar decisiones son problemáticas. En este artículo, se cuestiona la ética de decidir de manera unilateral sobre las prioridades de las partes interesadas en los proyectos de conservación, y se plantea una posible solución basada en numerosos talleres realizados en la región de Minyag, China, con el fin de desarrollar conocimientos sobre conservación. Estos talleres se diseñaron específicamente para los propietarios de viviendas que tienen pinturas murales importantes sobre soportes de tierra, con el objetivo de facilitar su participación en las decisiones de conservación.*

Keywords: conservation ethics, stakeholder, conservation decisions, Ladakh, wall paintings, awareness workshop, Minyag, traditional

Introduction

The Union Territory of Ladakh, India, is located on the northwestern end of the Himalayan range at an altitude of 3500–5000 m. The region has a large number of wall paintings on earthen surfaces in religious spaces such as temples, monasteries, and stupas. These paintings depict various gods of the Vajrayana (an esoteric form of Mahayana Buddhism) pantheon along with lineage masters, scenes from the life of Buddha, and other subjects. For believers, these images embody the deity in a physical sense (Bentor 1996). A large number of these paintings are damaged due to a variety of factors, the most prominent being material fragility and antiquity, with the earliest surviving paintings, in Alichi, dating from the eleventh to the twelfth century.

There has been an exponential growth in wall painting conservation projects in the Ladakh region over the last two decades, with emphasis on stakeholder participation. Despite this stated emphasis, the stakeholders' poor understanding of conservation principles, methods, and techniques ensures their exclusion from participating in conservation decisions, thereby facilitating the conservator/conservation team to assume the responsibility of interpreting intent or making critical decisions on behalf of the stakeholder. This paper examines the ethics of such an approach and provides potential solutions based on the experience of a project in the Minyag region of China where workshops were designed specifically for the owners of homes with significant wall paintings on earthen supports.

The Stakeholders

Most conservation projects in Ladakh privilege an individual or group that controls access to the site, which may be the management of a religious order (monasteries), a village collective (village temple, village stupa), or an individual owner/caretaker (family temple). In their paper, Martin de Fonjaudran, Sreekumar, and Singh Gill (2013) provide a comprehensive list of participant stakeholders in a conservation project, including local authorities and funders, among others. This focus on recognizing stakeholders on the basis of their utility excludes the cultural community: those who have major stakes in the heritage asset on account of their ability to impart significance and authenticity resulting from their historical association, acceptance, and recognition of its essential values (ICOMOS 1994). Here, the desired usage of the term "stakeholders" in general refers to the "people for whom the place of significance has special associations and meanings" and/or those who have social, spiritual, or other cultural responsibilities for the place (Australia ICOMOS 1999).

The Ethics of Representing Stakeholders

In Ladakh, the nature of stakeholder involvement in decision making related to conservation practice has evolved over the last thirty years. After India's independence in 1947, the Archaeological Survey of India (ASI), a constitutional body mandated to care for monuments recognized to be of national importance, was the only organization with the human and financial resources to undertake complex conservation work. ASI is a government organization with legal sanction and does not engage with stakeholders in any meaningful way. This approach has resulted in several monastic sects having stopped ASI from working on their temples or monasteries (Dogra 2008). From the mid-1980s, private international conservation teams initiated documentation and restoration of wall paintings in Ladakh. These initial efforts were supported by universities or educational institutions. In 2000, the first Indian conservation team was engaged on a project at Basgo (Dhar 2018). Today there are several regional, national, and international conservation teams that are working independently or collaborating on projects in the region.

All conservation teams in Ladakh need to interact with stakeholders with the aim of obtaining permission to execute the project. The focus in such an exchange is on establishing the bona fides of the conservation team, requiring them to share their plans and efforts to save/protect the heritage asset (fig. 1). This exchange may also include a brief on the manner in which the project is going to be funded and how the village community can benefit from the ongoing work (fig. 2). After a project is initiated, periodic engagements with the



FIGURE 1 Meeting conducted with village elders in 2002 to discuss the proposed project for the restoration of wall paintings in the temple of Dorje Chenmo, Shey.



FIGURE 2 Students visiting the wall painting conservation site at the temple of Dorje Chenmo, Shey, 2002.

stakeholders follow in order to address their concerns. Usually, substantial parts of the discussions are focused on issues related to the final presentation and how the losses will be treated (Dhar 2006; Luczanits 2013). Broader consultations such as those with village communities are also considered part of stakeholder participation, but these mainly serve to publicize the project. In each of the situations described, the role of the stakeholders is limited to providing information that helps authenticate values and define significance of the wall paintings and the building and, further, to allow or refuse access to the team to undertake the conservation work. To examine the role of stakeholders in conservation decisions, Henderson and Nakamoto (2016) have evaluated twenty-eight case studies where stakeholder interaction is cited. The results are similar to the practice described here. They also found that the role of stakeholders in conservation decisions was limited to appraisal, whereas their views on treatment and display were usually ignored.

The primary reason for this superficial engagement is due to the fact that the stakeholders may have very little understanding of conservation issues and the significance of the paintings in the art historical, historical, technical, and artistic context. For them, the temple is a place of worship, the center of religious activities, and, importantly, a place where gods reside. The apparent lack of perspective in the way stakeholders value their heritage is often characterized as their ignorance by conservation professionals (Pandey, Roy, and Noorjehan 2016). This bias is also responsible for the superficial manner in which stakeholder interests are considered in the conservation projects, with the implementation of decisions supposedly favoring their choices.

This situation is also facilitated by the theoretical framework that differentiates between a Eurocentric approach to conservation on one hand and a people-centric approach on the other (Winter 2012). Variously described as "living religious heritage," "living Buddhist heritage," "living heritage approach" (Poulios 2014), or as "rights-based approaches in conservation," these ideas have their genesis in the Nara document of authenticity and subsequent theoretical frameworks to make conservation-related decision-making processes accessible and democratic (ICOMOS 1994; Stovel, Stanley-Price, and Killick 2005). The acknowledgment of different values has resulted in a shift with terms such as "scientific conservation" and "Western emphasis on the material conservation" being used to distinguish a more people-centric approach. Much of this discussion is based around the supposed stakeholder preferences, traditions, and customs (where there are no social or religious studies to solicit opinions or understand issues). The idea that the local community has, over the centuries, ensured the survival of the heritage asset through traditional means of care is not considered consequential enough to allow for equal participation in decision making.

This raises ethical questions about the authenticity of stakeholder representation in the decision-making processes for conservation, contradicting the intent of several charters and ethical codes. The practice is so common that the conservator is unaware of the ramifications of such actions. Besides being in contravention of the code of ethics, for example, the American Institute for Conservation code of ethics requires proper Communication (Article 5) followed by Consent (Article 6) (AIC 1994). Article 3 of the International Council on Monuments and Sites' (ICOMOS) ethical commitment requires its members to promote effective community involvement in the conservation processes through collaborations with people or communities associated with the monument, site, or place, and recognizing, respecting, and encouraging the coexistence of diverse cultural values (ICOMOS 2002). There is also a conflict of interest in representing the stakeholder. For example, the conservation team proposes the project, raises the funds, hires the staff, makes all the decisions with regard to the project, and hence is in a unique position to profit, leaving very little for the stakeholder to decide except for providing permission and assistance through the project. An additional challenge in this situation is that the conservators and conservation teams are unaware of the conflict of interest in such an approach.

Stakeholder and Conservation Decisions

In order to overcome the ethical problems and the conflicts of interest discussed above, it is imperative that the stakeholders be aware of their rights and responsibilities and have a basic understanding of issues that can help in decision making (similar to identifying a contractor for construction or monitoring the quality of construction). This can be achieved through awareness and sensitization workshops for the stakeholders. In 2010, UNESCO initiated a program for protecting the wall paintings in the Minyag region of Sichuan Province in China titled "Gompas and Markets: Safeguarding the Legacy of Tibetan Culture" (Dhar and Van Hoa 2014). The program included several workshops based on the idea of "treating the audience with intellectual respect," which implies recognizing the intellectual capacities of the local stakeholders to understand complex ideas and issues related to the upkeep and management of the cultural asset in their care. Additionally, awareness-building workshops for trainers were conducted and a manual, supported by audiovisual media, was produced (Dhar 2015).

The objectives of these workshops were to ensure that the stakeholders had the information and understanding to make informed choices with focus on certain key areas that would help:

- Understand the significance of the painting beyond the local religious and cultural context;
- Build capacity to evaluate the bona fides of the team proposing to conserve the wall paintings;
- Develop understanding to make informed decisions in the selection/monitoring of conservation proposals by evaluating various parameters such as experience, expertise, funding sources, budget estimates, and the nature of the proposal;
- Develop an understanding of the conservation process to be able to recognize a poorly formulated plan that does not meet standards of good practice;
- Create basic awareness of processes, ensuring safety and the ability to monitor adherence to protocols.

Empowering stakeholders by sharing knowledge and building capacities will help to ensure that the basic principles of conservation ethics are maintained as well as prevent conflict of interest. It is important to acknowledge that wall paintings have survived over the centuries due to the collective experience and wisdom of the stakeholders, and further survival of these paintings also rests with them.

Acknowledgments

This paper is dedicated to the memory of Heather Peters, a friend and mentor.

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La importancia de ser el señor Cárdenas: El rol de la comunidad en la conservación y mantenimiento del templo de Kuñotambo, Perú

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Resumen: *Siendo uno de los miembros más comprometidos de la comunidad de Kuñotambo, un pequeño pueblo cerca de Cusco, Raúl Cárdenas ha sido uno de los actores clave involucrados en la conservación del templo de Santiago Apóstol. Su papel es representativo de la participación continua de la comunidad local mucho más allá de la obra de conservación. El templo de Kuñotambo es uno de los cuatro casos de estudio del Proyecto de Estabilización Sismorresistente (SRP, por sus siglas en inglés), una colaboración del Getty Conservation Institute y el Ministerio de Cultura del Perú. El SRP tiene como objetivo diseñar, probar y modelar técnicas de estabilización sismorresistente adecuadas para los edificios patrimoniales de tierra utilizando materiales de tecnología simple y capacidad local. El templo ha estado en uso desde su construcción en el siglo XVII y sigue siendo de gran importancia para el pueblo: los habitantes escribieron y firmaron una carta para solicitar su restauración, después de que quedara inutilizable en 2007. El señor Cárdenas escribió cartas al Ministro de Cultura y organizó varias visitas a Cusco hasta que el proyecto se hizo realidad; además, dirigió las actividades del Comité de Salvaguarda y Protección del Templo. Las obras por parte de la oficina regional del Ministerio de Cultura en Cusco se llevaron a cabo entre 2016 y 2019, y varios pobladores trabajaron en la obra. Representantes del Comité están actualmente involucrados en la implementación del plan de mantenimiento del templo. Esta contribución explicará la importancia de la participación de las comunidades locales en la conservación a largo plazo de su patrimonio.*

Abstract: *Mr. Raúl Cárdenas, one of the most active members of the community of Kuñotambo, a small village near Cusco, Peru, has been a crucial stakeholder in the conservation of the church of Santiago Apóstol. His role is significant because it expresses the ongoing participation of the local community far beyond the duration of the project's timeline. The church of Kuñotambo is one of four case studies of the Seismic Retrofitting Project (SRP), a collaboration of the Getty Conservation Institute and the Ministry of Culture of Peru. The SRP aims to design, test, and model seismic retrofitting techniques suitable to earthen buildings using low-tech materials and local expertise. The church has been in use since its construction in the seventeenth century and is still extremely significant for the village: the inhabitants wrote a letter to request its restoration after it became unusable in 2007. Mr. Cárdenas wrote letters to the minister of culture and organized several visits to Cusco until the project became a reality. He also managed the activities of the Committee for the Protection of the Church. Restorations by the regional branch of the Ministry of Culture in Cusco were carried out between 2016 and 2019, and several villagers worked at the site. Representatives of the committee are currently involved in the implementation of the maintenance plan for the church. This paper explains the importance of the involvement of local communities for the conservation and maintenance of their heritage.*

Palabras clave: comunidad, participación, arquitectura de tierra, conservación, mantenimiento, conocimientos locales, técnicas tradicionales, Perú

Introducción

Esta ponencia se basa en la obra teatral *La importancia de llamarse Ernesto*, una comedia de Oscar Wilde en la que los protagonistas mantienen relaciones ficticias para escapar de obligaciones sociales gravosas. Trabajando dentro de las convenciones sociales del Londres victoriano tardío, los principales temas de la obra son la trivialidad de las relaciones y las formas de la época. En algunos casos, la obra ha sido traducida al español como *La importancia de llamarse Honesto*.

En este caso, las relaciones a las que Wilde se refiere, vividas de manera honesta, permiten el avance de la sociedad civil y la conservación del patrimonio; más aún, sin haber contado con la presencia, disciplina y sabiduría del señor Raúl Cárdenas, el proyecto del Templo Santiago Apóstol de Kuñotambo jamás se hubiera podido implementar (fig. 1).

Es reconocido que la conservación del patrimonio histórico no corresponde a un acto limitado en tiempo, sino que es un proceso a largo plazo, en el que el cuidado diario tiene un papel más que crítico. Además, requiere la participación activa y responsable de todos los integrantes de la sociedad, especialmente de las comunidades locales, y el fomento de los conocimientos tradicionales (ICOMOS 2011, 2014).

En nuestra obra, el señor Cárdenas hace de actor principal. Siendo uno de los miembros más activos de la comunidad campesina y parte del Comité de Salvaguardia y Protección del Templo, su puesto ha hecho que estuviera en el centro de la atención, desempeñando un papel clave en la conservación del templo. Desde la primera vez que el equipo del Getty Conservation Institute (GCI) explicó el proyecto al señor Cárdenas, en febrero de 2009, recibimos su apoyo total, no sólo porque quería ver el templo restaurado, sino, sobre todo, porque entendió que el proyecto iba más allá del hecho físico de reparar el edificio. Esto lo llevó incluso a ser entrevistado para un artículo sobre la conservación del templo en la sección de "Ciencias" del *New York Times* en noviembre de 2018. Nuestro contacto para la comunicación con toda la comunidad fue siempre el señor Cárdenas, pero es importante mencionar que el éxito de un proceso de conservación –y su continuación en el futuro– no depende de una persona sola, sino de la participación de la comunidad entera; y va mucho más allá si consideramos la necesidad de desarrollar sinergias entre todas las partes interesadas, individuos o autoridades, para garantizar la vida del monumento histórico.



FIGURA 1 El señor Raúl Cárdenas (con chaleco azul) participando en una reunión en el templo de Kuñotambo durante la primera fase de estudio e investigación del SRP. Fotografía: Scott Warren, ©2011 J. Paul Getty Trust.

El templo de Kuñotambo como caso de estudio

El GCI lleva trabajando en el tema de la conservación de la arquitectura de tierra desde la década de los noventa (Cancino y Avrami 2015). Con el Proyecto de Estabilización Sismorresistente (SRP, por sus siglas en inglés), el interés de la institución se ha movido hacia las técnicas tradicionales y la posibilidad de corroborar científicamente la validez de métodos de tecnología simple, usando conocimientos y materiales locales para el reforzamiento de edificios patrimoniales de tierra (GCI, s. f.).

El SRP es una colaboración entre el GCI; el Ministerio de Cultura del Perú; la Facultad de Ciencias e Ingeniería de la Pontificia Universidad Católica del Perú, en Lima; y la Universidad del Minho, en Portugal. El Departamento de Arquitectura e Ingeniería Civil de la Universidad de Bath y el Departamento de Ingeniería Civil, Ambiental y Geomática del University College London también fueron socios del proyecto entre 2010–2012 y 2013–2014, respectivamente.

Como parte de la primera fase del SRP, en 2009 se identificaron cuatro edificaciones históricas, representativas del patrimonio en tierra del Perú en cuanto a uso, ubicación, técnicas constructivas y modos de falla (Cancino y Lardinois 2012). El templo de Kuñotambo fue seleccionado como representativo de las obras religiosas de las zonas rurales andinas, construidas durante el período del virreinato español. Está construido con gruesos muros de adobe y un techo a dos aguas con armadura de madera de par y nudillo. Ha sufrido pocas modificaciones a lo largo de su historia y conserva la

mayoría de sus valores históricos, sociales y artísticos con características arquitectónicas y decorativas únicas, además de haber estado en uso continuo como lugar de culto desde su construcción en el siglo XVII.

La comunidad campesina de Kuñotambo cuenta con una población aproximada de 300 personas, divididas en 64 familias (DDC–C 2015). Los medios de sustento económico principales son las actividades agrícola y pecuaria. La mayor parte de la población es de fe católica romana y se identifica con el templo, desde siempre relacionado con las actividades religiosas, los sacramentos y las fiestas patronales tradicionales.

Durante la fase de investigación del SRP, el edificio fue estudiado con ensayos de materiales y sistemas constructivos (Torrealva *et al.* 2018), pruebas *in situ* y modelos numéricos (Lourenço y Pereira 2018; Lourenço *et al.* 2019) y análisis sobre morteros de inyección para las pinturas murales (Vernaza *et al.* 2018). Los resultados de estos estudios determinaron la vulnerabilidad sísmica de la construcción y definieron las recomendaciones para su conservación y reforzamiento.

La obra se hace realidad

Si el SRP pudo desarrollar estudios académicos novedosos en el campo, hay que reconocer que la realización de la conservación del templo no hubiera sido posible sin el compromiso de la Dirección Desconcentrada de Cultura de Cusco (DDC–C), oficina regional del Ministerio de Cultura del Perú. La DDC–C desarrolló las especificaciones técnicas del proyecto, en colaboración con el GCI y sus consultores, y proporcionó los recursos para la ejecución de la obra.

Sin embargo, la decisión de intervenir en Kuñotambo fue impulsada por el interés y la participación de la comunidad, que formó un Comité de Restauración encabezado por el señor Cárdenas. El templo había siempre representado un foco a nivel urbano y un símbolo de identidad local a tal punto que el Comité escribió cartas solicitando su restauración, firmadas por el resto de los pobladores. Una de éstas fue dirigida al entonces director de la DDC–C y entregada personalmente por parte del Comité que viajó hasta el Cusco para hacerlo; otra fue dirigida a la entonces Ministra de Cultura y entregada por parte del equipo del SRP durante una reunión de trabajo. En estas misivas, la comunidad se comprometió a participar en la obra, ofreció materiales básicos al alcance del pueblo y prometió cuidar del edificio una vez recuperado.

Un paso importante fue cuando, en 2011, el templo fue nombrado Patrimonio Cultural de la Nación, reconociendo su significado basado en su carácter histórico, artístico y arquitectónico. Con la declaración, la DDC–C pudo financiar el proyecto de restauración y puesta en valor, contando con el apoyo del GCI y del Arzobispado del Cusco. A partir de 2015, la Oficina de Gestión de Proyectos de la DDC–C desarrolló la propuesta arquitectónica y de conservación, mientras el GCI y sus consultores diseñaron la propuesta estructural y la metodología para la estabilización *in situ* de las pinturas murales. El Expediente Técnico Integral de la obra incluyó un apartado específico sobre Difusión y Sensibilización, orientado a la defensa del patrimonio cultural material e inmaterial (DDC–C 2015). Este componente abarcó un conjunto de propuestas para fomentar la participación activa de todos los actores. Con respeto a los miembros de la comunidad campesina, las actividades y los talleres tenían como objetivo principal la adopción de hábitos de manejo adecuado y la colaboración en la protección del sitio.

Pobladores obreros

La obra empezó en septiembre de 2016. Siguiendo las recomendaciones del SRP, se implementaron técnicas de estabilización sismorresistente tradicionales, corroboradas a través de ensayos y análisis de modelos de elementos finitos (Cancino *et al.* 2020).

Una de las características de la construcción de tierra en el Perú es el hecho de que las técnicas tradicionales de construcción aún son utilizadas en la región, lo que permitió que varios pobladores de la comunidad trabajaran como obreros durante el desarrollo de la obra (figs. 2–3). El involucrar a los pobladores, no sólo significó un ingreso económico adicional para la comunidad, sino que además implicó la preservación del patrimonio inmaterial de técnicas tradicionales con la posibilidad de implementar las mismas en la infraestructura del pueblo, promover la identificación con el patrimonio y fomentar el cuidado de éste a futuro.

Durante el proceso de obra, el Comité de Restauración se convirtió en el Comité de Salvaguarda y Protección del Templo, con la adición de otros miembros. Este cambio tuvo como objetivo propiciar actividades para la protección del sitio, involucrar a la comunidad local y coordinar las acciones de todas las partes interesadas. Los miembros adicionales del Comité fueron elegidos por votación entre los pobladores de Kuñotambo. Actualmente, el Comité está integrado por una junta directiva de seis miembros: el alcalde de Rondocan como presidente, el párroco como vicepresidente, el señor



FIGURA 2 Trabajadores de la Dirección Desconcentrada de Cultura y pobladores de Kuñotambo transportan a la obra los adobes preparados en el sitio usando materiales locales y técnicas tradicionales. Fotografía: Juan Carlos Mellado, ©2017 J. Paul Getty Trust y Dirección Desconcentrada de Cultura de Cusco.



FIGURA 3 La señora Felicita, esposa del señor Raúl Cárdenas y expresidenta de la comunidad campesina, realizando el emboquillado de los sobrecimientos de piedra usando un mortero de tierra y cal. Fotografía: Juan Carlos Mellado, ©2017 J. Paul Getty Trust y Dirección Desconcentrada de Cultura de Cusco.

Cárdenas como secretario, además de tres vocales. El presidente tiene la responsabilidad de elaborar un plan de trabajo anual para el cuidado del templo y coordinar la realización de todas las acciones descritas en el mismo. El vicepresidente representa al presidente, en caso de que éste no pueda desempeñar sus funciones en algún momento. El secretario es encargado de facilitar la implementación de las acciones, guardar todos los documentos, redactar el libro de actas de la parroquia y actualizar el inventario de sus bienes.

La obra de conservación y estabilización sismorresistente terminó en junio de 2019 (fig. 4). Las partes interesadas colaboraron en la organización de una ceremonia en la que participaron los pobladores de Kuñotambo, habitantes de los pueblos cercanos y profesionales del Arzobispado del Cusco, de la DDC–C y del GCI (fig. 5), además de representantes de las autoridades del Ministerio de Cultura de Lima. Hubo música y bailes tradicionales, una procesión (fig. 6) y una misa con la participación del coro nacional del Perú, haciendo uso este último del espacio del coro también restaurado. Al finalizar la misa, a la cual asistió todo el pueblo,



FIGURA 4 Los participantes de la ceremonia de entrega y consagración del templo de Santiago Apóstol de Kuñotambo marcando la conclusión de la obra de conservación y estabilización sismorresistente llevada a cabo por la Dirección Desconcentrada de Cultura de Cusco, en colaboración con el Getty Conservation Institute. Fotografía: Anna Flavin, ©2019 J. Paul Getty Trust.



FIGURA 5 Una representante de la comunidad campesina de Kuñotambo da la bienvenida a Jim Cuno, presidente emérito del Getty, durante la ceremonia de consagración y entrega del templo de Santiago Apóstol de Kuñotambo. Fotografía: Anna Flavin, ©2019 J. Paul Getty Trust.



FIGURA 6 La procesión de la imagen de Santiago Apóstol, patrón del templo, siguiendo la tradición peruana. El Getty Conservation Institute donó nuevas vestimentas para la imagen. Fotografía: Anna Flavin, ©2019 J. Paul Getty Trust.

las autoridades firmaron el acta de entrega del templo conservado de la DDC–C al Arzobispado del Cusco, propietario del edificio.

Cuidado continuo para un patrimonio vivo

Tras la conclusión de la obra, representantes de la comunidad y de las partes interesadas están colaborando para desarrollar un plan participativo de monitoreo y mantenimiento del monumento histórico, con el apoyo del GCI y sus asesores. La sinergia de los actores involucrados es necesaria para diseñar el plan y asignar roles y responsabilidades, pero sobre todo para garantizar su sostenibilidad a largo plazo. El equipo de trabajo está todavía colaborando para detallar el plan, así que la información en los párrafos siguientes sobre los roles y responsabilidades de cada una de las partes a modificaciones y ajustes a futuro.

El Arzobispado del Cusco, como propietario del templo, es responsable de mantener y proteger el recinto religioso invirtiendo en su cuidado permanente (Gobierno del Perú 2020). A través de la Oficina de Proyectos Patrimoniales de Conservación y del Área de Conservación y Restauración de Obras de Arte, el Arzobispado gestiona y participa en inspecciones de monitoreo, administra recursos y planea intervenciones urgentes, anuales y según se requieran, con base en los resultados de las inspecciones o avisos de la comunidad. Además, garantiza el uso del templo, asegurando la presencia del padre para dar misa y administrar sacramentos.

La DDC–C, a través de la Oficina de Patrimonio Histórico, apoya al Arzobispado en la realización de inspecciones anuales y revisa los expedientes para intervenciones de mantenimiento o reparación; adicionalmente, conserva copias de los informes de las inspecciones, así como planos e informes de las intervenciones realizadas.

La municipalidad de Rondocan apoya al Arzobispado del Cusco en algunas actividades específicas de mantenimiento del templo, que forman parte de su plan y presupuesto anual.

El Departamento de Edificios y Sitios del GCI, en colaboración con la Universidad del Minho en Portugal y la Pontificia Universidad Católica del Perú en Lima, ofrece apoyo científico a las partes interesadas en el desarrollo e implementación del plan de monitoreo y mantenimiento del templo en el periodo 2019–2025.

Los miembros de la comunidad campesina de Kuñotambo son en parte responsables de la implementación de los planes de mantenimiento y monitoreo del templo. Con relación a este último, llevan a cabo inspecciones básicas una vez al mes e implementan actividades de limpieza y pequeñas reparaciones que no necesitan permiso de las autoridades. Asimismo, están capacitados para reconocer situaciones que requieren atención urgente por parte de especialistas y, si es necesario, contactan al Arzobispado del Cusco o la DDC–C. Adicionalmente, conservan y actualizan copias de todos los documentos, incluidos los relacionados con las inspecciones

realizadas por las diferentes partes involucradas en el plan de monitoreo.

Como parte de las actividades de desarrollo e implementación del plan de mantenimiento, se ha entregado a la comunidad un Manual de Uso del monumento histórico –con instrucciones básicas de cuidado regular; un calendario que incorpora actividades mensuales; una ficha de inspección simplificada; planos y diagramas del edificio y de sus sistemas de electricidad, agua y desagüe– además de materiales y equipo para limpieza, remplazos y pequeñas reparaciones.

Finalmente, y para la correcta implementación de ambos planes, se llevan a cabo actividades de capacitación para la comunidad a través de talleres que cubren la limpieza básica, identificación de daños y el reconocimiento de situaciones que requieren atención por parte de especialistas.

Conclusiones

Contrario a lo que Wilde nos hace ver en su obra, el caso de Kuñotambo demuestra la importancia de relaciones basadas en mutuo entendimiento, comunicación abierta y objetivos comunes. Sobre todo, representa un ejemplo de la importancia del compromiso activo de todos los integrantes de la sociedad para la protección y el cuidado del patrimonio. El proyecto de conservación y estabilización sismorresistente, ejecutado por parte de la DDC–C con el apoyo del GCI, fue impulsado por el interés de los pobladores que deseaban volver a tener un lugar donde celebrar sacramentos y fiestas religiosas. A la fecha, se han realizado diversos matrimonios, confirmaciones, primeras comuniones y bautizos.

Varios pobladores participaron en la implementación de las intervenciones como mano de obra de apoyo, contribuyendo al fomento de técnicas tradicionales de construcción en tierra. Actualmente, miembros de la comunidad campesina están involucrados en el desarrollo del plan participativo de monitoreo y mantenimiento del monumento que hemos descrito, siendo responsables de su uso adecuado y de actividades de limpieza y reparación, además de comprobar su estado de conservación. Esto demuestra el rol crucial de las comunidades locales para garantizar la conservación del patrimonio como acto participativo a largo plazo.

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Pequeños y Grandes Arquitectos: Tendiendo puentes entre generaciones—Los casos de Oña y Susudel en Ecuador

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Resumen: *Los poblados de Oña y Susudel, en el sur de Ecuador, son portadores de un patrimonio cultural material e inmaterial manifestado en una riqueza de edificaciones vernáculas, resultado de la aplicación de varias técnicas constructivas tradicionales con tierra. Aquí, la albañilería como oficio se aprende y se transmite de generación en generación, y constituye el principal sustento económico del sector. En este contexto, la Universidad de Cuenca ha trabajado por cerca de 14 años de manera consistente en estas localidades, enfocando su trabajo docente y de investigación en la recuperación del patrimonio cultural edificado y sus valores asociados. Como parte de estos procesos, en los que las propias comunidades han reconocido la necesidad de generar puentes generacionales de aprendizaje, se han planteado varios talleres como iniciativas que se constituyen en procesos para* aprender haciendo. *El objetivo aspira a promover al patrimonio cultural como un recurso educativo, incentivando el diálogo entre niños y adultos, y con ello, el desarrollo de la conciencia, de la comprensión del pasado de su comunidad, la valoración de la historicidad en el presente y la participación en la construcción de su futuro personal por medio de la capacitación y el empoderamiento social de su patrimonio. En esta experiencia, el patrimonio contribuye con recursos que son transmitidos a las futuras generaciones, promoviendo la participación de los niños y adultos, compartiendo destrezas y sensibilidad frente a la valoración y preservación de la cultura constructiva tradicional.*

Abstract: *The towns of Oña and Susudel, in southern Ecuador, are sites of tangible and intangible cultural heritage manifested in a wealth of vernacular buildings, the results of various traditional earthen construction techniques. Here, masonry is learned as a trade and passed on from generation to generation, acting as the main economic support for the sector. In this context, the Universidad de Cuenca has worked consistently in these locations for nearly fourteen years, focusing its teaching and research on the recovery of the built cultural heritage and its related values. Recognizing the need to support generational learning bridges, the communities offered several* learning-by-doing *workshops. Using heritage as the catalyst for passing on resources to future generations, the workshops aim to promote cultural heritage as an educational resource by encouraging dialogue between children and adults. Further goals include a development of awareness and understanding of the community's past, appreciation of history in the present, and participation in the construction of the community's future through training and the social empowerment of their heritage.*

Palabras claves: enseñanza, adobe, patrimonio, niños, construcción tradicional

Introducción

El grupo de investigación Ciudad Patrimonio Mundial (CPM) es un espacio académico de la Universidad de Cuenca con más de una década de trabajo en investigación científica, a partir de lo cual ha generado bases conceptuales desde varias líneas de investigación, como la conservación preventiva, el patrimonio como recurso de desarrollo y el paisaje urbano histórico; el CPM se ha empeñado en promover procesos multidisciplinarios, nacionales e internacionales buscando el fortalecimiento, con novedosas estrategias de conservación del patrimonio cultural. En el ámbito internacional su trabajo ha tenido el apoyo de la Universidad Católica de Lovaina (KULeuven), el Centro Internacional Raymond Lemaire para la Conservación (RLICC), la cátedra[1] PRECOM[3]OS, la Red Iberoamericana PROTERRA, el ICOMOS y la Universidad de Hasselt (Bélgica), entre otras (Astudillo *et al.* 2018). En el ámbito nacional su trabajo está directamente relacionado con la inserción de acciones con la comunidad dirigidas a contribuir con su desarrollo, vinculando diversas instituciones públicas o privadas, como los gobiernos parroquiales y cantonales, el Ministerio de Cultura y Patrimonio, el Instituto Nacional de Patrimonio Cultural o el Gobierno Provincial del Azuay, entre otras.

Uno de los objetivos del grupo CPM se enfoca en el estudio y la enseñanza de la arquitectura en tierra, promoviendo talleres en torno a la transferencia de conocimientos a partir de la conservación preventiva; estimulando el fomento de técnicas constructivas tradicionales y el uso de la tierra en edificaciones contemporáneas; y generando espacios para la inclusión de estudiantes, profesores, comunidades y otros actores.

El proyecto está establecido en el centro urbano de Cuenca –Ciudad Patrimonio de la Humanidad desde 1999– y en la parroquia rural de Susudel del cantón Oña, donde se han ejecutado varias iniciativas como las Campañas de Mantenimiento de las edificaciones patrimoniales y su cementerio ancestral, y el diseño participativo para la restauración de la Casa-Hacienda, que es el origen del poblado actual (fig. 1). Estas iniciativas han contado con la participación activa de la sociedad mediante el trabajo comunitario denominado *minga*[2]. Además, se han desarrollado importantes proyectos como *Later Eris*, empeñado en la diversificación de ladrillos, y Tierras de Colores, que busca la utilización de pinturas de tierra en la arquitectura y el arte. Actualmente se gestionan tres proyectos internacionales que enlazan el patrimonio con la salud, la cooperación nacional e internacional con la creatividad.

En este camino recorrido, se ha incentivado la recuperación del patrimonio cultural edificado y sus valores asociados, evidenciando la importancia de acompañar este esfuerzo con procesos que ayuden a estas comunidades a tejer relaciones intergeneracionales, teniendo presente que, como decía Nelson Mandela, "la educación es el arma más poderosa que puedes usar para cambiar el mundo."

Tendiendo puentes entre generaciones

Susudel es la única parroquia rural del cantón Oña y posee un legado patrimonial de arquitectura vernácula muy valioso,



FIGURA 1 Localización de las zonas de estudio. Dibujo: Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.

que usa materiales locales como fibras, madera y tierra, lo que ha incidido en su reconocimiento como patrimonio cultural de la nación (2013).

Sin embargo, la herencia del conocimiento se encuentra amenazada por la vida moderna, el consumismo de las nuevas generaciones, la pérdida de identidad y el impacto de la migración con la integración de modelos replicados fuera del contexto de la ruralidad, que marcan una ruptura intergeneracional (Cardoso 2015).

La práctica del uso de estos materiales y sus saberes para su aplicación se preserva sobre todo en la memoria de personas mayores o ancianas, por lo que resulta primordial generar procesos de transferencia de conocimientos y experiencias para que no desaparezcan y que, en cambio, se creen nuevas oportunidades y emprendimientos productivos en la región. Los talleres más recientes que se han puesto en marcha son los tres siguientes.

Taller de aplicación de tierras de color

Las campañas de mantenimiento realizadas en la zona rural evidenciaron el uso de pinturas a base de pigmentos minerales, y ubicaron la existencia de este material en la geografía de Oña y Susudel. Esto motivó la activación de un proceso de investigación dirigido al estudio científico de estos materiales –su procesamiento, producción y utilización– mediante el diseño de emprendimientos y difusión de resultados. Así surgió Tierras de Colores, proyecto multi y transdisciplinario que sumó esfuerzos de tres Facultades de la Universidad de Cuenca (Arquitectura, Ciencias Químicas y Artes), además de la participación de la Universidad Federal de Viçosa (Minas Gerais, Brasil), el Gobierno Autónomo Descentralizado (GAD) del cantón Oña y la Prefectura del Azuay (Amaya *et al.* 2018). En este proyecto se conocieron y entendieron los procedimientos empíricos desarrollados en la región de Oña y Susudel para la aplicación de pinturas de pigmentos minerales. Se desarrollaron científicamente dosificaciones de diferentes colores que podían aplicarse a la arquitectura patrimonial y contemporánea, y se identificó una alternativa de producción de pinturas de tierra, que pueda ser implementada por las comunidades de esta zona. Otro de los objetivos del proyecto fue la difusión de los resultados por medio de capacitaciones a niños y jóvenes, en coordinación con diferentes instituciones educativas. En este contexto, en los meses de mayo y junio de 2018, se realizaron encuentros participativos para identificar los valores culturales tanto en Oña como en Susudel. La intención de estas actividades era determinar los elementos relevantes reconocidos como patrimonio cultural del sitio, considerando que las personas son quienes tienen en sus manos la decisión de definir qué tiene valor o no en su entorno cultural. Al identificarse, lo vinculan con su pasado y son capaces de apreciarlo (fig. 2), conservarlo y transmitirlo a las presentes y futuras generaciones (Achig, Abad, y Barsallo 2017).

A partir de la determinación participativa de valores se realizaron talleres prácticos como parte de la devolución de



FIGURA 2 Dibujo infantil y capilla de Susudel. Fotografía: Fausto Cardoso. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.



FIGURA 3 Niños creando arte con tierra de colores. Fotografía: Santiago Ordoñez. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.



FIGURA 4 Grupos de trabajo. Fotografía: Fausto Cardoso. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.

la información construida previamente, para luego organizar grupos mixtos con niños y jóvenes reunidos en un espacio educativo, en donde experimentaron el uso de la pintura a base de tierra de colores (fig. 3).

Taller "Pequeños y Grandes Arquitectos"

El grupo CPM, mediante otra experiencia participativa, promovió el diseño para la restauración de la Casa-Hacienda de Susudel, generando espacios de cocreación entre varios actores (académicos, institucionales, privados y comunitarios). Se promovió el entendimiento del lugar, la valoración de la construcción con tierra, y el interés por los oficios tradicionales aprendidos en obra o transmitidos de generación en generación. Se desarrollaron así sinergias entre diversos actores, pero especialmente entre jóvenes y personas mayores (padres-abuelos-hijos-nietos). En junio de 2019 se propuso poner en marcha el taller "Pequeños y Grandes Arquitectos", con el fin de motivar a los niños de manera didáctica a trabajar con materiales existentes en la región como la tierra y la madera, estimulando sus sensaciones táctiles en procesos creativos para aprender haciendo. Este taller tuvo una duración de una semana, en la que participaron niños de diferentes niveles educativos y sus familias. Se organizaron tres grupos (fig. 4) conformados por alrededor de 13 niños y varios integrantes del grupo CPM. La labor de cada grupo fue desarrollar una réplica a escala de una edificación local de valor patrimonial.

La imaginación fue un insumo necesario para la preparación del taller, ya que se requirió crear elementos a escala pequeña para la construcción de las edificaciones, elaborando manualmente adobes de tierra de 4 × 2 × 2 cm para facilitar la dinámica de preparación de materia prima, moldeado, secado, empacado y traslado a la obra en Susudel. Se alcanzó una producción de aproximadamente 5800 adobes: un verdadero LEGO de tierra. Además de preparar piezas de madera para estructurar techos, portales y entrepisos, se emplazaron didácticamente los materiales para generar cimentaciones, se previeron herramientas para la ejecución de la obra y se dibujaron planos de las edificaciones que servirían de guía para la enseñanza práctica de la construcción. En todas las actividades desempeñadas por los niños, se fomentó el juego como método de enseñanza.

Como resultado, se obtuvo la construcción de: (a) la capilla de la comunidad (escala 1:250), elemento patrimonial de valor material e inmaterial (fig. 5); (b) una casa diseñada para el contexto consolidado (escala 1:50) resuelta en dos plantas, con portal; (c) una casa diseñada para el área agrícola (escala 1:50) organizada alrededor de un patio central, distribuida en tres bloques de varias funciones (Barsallo *et al*. 2020). En el taller se aquilató la potencialidad del aprendizaje en los niños y jóvenes con la práctica y, a su vez, la apropiación que ésta suscita sobre su legado patrimonial, la valoración y reflexión sobre la arquitectura vernácula, y el fortalecimiento de vínculos generacionales por la participación interactiva de niños y adultos (fig. 6).



FIGURA 5 Capilla de Susudel construida a escala. Fotografía: Fausto Cardoso. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.



FIGURA 6 Integración de adultos al taller de Pequeños y Grandes Arquitectos. Fotografía: Fausto Cardoso. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.

Taller de pintura de tierra de colores para niños

A finales del mes de marzo del 2021, como parte del esfuerzo de reactivación social en respuesta al confinamiento generado por la pandemia de covid-19, se realizó en Susudel la Fiesta del Patrimonio y el Chanchito Rey, celebración que contó con varias actividades culturales, entre ellas el taller de pintura de tierra de colores para niños.

En esta oportunidad, los pequeños emplearon lienzos reutilizables de plástico enmarcados con madera, aplicando tierras locales de colores (figs. 7–8). Desencadenando sin restricción sus habilidades y sensibilidad artística, los niños promovieron la valoración patrimonial de técnicas constructivas y materiales orgánicos, como el uso de la pintura de tierra, con costos en recursos y equipos de trabajo extremadamente discretos.



FIGURA 7 Arte y creatividad en las manos de los niños de Susudel. Fotografía: Fausto Cardoso. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.



FIGURA 8 Pequeño artista y su obra en tierra. Fotografía: Fausto Cardoso. Grupo Ciudad Patrimonio Mundial (CPM), Universidad de Cuenca.

Conclusiones

La conservación del patrimonio cultural puede activar procesos de resignificación de valores comunitarios compartidos y generar acciones pedagógicas en la medida en que se estimula la capacidad de hablar y escuchar, suscitando la reflexión profunda como método de aprendizaje. Estas experiencias estimulan a las nuevas generaciones a promover la revalorización de su patrimonio material e inmaterial, el uso de recursos naturales y culturales de la zona, y la generación de vínculos con el arte y la arquitectura.

Mediante estos talleres se incentivó el conocimiento de las técnicas constructivas tradicionales –aplicando saberes con prácticas didácticas alrededor de la conservación preventiva del patrimonio del sector y promoviendo la elaboración de productos basados en la tierra–así como la generación de oportunidades y la valoración de saberes ancestrales. Estas actividades demuestran la inagotable imaginación y creatividad de los niños, que son capaces de contagiar a los grandes y desarrollar conjuntamente acciones creativas.

Se puede afirmar que, además de aprender sobre técnicas y materiales, se moldean criterios personales sobre tipologías y formas de construcción emplazadas en entornos rurales, a través de experiencias amigables con el paisaje y las culturas locales.

Finalmente, es importante remarcar que se ha puesto énfasis en el trabajo con las comunidades por la clara convicción de preservar el patrimonio en toda su compleja diversidad, reforzando la cohesión social y restableciendo vínculos intergeneracionales.

Incidir en la potencialidad del patrimonio para la educación, incluyendo a las generaciones más jóvenes, es una siembra fundamental para contar a futuro con personas nutridas de sensibilidad y amor por sus bienes culturales. Ello implica abrir un horizonte de posibilidades aún inexplorado por las comunidades locales, lo que puede convertirse, en un futuro no lejano, en nuevas fuentes de trabajo, inspiración para la creatividad y, consecuentemente, una sustancial mejora en la calidad de vida de la población de entorno patrimonial.

Notas

1 La cátedra PRECOM³OS UNESCO (Conservación Preventiva, Monitoreo y Mantenimiento de Monumentos y Sitios).

2 La *minga* se define como "trabajo no remunerado colectivo para beneficios comunes de una comunidad." La minga (*minka* en quechua) es una tradición precolombina de trabajo comunitario o colectivo voluntario con fines de utilidad social o de carácter recíproco actualmente vigente en varios países latinoamericanos como Colombia, Perú, Ecuador, Bolivia, Chile y Paraguay.

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La Casa-Hacienda de Susudel: Un proyecto de cocreación y beneficio comunitario

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Resumen: *Susudel es un poblado al sur de la región andina del Ecuador, de una riqueza cultural y paisajística excepcional. De origen cañari, pasó del dominio inca (s. XV) a ser territorio de encomienda en la época de la colonia española (s. XVI). Su asentamiento es el resultado de una sedimentación de culturas hasta un modo de producción agrícola de carácter feudal denominado "hacienda", en el que los indígenas trabajaban a cambio de un lugar para vivir hasta que, en 1964, la Reforma Agraria posibilitó que los trabajadores tomaran posesión de las tierras cercanas a la Casa-Hacienda. Desde entonces, esta construcción con su capilla es uno de los hitos históricos relevantes, por lo que fue declarada Patrimonio Cultural Nacional en 2013. Este artículo pone en relieve el valor de esta edificación de arquitectura vernácula en tierra. La estrategia se apoya en un proceso participativo activado para la elaboración del anteproyecto para su recuperación, actualmente, con algunas partes en estado ruinoso, lo que pone en riesgo su perduración. La Universidad de Cuenca, desde la Opción de Conservación 2018–2019 de la Facultad de Arquitectura, abre un espacio común de reflexión de las distintas voces interesadas en rescatar este importante legado. La metodología implementada favoreció el diálogo y la cocreación entre varios actores: propietario, vecinos, académicos y técnicos municipales. Como resultado, se obtuvo la "lectura histórico-crítica" del bien patrimonial, los criterios de intervención y la propuesta de usos a partir de distintos escenarios, proyectando participativamente una restauración integral combinada con estrategias sustentables de desarrollo comunitario.*

Abstract: *Susudel is a town in the south of Ecuador's Andean region with an exceptional richness in both culture and landscape. Originally Cañari, it went from being part of the Inca domain (fifteenth century) to being an encomienda territory at the time of Spanish colonialization (sixteenth century). Its settlement is the result of a gradual buildup of cultures that led to a feudal-type agricultural estate called a hacienda, where Indigenous people worked in exchange for a place to live until 1964, when the Agrarian Reform made it possible for the workers to take possession of the lands near the Casa-Hacienda. This structure and its chapel comprise one of the more important historic landmarks, and in 2013 it became a National Cultural Heritage Site. This article highlights the building's value in terms of vernacular earthen architecture. The strategy, based on a participatory process, was established for the preparation of a preliminary restoration project as some of the structure's parts are currently in ruins, putting its survival at risk. The Universidad de Cuenca, as part of the 2018–2019 Conservation Division of the School of Architecture, opened a communal space of reflection for the various voices interested in rescuing this important legacy. The methodology promoted dialogue and co-creation between various stakeholders: owner, residents, academics, and municipal technicians. As a result, a "historical-critical reading" of the heritage asset—the intervention criteria and the proposal for different use scenarios—was obtained, creating a participatory project for comprehensive restoration combined with sustainable community development strategies.*

Palabras clave: patrimonio vernáculo en tierra, restauración integral, diseño participativo, red de actores, cocreación

Introducción

La parroquia de Susudel pertenece al cantón San Felipe de Oña de la provincia del Azuay en Ecuador. Su economía se basa en la agricultura y ganadería, lo cual representa el 48.98 % del ingreso primario de los hogares. Su paisaje de montaña (2550 m s. n. m.) enmarca la configuración del poblado, con edificaciones construidas con materiales vernáculos coherentes con el entorno natural. También es una importante zona productora de ladrillos, pero su vida original siempre giró en torno a la antigua Hacienda, de la cual se desprende una fuerte forma de organización comunitaria.

Desde un proceso de acompañamiento académico que se desarrolla desde hace más de 14 años en Susudel por parte del proyecto Ciudad Patrimonio Mundial (CPM) de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca, se han podido abordar las necesidades locales con planteamientos académicos en relación con la conservación del patrimonio cultural. Grupos de docentes y estudiantes desarrollan regularmente investigaciones aplicadas, entre las que destacan las Campañas de Mantenimiento (de las viviendas campesinas en 2011 y del cementerio en 2013), todos ellos vinculados con un proceso de valoración del patrimonio como recurso de desarrollo.

En este marco, en 2018, docentes y estudiantes de la opción de Conservación del Patrimonio pusieron en marcha un proceso de investigación y diseño participativo en el complejo patrimonial de la Casa-Hacienda de Susudel con la misión de recuperar el bien cultural desde la caracterización de sus valores hasta la puesta al servicio de la comunidad, pasando por el aseguramiento de su estabilidad y equilibrio estructural.

La Casa-Hacienda de Susudel

La hacienda colonial fue una institución que afianzó las actividades minera y agrícola (Colmenares 1992); ya en el siglo XIX, la "fiebre del oro" puso la mira en la región de Zaruma y Portovelo (Morejón 2012), lo que involucró a comunidades regionales como Oña y Susudel en la búsqueda de minas de oro y cuarzo, presentes en el cercano río León.

La hacienda de Susudel es el núcleo original del poblado de Susudel; su posición es estratégica, pues constituía un punto intermedio de comunicación entre Loja y Cuenca (Muñoz 1990). Ya en 1767 se tiene memoria de la existencia de la edificación de adobe, la cual incluía una capilla con espacios rituales al aire libre para las ceremonias funerarias.

Hoy, el complejo arquitectónico Casa-Hacienda de Susudel, junto con la capilla y la Plaza de las Escaramuzas



FIGURA 1 Vista del complejo arquitectónico Casa-Hacienda de Susudel. Fotografía: Cristian Allaico, 2019. Cortesía del autor.

(fig. 1), es un hito de relevante valor patrimonial, relacionado directamente con la cultura y tradiciones locales, y fue declarada Patrimonio Cultural Nacional en 2013. La Casa-Hacienda es una clara muestra de las haciendas coloniales del Ecuador y está configurada por una serie de bloques articulados en torno a patios que forman la casa principal, y una capilla que sobresale en la lectura del paisaje. Su grado de conservación es aceptable, a diferencia del de la casona, en la que incluso existen áreas en estado de ruinas. El actual propietario ha sido un benefactor constante y ha entregado parte de sus espacios a la comunidad, con la idea de generar emprendimientos para activar la economía local. Su intención de donar una parte más de la edificación a la comunidad se alinea con el deseo comunitario de crear nuevos emprendimientos vinculados con el patrimonio. Por estas razones, desde la Universidad de Cuenca se promovió un proceso participativo para desarrollar una propuesta de restauración, en el que se incluyan, desde el inicio, al propietario, su familia y la comunidad.

Metodología

La metodología aplicada en este proyecto se basa en los principios para el análisis, conservación y restauración de las estructuras del patrimonio arquitectónico que planteó el Consejo Internacional de Monumentos y Sitios (ICOMOS 2003). Esta iniciativa se inserta, además, en el proceso de

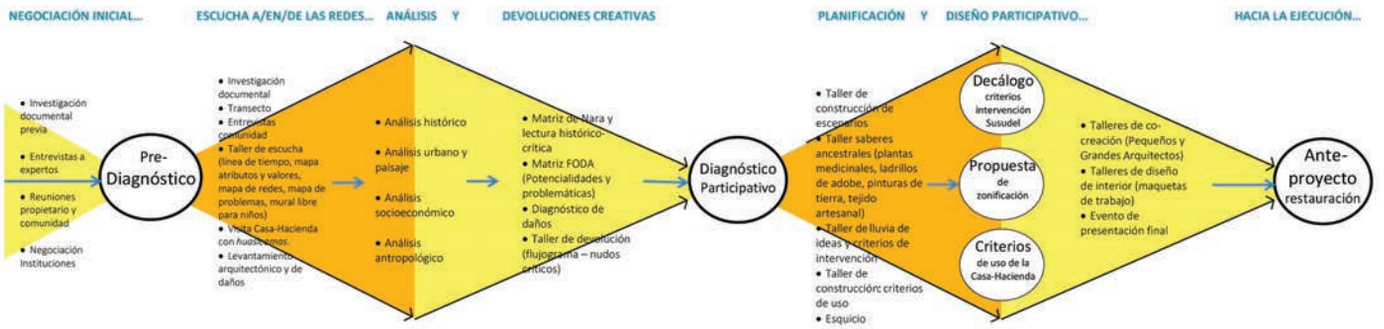


FIGURA 2 Proceso metodológico del diseño participativo del anteproyecto de restauración de la Casa-Hacienda de Susudel. Gráfico: Alicia Tenze, 2019. Cortesía de la autora.

desarrollo comunitario apoyado por el Proyecto CPM en Susudel, mediante metodologías participativas, con el fin de integrar distintas voces, no sólo como insumos técnicos, sino como estrategia de un proceso para la toma de decisiones. Esto sugiere un cambio de paradigma en la manera de proyectar, que implica incluir activamente también a la gente con sus diversas experticias de vida. Salir, escuchar y analizar para organizar la información y devolverla en encuentros plurales de reflexión colectiva, donde se compartan los distintos saberes y se construyan tanto los problemas como las soluciones, es la estrategia aplicada en este proceso. Esto implica determinar escenarios que puedan también ponerse en discusión y codiseñar una propuesta que sea adecuada en términos técnicos, pero también en términos sociales de uso, funcionalidad, calidad de vida y sustentabilidad (Alberich *et al.* 2015).

El proceso de investigación y diseño participativo (fig. 2) partió de una fase de aproximación inicial que contempló las primeras visitas, reuniones y la organización del programa académico. Le siguió una fase de escucha para conocer las distintas opiniones y percepciones de la comunidad sobre el bien para estudiarlo desde diferentes ámbitos, valorarlo y analizarlo con levantamientos espaciales, estructurales y de daños en cada uno de sus ambientes y elementos constructivos. Se procedió, consecuentemente, a devolver la información para realizar una interpretación conjunta de los estudios, contrastándolos con las necesidades e intereses de los actores claves involucrados, y se finalizó con una fase de diseño participativo, construyendo escenarios y criterios de intervención e identificando las prioridades y propuestas de uso del bien. La experiencia culminó con una serie de talleres de cocreación para diseñar de manera conjunta, incluyendo a jóvenes y adultos de la comunidad de Susudel, técnicos de las instituciones y profesores y estudiantes universitarios, la distribución específica de algunos de los espacios del complejo, lo que contribuyó a la definición del anteproyecto final de restauración.

Resultados y discusión

Aproximación inicial

La Casa-Hacienda de Susudel se consideró importante por sus valores, su rol histórico en la región y el desarrollo espacial del poblado. Para entenderla, se realizó un prediagnóstico que permitió contextualizar el poblado y el complejo arquitectónico. Posteriormente, mediante reuniones participativas se activó un proceso de conciliación de los diversos intereses de los actores involucrados (comunidad, propietarios y gobiernos locales).

Trabajo de campo

La documentación se basó en informes técnicos, artículos, tesis y talleres. Una de las primeras actividades fue la realización de un *transecto* o recorrido comentado, en el que personas de la localidad e integrantes del equipo del proyecto intercambiaron ideas, anécdotas y datos respecto de la vida en el poblado y su entorno. Otra actividad fue un taller de *escucha* al que asistieron tanto técnicos y miembros del Gobierno Parroquial, así como vecinos adultos, mayores y niños, quienes intercambiaron sus conocimientos y sensibilidades respecto al rol del bien y su potencial vínculo con el desarrollo comunitario (fig. 3). Gracias a la participación de los *huasicamas* (servidumbre del hacendado), se pudo conocer la vida en la hacienda antes de 1964. Finalmente, se realizó un levantamiento arquitectónico del bien, lo que puso en evidencia su estado de conservación.



FIGURA 3 Taller de escucha para el anteproyecto de restauración de la Casa-Hacienda de Susudel. Fotografía: Fausto Cardoso, 2018. Cortesía del autor.

Análisis y devolución

Mediante la consulta de fuentes secundarias, se analizaron aspectos históricos, socioeconómicos, antropológicos, urbanos y paisajísticos, lo que permitió una aproximación holística al sitio. Las conclusiones se entregaron a la comunidad en un nuevo taller de escucha interactiva en el que emergieron, además, las primeras ideas para su recuperación. En este taller se devolvió también el *diagnóstico de daños* (fig. 4) y la *lectura histórico-crítica*, en la que se explicitaron los valores históricos, sociales, estéticos o culturales asociados a la Casa-Hacienda.

En el taller, se logró interrelacionar la información recolectada, desarrollándose un diagnóstico participativo entre distintos actores y priorizando situaciones que requerían de atención: apoyo de las instituciones, normas para la protección del patrimonio, rescate de la sabiduría ancestral y la organización social para la protección del patrimonio (fig. 5). Asimismo, se constató el delicado estado de conservación del inmueble. La mayoría de los problemas están asociados a la presencia de humedad, el abandono y desuso, por lo cual se propuso un plan de obras emergentes de acción inmediata.

Diseño participativo

En esta fase fueron muy importantes los encuentros dirigidos a cocrear criterios de diseño de interés comunitario y aquellos asociados al bien patrimonial. En los talleres se hipotetizaron tres escenarios como referencia para el diseño: un primer escenario tendencial, donde si no se toman las decisiones correctas la Casa-Hacienda podría caer en un segundo escenario de total deterioro, y un tercer escenario en base al deseo de la comunidad de cambios significativos de apoyo a

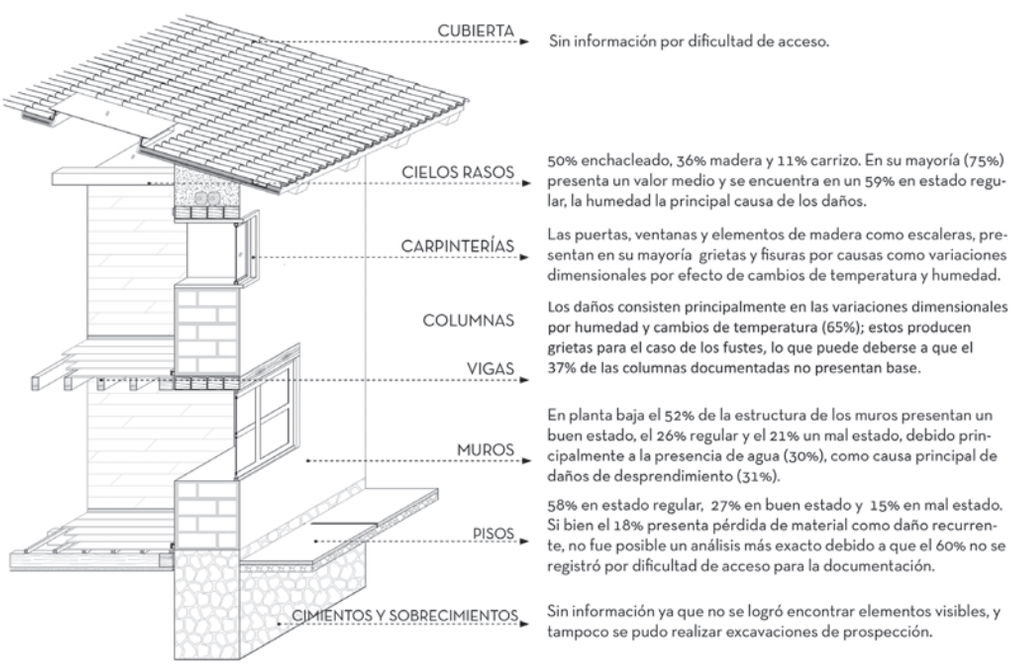


FIGURA 4 Diagnóstico de daños por elemento para el anteproyecto de la Casa-Hacienda de Susudel. Gráfico: Cristian Allaico, 2019. Cortesía del autor.



FIGURA 5 Taller de devolución para el anteproyecto de restauración de la Casa-Hacienda de Susudel. Fotografía: Fausto Cardoso, 2019. Cortesía del autor.



FIGURA 7 Taller de autoformación en prácticas ancestrales con la comunidad de Susudel. Fotografía: Cristian Abad, 2019. Cortesía del autor.

la conservación y restablecimiento de actividades, para un futuro prometedor para todos (fig. 6).

Un tema sensible fue constatar la pérdida de saberes ancestrales, por lo que se planteó realizar un taller de autoformación en prácticas sobre plantas medicinales, tejido artesanal, técnicas de fabricación de adobe y pinturas a base de tierra de colores (fig. 7). Con los participantes se realizó también una lluvia de ideas sobre los criterios a considerarse para mitigar las problemáticas identificadas.



FIGURA 6 Taller de construcción de escenarios con la comunidad de Susudel. Fotografía: Cristian Abad, 2019. Cortesía del autor.

Este proceso condujo a la definición de criterios de uso del inmueble, que, cuidando la conservación de la integridad del bien, potenciaran sus valores patrimoniales. Por un lado, se definieron los límites de actuación con la prevalencia de criterios de integridad y autenticidad, y, por otro lado, se definieron conjuntamente con la comunidad los nuevos usos, en el que se primó la preferencia por un uso ecoturístico para el complejo arquitectónico, en común acuerdo con sus propietarios.

Finalmente, los estudiantes desarrollaron un primer borrador de anteproyecto que equilibrara los diversos insumos trabajados de manera colectiva. Esta propuesta fue puesta a consideración de la comunidad de Susudel en un taller de cocreación llamado "Pequeños y Grandes Arquitectos," realizado con la colaboración de profesores y estudiantes de la Universidad de Hasselt (Bélgica), especialistas en el diseño de interiores, y de la Universidad de Cuenca. En este último taller se compartieron ideas, historias y conocimientos tecnológicos, construyendo distintos escenarios para el patrimonio edificado de Susudel en maquetas de trabajo. El anteproyecto se desarrolló resolviendo los problemas arquitectónicos y atendiendo su tipología, morfología y memoria. Con ello, se concretó la parte constructiva y material del proyecto, así como los planos para una comprensión integral de la propuesta de restauración (fig. 8).



FIGURA 8 Vista del área comunitaria del anteproyecto de restauración de la Casa-Hacienda de Susudel. Ilustración: Cristian Allaico, 2019. Cortesía del autor.

Conclusiones

La falta de uso y mantenimiento de la Casa-Hacienda y las agresiones ambientales a través del tiempo han conducido al bien cultural a un preocupante estado de deterioro, lo que pone en riesgo la supervivencia de sus valores. La labor de las instituciones rectoras del patrimonio hasta el momento ha sido insuficiente y poco clara en cuanto a políticas, recursos o bases legales para la gestión del patrimonio en estos poblados.

Con el proceso participativo que se activó para dar forma al anteproyecto de restauración de la Casa-Hacienda, se abrió el diálogo (academia-instituciones-comunidad) alrededor del enfoque de desarrollo que se ha previsto para Susudel, los criterios de sustentabilidad que cualquier intervención propuesta debería tomar en cuenta y la preocupación sobre el uso de las tecnologías vernáculas y la aplicación de los principios de la restauración y conservación de bienes patrimoniales. La familia propietaria, la comunidad y las instituciones están conscientes de los problemas que enfrenta la Casa-Hacienda, así como de la inminencia de pérdidas irreversibles, de no actuarse oportuna y consistentemente para su conservación. La pandemia de covid-19 detuvo temporalmente el proceso desde marzo de 2020, pero existe apropiación social y voluntad institucional por continuar, avanzando en la reflexión y búsqueda de fondos y de caminos creativos para la concreción de las obras proyectadas.

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Participatory Planning and Management: A Tool for the Conservation and Enhancement of Douar Azrou in Morocco

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Abstract: *Revitalizing an abandoned site 35 km south of Marrakech and generating benefits for the local population through participatory planning and management is the objective of this work. This objective is based on an assertion that the emblematic study site—Douar Azrou—has lost its soul and has deteriorated rapidly, despite the large number of visitors attracted to its natural landscapes and authentic architecture that melts into the mountainous landscape. The architectural ruins reflect the poor management of the site. Most of these structures are made of raw materials (mainly earth and stone), and they constitute an invaluable heritage and a living memory that reflect the know-how of the inhabitants, their social organization, and their daily lives. The aim of this work is to establish a scenario for the redevelopment and rehabilitation of Douar Azrou. This scenario must integrate the site's assets, future challenges, and its potentialities. The management plan will be developed with the active participation of the population, all government agencies active in the region, and heritage experts. After the preparation of the plan, we will assess its impact on private and public initiatives and list all the activities that have been made possible by the better distribution of roles and responsibilities. The site thus can be revitalized by increasing the number of actors who, rather than fighting for selfish interests, share a common vision of the place.*

Resumen: *Revitalizar un sitio abandonado a 35 km al sur de Marrakech y generar beneficios para la población local mediante una planificación y gestión participativas es el objetivo de este trabajo. Este objetivo se basa en la afirmación de que el emblemático sitio de estudio Douar Azrou había perdido su alma y se había deteriorado rápidamente, a pesar del gran número de visitantes atraídos por sus paisajes naturales y su auténtica arquitectura que se funde con el paisaje montañoso. Las ruinas arquitectónicas reflejan la pobre gestión del lugar. La mayoría de estas arquitecturas están hechas de materias primas naturales (principalmente tierra y piedra) y constituyen un patrimonio inestimable y una memoria viva que refleja el conocimiento tradicional de los habitantes, su organización social y su vida cotidiana. El objetivo de este trabajo es proponer posibles respuestas, con el fin de establecer un escenario para la reurbanización y rehabilitación del Douar Azrou. Este escenario debe integrar los activos del lugar, los retos futuros y todas las potencialidades que se puedan desarrollar. El plan de gestión se elaborará con la participación de la población, todos los organismos gubernamentales presentes en la región y los expertos en patrimonio. Tras la elaboración del plan, se consigue evaluar su impacto en las iniciativas privadas y públicas, y se enumeran todas las actividades que han sido posibles gracias a un mejor reparto de funciones y responsabilidades. Así, se podrá revitalizar el sitio aumentando el número de actores que, en vez de luchar por intereses egoístas, compartirán una visión común del lugar.*

Keywords: participatory planning, conservation of architectural values, rehabilitation, abandoned sites, Douar Azrou

Introduction

Architectural and cultural inherited legacy is a resource of collective interests in rural communities (López et al. 2012). Both tangible and intangible qualities can improve the current and future societies of any area (Dela and Anril 2019; Amit-Cohen and Sofer 2016) and enable the history to be honored as the neighborhood becomes a tourist destination and a source of entertainment for locals (Quintana, Diaz-Puente, and Gallego-Morenzo 2022). In fact, a few kilometers from Marrakech, in the majestic setting of the High Atlas in the center of Morocco, is a site of nearly 6 ha that is animated by the juxtaposition of natural landscapes, a source of fascination for many locals and tourists. In this place, known as Douar Azrou, the sky, water, and vernacular architecture unfold in the middle of the mountain, forming a harmonious natural and architectural framework that is surrounded by land dotted with olive groves and orange and lemon trees. This geomorphological name, of Berber origin, translates the shape of the relief itself. Indeed, the village owes its name to the building system that is mainly based on the use of the locally sourced stone and earth (fig. 1).

Historical structures and cultural landscapes are also intrinsically valuable as works of art (Stipe 2003). The recognition of the value of local experiential and place-based knowledge provides more comprehensive understanding on the complex socio-ecological systems (Tan and Ti 2020). In this case, the historical legacy is made up of emblematic landmarks in harmony with these natural elements that punctuate the village or Zaouia (mausoleum), as well as a multitude of buildings constructed according to traditional Berber techniques. The current state of ruin of a number of these landmarks threatens the place as a whole.

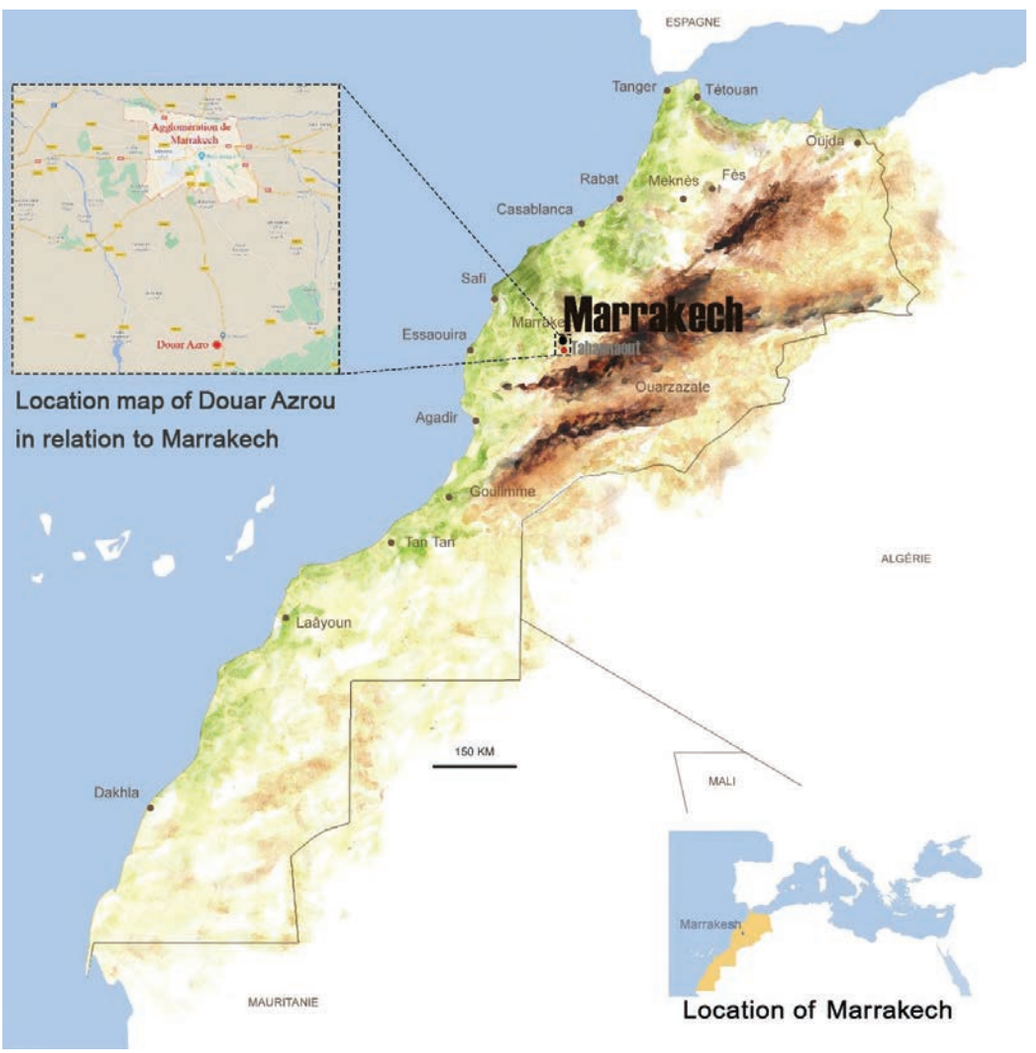


FIGURE 1 Location maps, Marrakech. InterCarte 2004, modified 2020.



FIGURE 2 Panoramic view of Douar Azrou, perched on the mountain. Photo: Karima Mazirh, 2019.

Is the village of Azrou worthy of such a future? Will the COVID-19 health crisis change the perception and future design of this abandoned heritage? Should we not expect a better fate for this place? The outcomes could include a reestablished link between its constituents, a controlled development at the service of its inhabitants, a field open to the genius and creativity of new generations (fig. 2).

Issue

It is well known that cultural and architectural heritage gives value and purpose to local territories (Carpio 2000), raising concerns for the future of these extremely strategic abandoned territories. The aim of this work is obviously not to provide a precise, immutable, and irrefutable solution to the questions raised. It is, on the contrary, to open the debate on the future evolution of these areas following the global recession of the coronavirus and to gather information on how to manage the aftereffects on the douar in order to have a positive impact on the city of Marrakech. We also plan to think about the post-crisis period, the rebound, anticipating how we can take advantage of this rebound. Thus, architecture can be a means to explore more autonomous lifestyles or practices that are more rooted in a local production economic model. Also, rethinking local autonomy can drastically reduce one's carbon footprint, as the construction field represents one-third of global emissions. Our contribution aims to open up a forgotten place, to take advantage of a complex global situation, and to act to revitalize this abandoned site.

Objectives

The objective of the present research is to reinvest the abandoned heritage and reconvert its strategic rights of way by offering a rare ecological commodity for the dense urban fabric of Marrakech. The COVID-19 epidemic, which helped to define this objective, revealed unflattering findings on our methods for conceiving cities and organizing society. A new configuration for effective planning of rural territories must be studied, requiring an understanding of the mutations taking place in these territories and enhancing social connections to improve people's quality of life, which is essential for ensuring sustainable projects (Provenzano, Arnone, and Seminara 2016).

Methodology

There are varied ways of understanding the problems posed by abandoned villages in a post-COVID development vision:

- Research, diagnosis, and analysis phase: This involves collecting data related to the problem and the site by doing preparatory reading of documents, articles, and similar works. This is followed by carrying out fieldwork that will add new information to the collected documentation. This work will be based on the diagnosis and analysis of the site to better understand its characteristics. We will also look at the health characteristics of the coronavirus that will have an impact on the intervention process in the douar;
- Recommendations and guidelines phase: The interpretation of these studies will help in the development of guidelines that highlight the potentialities of the site, remedying its deficiencies and problems in order to propose adequate solutions.

Research, Diagnosis, and Analysis Phase

This phase will constitute an in-depth analysis of the current situation based on the investigations carried out, highlighting the potentialities, constraints, and issues characterizing the area under study in order to enable a more refined understanding of the problem.

General Data on Douar Azrou

The work was carried out to reflect on the different historical dimensions, heritage, physical aspects, natural constraints and nuisances, and socio-economic aspects, while integrating the current health situation.

On a physical level, Douar Azrou is characterized by a strong topography, its plateaus displaying a series of varied landscapes. These views and perspectives combine to create a most

striking setting. The strong natural charge that they provide questions the seriousness of the intervention and its impact on the landscape. The douar is crossed by the Oued Ghighaya, a left-bank tributary of the Oued Tensift, whose source is in the High Atlas and flows into the Tensift, about 10 km west of Marrakech.

The site conceals natural environments of flora and fauna populated with different species of bird as well as a flourishing agricultural activity (poultry and sheep breeding). The village is, moreover, framed by the High Atlas Mountains, the highest massif in North Africa. The major natural constraints are due to the sloping topography of the site. The construction of a car bridge over the lake made it possible to weave its two parts together and facilitate access to the douar. It is important to note that despite the construction of the bridge, access to the village remains difficult.

The history of the village is intimately linked to that of the lake, which has been a vector of civilization since the earliest times. The richness and diversity of the architectural and urban heritage is due to the works bequeathed by history, implementing a traditional know-how that Moroccan craftspeople and *maâllem*s have never ceased to expand, enrich, and preserve (fig. 3). The socio-economic dimension must take into consideration the village as a whole. Its proximity to Marrakech is an asset to be exploited, and, as the village could be a place that rebalances the whole agglomeration, the creation of a tertiary development pole seems to be an imperative for the current development project.

Thus, the main objective of this initial phase of reflection was to think, with a global vision, of all the components of the project. The originality of this approach distinguishes it from those that characterized previous projects undertaken in the village. The result is an overall vision whose main axes can be summarized as follows:

- The village is an ecological space whose preservation is an imperative. The proposal must include the hinterland of the High Atlas Mountains and the surrounding agricultural land in its development;
- It must integrate its two parts, separated by the Ghighaya tributary, into a single development, constituting a center of activity that meets the needs of the local populations and tourists in terms of relaxation, leisure, and culture. Its development should aim to retain the uniqueness of the whole village;
- The architectural ruins, which have great symbolic significance, must be renovated to extend the historical continuity of the site;
- Finally, Douar Azrou must be developed with a view to opening it up to activities with a guaranteed economic return.

Pathology

The architectural ruins reflect the poor management of the site. The main pathologies noted are related to capillary rise, structural cracks, and other deteriorated elements linked to human degradation. The structural pathologies noted are due to the implementation methods of the materials used and the lack of know-how and quality in their execution (fig. 4).

Given the condition of several buildings within the village, some restorations have been carried out. However, these were not successful—several structural elements of the buildings were rebuilt using reinforced concrete and are now in direct contact with the earth, which will eventually cause problems of capillarity, the detachment of plaster, and, in extreme cases, the collapse of the structures.

Recommendations and Guidelines Phase

This phase consists of the presentation of recommendations for defining the future needs of the local population as well as the developmental challenges of the douar. These guidelines will be the subject of consultations between the various parties concerned—namely, the community—with a view to completing, verifying, and validating them.



FIGURE 3 Photo of the old Zaouia in ruins. Photo: Karima Mazirh, 2019.

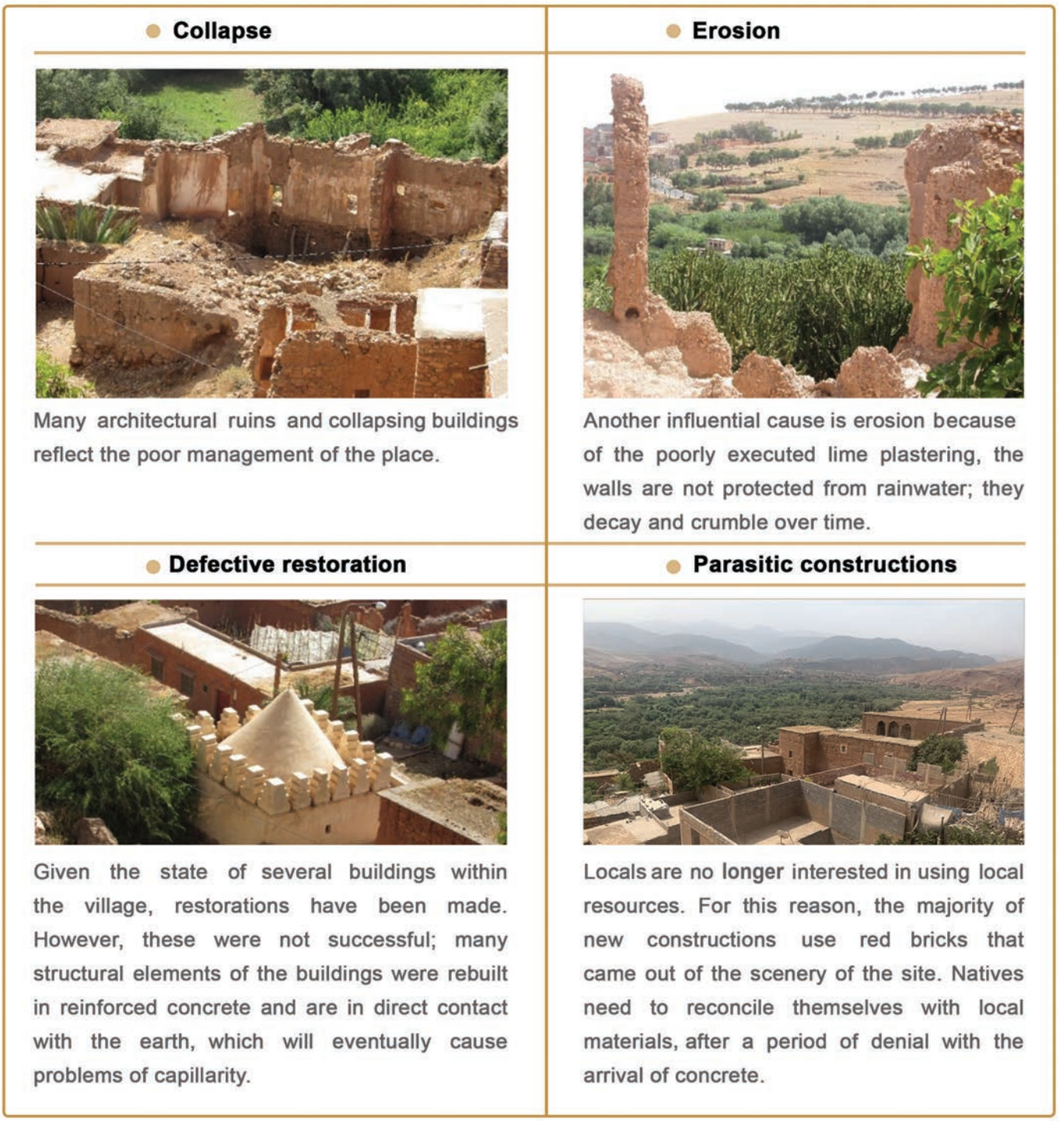


FIGURE 4 Pathology of the douar in images. Photos: Karima Mazirh, 2019.

Proposal of Preservation Measures

In our case, one of the objectives is to stop the degradation of the vegetation and to develop the "green" character of the douar. Vegetation protection measures have to be adapted to local climatic and soil conditions. These processes include maintaining sound agricultural ground surfaces and monitoring the status of the fauna.

Improving Traffic, Infrastructure, and Quality of Life

In order to ensure successful traffic patterns within the douar, we propose adapting the road (RN203) to accommodate at least two lanes for cars and buses and additional lanes for pedestrians and bicycles. The main orientations include the restitution of public spaces, the restoration of existing historical sites, and the introduction of new concepts that will unite the village in a harmonious way, improving citizens' quality of life. The ecological vocations are expressed through the conservation of the existing natural heritage by developing an inventory of species, classifying them according to selection criteria, and then drawing up a plan for their safeguarding. Additionally, the restitution of public space must be addressed, with a view to creating large squares, forecourts, esplanades, and promenades along the banks of the wadi. These developments reinforce the sanitary rules imposed by the current situation. The Zaouia will be restored and the surrounding area will house a symbolic space in the form of a meeting place for the population of the douar, where an emblematic project designed for and by the local community will be erected. In addition, a sports complex for the predominantly young population will be created.

Revitalization of the Abandoned Architectural Heritage

The different forms of local traditional architecture find their full development in Moroccan heritage. While city models tend to invade the architecture of the countryside, Douar Azrou has an artistic expression of its own. Far from giving in to uniformity, it has managed to preserve its identity. The return to the use of local materials is an unavoidable necessity and an action that is in line with sustainable development. This return can only be made by revalorizing earth and stone construction in rural areas, reviving lost construction knowledge, and modernizing traditional construction techniques. The rehabilitation of existing buildings, which will increase the quality of life of rural populations and serve as a campaign to raise awareness in the community, is also essential.

Conclusions

Our research suggests a process of evaluating new methods for revitalizing abandoned earthen heritage. This mechanism proposes a global voluntarist and participatory approach for Douar Azrou, close to the agglomeration of Marrakech. It is based on the effective involvement of stakeholders, governments, and local communities (Mu and Aimar 2022) in the implemented management process (Fredholm 2017).

Many authors have noted the engagement of rural communities in enhancing heritage and creating positive social and economic impact by providing effective solutions (Dente, Bobbio, and Spada 2005; Boniotti 2021). At the end of the study, the management approach seems to answer the questions posed at the beginning:

- Through voluntary participatory action, has it been possible to act on an environment that is essentially ecological, without affecting its constituents?
- Does the proposed development of the douar tend toward the reconversion of an abandoned, unbalanced place in order to restore it and give it a new appeal that meets the needs of the concerned population as well as for the population of Marrakech?
- Have we assumed the weight of history at the site as we want to develop it? Have we inscribed a modern identity that is meant to ensure the continuity of this history and the richness of the constructive cultures used?
- Finally, is the innovative approach relevant enough to ensure the operationality of the urban and architectural choices made for decades to come? Could it possibly be exemplary in nature?

Any affirmative answer to these questions can only be pure speculation, far from the realities and issues that are inescapable in any study project. Nevertheless, it cannot be denied that the development proposals constitute a decisive contribution to the in-depth knowledge of the site. In this context, spatial interventions specific to the architecture and urban planning of the douar could also bring elements of improvement to the quality of life of the population. Indeed, the rich lessons learned from the history of the site and the different construction techniques used have guided the study approach of the douar.

The physical dimension of the site was explored: landscape features, views and perspectives, and climatology revealed the douar's immense assets. Its handicaps and pathologies were highlighted: the architectural ruins, the lack of infrastructure and equipment, and the nuisances affecting the site and its environment have been the subject of inventories and studies to develop concrete proposals for their remediation.

This knowledge of the environment and its immediate and distant surroundings has provided the raw material for highlighting the douar's vocations and potential. These multiple vocations go hand in hand with a quasi-natural sequencing imposed by the current state of the site: a sequence at the foot

of the road, a sequence of the douar's plateaus, and, finally, a panoramic sequence. The theoretical foundations of the project, including the physical elements and the intangible values that have been progressively added, aim to inscribe a future image of the developed site in the memory of the various participants. The water and vegetal elements, the heritage markers and their significant insertion in the development, and the site's architectural identity were introduced as the main referents that should impact the development of the projected human settlements.

Decisions as to which specific projects could be developed are decided not only for reasons of strict functionality and general coherence but also for reasons of composition and current context. These include the development of esplanades, restoration of existing landmarks, infrastructural reinforcement, and realization of a leisure center. Public projects are also planned for the "driving" role they can play in the development of activities: a craft complex, local shops, a sports center, family leisure parks, and a historical museum.

Finally, what is the opinion on this experience of revitalizing an abandoned heritage near a fast-growing urban area such as Marrakech? It is, above all, the ambition of a new dynamic within the urban evolution of Marrakech in general and that of Douar Azrou in particular. The vision of the study is especially concerned with the cultural and socio-economic concerns of tourists and the local population—of rebalancing the components of the site and their tendency to uniqueness and complementarity for the Ochre City.

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Conservación sostenible en comunidad: Aprendizajes técnicos y adaptativos de la conservación de templos andinos en Arica y Parinacota, Chile

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Resumen: *El sector del patrimonio cultural está amenazado. Se enfrenta a un reto crítico dentro de la crisis natural y social global. Surge un nuevo propósito de preservación cultural que se vincula con la profunda necesidad de conservar para las próximas generaciones lo que han dejado las antiguas. Entre los años 2000 y 2020, la ONG Fundación Altiplano ha desarrollado un complejo proceso de aprendizaje a partir de la solicitud de ayuda de comunidades andinas, de Arica y Parinacota, Chile, que luchaban por conservar sus templos de adobe en sus pueblos ancestrales abandonados, raíz y fuente de su cultura y sentido de vida. Una vez resueltas las cuestiones técnicas, el reto se abrió a cuestiones adaptativas relacionadas con el valor trascendente que la comunidad otorga a su patrimonio, la necesidad urgente de conservar los tesoros en riesgo y la contribución del patrimonio cultural a un desarrollo más justo y sostenible del planeta. Este aprendizaje técnico-adaptativo se ha sistematizado en el denominado "Modelo de Conservación Sostenible en Comunidad," que tiene como eje central la necesidad de conservación de las personas y comunidades, en un escenario global con la humanidad tratando de ser sostenible. El modelo se sustenta en 5 piedras: (1) somos un planeta-paisaje patrimonial; (2) la conservación es una necesidad humana profunda; (3) diseñar desde el valor, no desde el problema; (4) conservar es aprender, por eso es una pérdida; y (5) la demanda responsable de conservación/sostenibilidad. El artículo presenta evidencias y análisis de proyectos ejecutados en comunidades andinas, con indicadores y testimonios relevantes del impacto de la conservación del patrimonio en el desarrollo local.*

Abstract: *The cultural heritage sector is under siege. It faces a critical challenge within the global natural and social crises, generating a new purpose for cultural preservation to conserve what has been left by predecessors for future generations. This paper presents the evidence and analysis of projects undertaken in Andean communities, with relevant indicators and testimonies of the impact local development has on heritage conservation. Between 2000 and 2020, the Andean communities of Arica and Parinacota, Chile, asked the nongovernmental organization Fundación Altiplano for help to preserve the adobe temples in their abandoned ancestral villages. These temples are the sources of their culture and sense of life. Once the technical issues were resolved, challenging adaptive issues arose. These were related to the transcendent value that the communities give to their heritage, the urgent need to conserve treasures at risk, and the contribution of cultural heritage to a more just and sustainable future for the planet. The technical-adaptive learning derived from this project has been systematized in the so-called Sustainable Conservation in Community model, which has at its core the need for the conservation of people and communities in a global, sustainable scenario. The model is based on five main pillars: (1) we are a heritage landscape-planet; (2) conservation is a deep human need; (3) design should follow value, not the problem; (4) conservation is learning, but so is a loss; and (5) conservation and sustainability are responsible demands.*

Palabras clave: tradiciones, descolonización, ruralidad, habitar responsable, tesoros culturales

Dedicado a don Mariano Cutipa, Hernán Mamani, Pío Quispe y Telmo Sarauz, maestros restauradores, que nos han enseñado todo esto.

El patrimonio cultural bajo acecho

No lo decimos en el sentido de que los bienes patrimoniales están bajo riesgo, lo cual es tan obvio como inherente al valor patrimonial. Lo decimos parafraseando a Porter y Kramer 2011; Michael Porter, un economista liberal, seguramente no estaba muy preocupado del propósito del patrimonio cultural cuando describía la situación crítica en que quedaba el capitalismo tras el circo financiero del 2008. Una actividad humana tan relevante como es preservar los tesoros heredados de las generaciones pasadas –que genera conocimiento, empleo y bienestar a las comunidades y posee directa relación con sectores económicos al alza, como son el turismo, la educación o la industria cultural o creativa– parece estar desafiada hoy en su propósito, en su razón de ser, al no lograr influir en los comportamientos que van afectando dramáticamente el tesoro al que está llamada a proteger.

Ya en 1998, un valioso estudio acerca de patrimonio cultural y economía del Getty Conservation Institute (1998) planteaba que la sostenibilidad sería factor clave en el desarrollo del sector, generando mayor equidad intergeneracional en la gestión del patrimonio y mayor influencia del sector en el desarrollo humano global. Han pasado más de 20 años; se han publicado miles de estudios académicos, se han dictado cátedras y formado especialistas, se han declarado nuevos sitios patrimonio mundial UNESCO, se han invertido millones en preservación histórico. Sin embargo, no es evidente que el patrimonio cultural esté efectivamente orientado al desafío global de sostenibilidad, logrando instalar agendas políticas y económicas y modificando comportamientos, tal cual lo ha hecho el sector de la conservación natural, pese a contar con gran aceptación y con alta capacidad de movilizar personas.

El crecimiento urbano sigue en su marcha sin contrapeso, afectando la persistencia cultural de comunidades indígenas y campesinas, que se ven forzadas a migrar, con la consecuente pérdida de sus tesoros naturales y culturales. Salvo excepciones, en las ciudades del siglo XXI, la necesidad de crecimiento no tiene mayor limitación en una conciencia patrimonial efectiva. El patrimonio cultural se va refugiando en barrios históricos, circuitos turísticos, museos, creación artística, estudios, conferencias, libros, millones de *papers* e incluso en entretenimiento y moda de alto consumo. Pero el vasto e invaluable "saber habitar" que está en la base del valor del patrimonio cultural no impacta mayormente. Mientras la conservación natural ha modificado el actuar de industrias tan agresivas como energía y transporte, la actividad inmobiliaria es inmune al sentido de la conservación cultural y a la aspiración de un habitar más justo y sostenible.



FIGURA 1 Festival Arica Barroca 2018 en Pachama. Fotografía: Fundación Altiplano.

Para describir esta amenaza desafiante para el sector, focalizaremos el relato en el proceso de aprendizaje vivido por una organización sin fines de lucro, que se creó en el año 2000 para responder a la solicitud de apoyo de comunidades andinas (indígenas) de la región de Arica y Parinacota, en Chile. Parte de los planteamientos compartidos aquí están previamente referidos en otros textos que hemos logrado en equipo desde Fundación Altiplano. Las ideas han ido surgiendo en el camino, sin ninguna pretensión académica y al servicio del ejercicio contributivo de conservar en comunidades (fig. 1). La inspiración surge desde el saber ancestral de las comunidades, únicas voces realmente autorizadas para hablar de conservación. Como dice Adelaida Marka, amiga agricultora de Socoroma: "Conservar no es sólo cuidar nuestros bailes, nuestra arquitectura. Es un todo… Es ofrecer lo que tenemos, lo que hemos sabido guardar y cuidar, nuestros tesoros, el saber compartir, el respeto a la naturaleza y a las costumbres de nuestros abuelos."

Problema-Solución

Para Terra 2012 en Lima, nos correspondió, con Magdalena Pereira, presentar el artículo "Plan de restauración del conjunto patrimonial de iglesias andinas de Arica y Parinacota, modelo de desarrollo sostenible" (Fundación Altiplano 2012).

Se presentaba con el plan en pleno desarrollo, ya instalado el apoyo formal del Gobierno de Chile y de instituciones como World Monuments Fund. En la presentación, se describía el valor excepcional de los templos como complejas manifestaciones estéticas andinas y centros de preservación de la cultura ancestral de sus comunidades.

Los templos andinos de Arica y Parinacota, Chile, se inscriben en el paisaje cultural sur andino de América, escenario de grandes desarrollos culturales prehispánicos y del complejo proceso de mestizaje colonial, tras la invasión y conquista del imperio español en el siglo XVI. Se construyen con piedras, tierra y paja brava, en un paisaje natural excepcional, determinado por la Cordillera de los Andes y el Gran Desierto del Pacífico. Los templos adaptan saberes y costumbres constructivas prehispánicas y generan un circuito de barroco indígena en una periferia del vasto territorio sur andino. Poseen un valor histórico y estético excepcional para la comprensión de la historia y cultura andina. Pero su valor principal radica en el uso sagrado que le dan sus comunidades. Los templos encierran una paradoja notable: siendo un patrimonio generado en la invasión y hegemonía de una cultura conquistadora, formalizan también la resistencia cultural indígena y un proceso de descolonización que aún no está bien atendido, comportándose hasta hoy como refugio de saberes y prácticas culturales ancestrales. En la necesidad de conservación de las comunidades, está ante todo el anhelo del *Suma Qamaña*, o buen habitar de los antepasados (fig. 2).

En el año 2000, se crea la organización para responder a la solicitud de apoyo de comunidades que necesitan preservar sus templos y patrimonio ancestral en el territorio andino de Arica y Parinacota, que Chile anexó tras la Guerra del Pacífico (1879–1882). El trabajo se focaliza especialmente en el llamado Plan Templos Andinos de Arica y Parinacota/Ruta de las Misiones-Saraña (Caminar). Referiremos aquí los principales logros obtenidos entre comunidades, gobierno de Chile y donantes:



FIGURA 2 Pat Taylor y Victor Mollo conversan en Belén durante talleres de conservación de viviendas. Fotografía: Cristóbal Correa para Fundación Altiplano.

- 130 iniciativas dedicadas al desafío de conservación sostenible de los templos andinos, desde estudios a restauraciones.
- Más de 1000 contratos de empleo + aprendizaje con aproximadamente el 70 % de la oferta dedicada a comunidades beneficiarias.
- Más de 1000 personas capacitadas en temas de conservación patrimonial.
- 30 solicitudes de apoyo de comunidades por año.
- Inversión total estimada de USD 13 millones, 80 % de aporte público y 20 % de aporte privado.
- 7 estudios base y 21 estudios para declaratoria de monumento nacional.
- 10 diseños de proyectos de restauración.
- 12 restauraciones integrales de templos.
- 11 restauraciones parciales de templos.
- 15 actuaciones patrimoniales en entornos de templos (plazas, viviendas, cementerios).
- 286 viviendas andinas conservadas.
- 28 conservaciones preventivas + 29 señaléticas patrimoniales en templos.
- 3 museos o centros patrimoniales comunitarios.
- 13 publicaciones.
- 3 proyectos complementarios para la promoción cultural de la región: Arica Nativa, Festival de Películas Nativas (16 ediciones); Arica Barroca, Festival de Arte Sur Andino (8 ediciones); Escuela de Conservación Sostenible Sarañani!.
- Alianzas con Universidades y Organizaciones de Chile, Perú, Bolivia, EE. UU., México, Alemania, España e Italia (2007–2019).
- Investigación aplicada y permanente para el reforzamiento estructural de construcciones de tierra, guiada por el ingeniero Julio Vargas de la Pontificia Universidad Católica del Perú (2007–2019).

En los inicios del plan, la Fundación Altiplano se ocupó especialmente en enfrentar cuatro problemas técnicos que parecían de difícil solución.

- La cuestión metodológica. Enfrentar el diseño de proyectos de conservación con nuevos criterios y metodologías en un país que no tenía un sector de la conservación patrimonial bien instalado.
- La cuestión técnica de la conservación de patrimonio tierra. En una zona altamente sísmica, sin normativas que reconocieran y resguardaran el valor de la construcción en tierra, esto resultó especialmente complejo y sólo se logró con el apoyo de los ingenieros Julio Vargas y Daniel Torrealva, de la Pontifíca Universidad Católica de Lima. No hay espacio aquí para referir esta peripecia, que aportó a la protección de la arquitectura en tierra en Chile. Hasta hoy, el ingeniero Julio Vargas colabora en los proyectos de restauración del plan, lo que merece un especial y sentido reconocimiento.
- La cuestión financiera. Se proponía un plan de inversión de entre 12 y 14 millones de dólares para la conservación del conjunto patrimonial, algo impensable para una región rezagada de Chile.
- El rol de las comunidades en la sostenibilidad del esfuerzo. Esto se proponía con liderazgo en la gobernanza de cada iniciativa y la participación activa mediante empleo + aprendizaje en las restauraciones, en sistema escuela taller.

Pese a lograr superar estos cuatro grandes problemas técnicos e instalarse el plan como una política pública de conservación en Arica y Parinacota, hacia 2014 comienza a generarse una duda persistente en el equipo de trabajo. Frente a los costos estructurales crecientes de la organización y al desgaste de lograr el financiamiento desde el sector público o privado, la pregunta es esencial: ¿Para qué, por qué conservar? ¿Cuál era el real aporte que se estaba realizando en el territorio al conservar este conjunto patrimonial de templos andinos, corazones de sus comunidades ancestrales? Se abrió entonces una sincera reflexión, que iba más allá de estas cuatro cuestiones técnicas que se habían priorizado (fig. 3).

La revolución patrimonial (Fundación Altiplano 2020)

"Patrimonio somos nosotros," sentencia don Mariano Cutipa, maestro mayor y *yaitiri* aymara de la Fundación Altiplano, que ha dedicado cariño y oficio en todos los proyectos logrados a la fecha. El gran aprendizaje tiene relación con el sentido o el propósito de la conservación patrimonial que surge de su hermosa definición. En rigor, hay bastante consenso a nivel académico sobre esto del nuevo sentido patrimonial, desde lecturas poscoloniales o descolonizadoras, pero hay que referirlo lejos de la Academia que ha monopolizado el saber patrimonial. Lo hacemos entonces con los pies en el barro, desde los aprendizajes que hemos tenido en el trabajo directo en las comunidades, y con el aporte fundamental de fabriqueras, mayordomos y maestros mayores del equipo, como don Mario: personas andinas y sabias, herederas de un sentido de la conservación que no tiene nada en común con escritorios y *papers*. Hablaremos de una revolución, un cambio de estado, un camino de aprendizaje entre A y B.



FIGURA 3 Escuela taller para conservación de viviendas andinas de tierra, Belén. Fotografía: Cristóbal Correa para Fundación Altiplano.

Estado A del patrimonio cultural

Definido por la Academia y el poder político: Es eurocentrista; es urbano; asociado al saber-poder académico; separa Naturaleza y Cultura y subdivide en categorías definidas por UNESCO; es público-nacional; es jerárquico y monumental; es utilitarista, para beneficio de otros y para desarrollo-beneficio cultural de las élites que han determinado su valor; es turísticamente o culturalmente rentable. Está asociado a un paradigma de "Sociedad," a progreso, a un estado unitario y estático; con el ciudadano, "el yo," en el centro de la estrategia de conservación: "investigo, publico, visito, capturo valor."

Estado B

Definido por cada comunidad desde su necesidad de conservar-preservar: Es holístico, integra Naturaleza y Cultura en la visión de mundo; es rural; es poscolonial pero

no es académico; es participativo y comunitario, es sencillo y no monumental; es un tesoro heredado para la dignidad de quienes lo custodian y de los que vienen. Está asociado a un paradigma de "Comunidad," a persistencia, al discurrir hacia un futuro mirando el origen. Genera dignificación de los que son pobres a la luz del progreso. Se consolida "el nosotros," con la comunidad en el centro de la estrategia: "convocamos, conservamos, compartimos, persistimos."

En la base de esta revolución está la distinción entre Comunidad y Sociedad planteada a fines del siglo XIX, entre otros, por Ferdinand Tönnies (2002). El paradigma Sociedad es urbano, racional, a gran escala, y avanza/progresa hacia el futuro con pactos formales. Ha predominado desde hace siglos, pero en este siglo XXI luce tan desprestigiado, por no ofrecer el "progreso" como un futuro sostenible. Frente al paradigma de Sociedad, surge fortalecida la Comunidad, que se ocupa de la pequeña escala y lo rural, desde la emoción y con grupos humanos que comparten identidad en su origen e interés común para persistir. Ante la idea de progreso de la Sociedad, la Comunidad subsiste y persiste con la mirada puesta en el origen. Frente al decrecimiento global de la ruralidad, el fenómeno se torna evidente en la urbe, donde renace la escala comunitaria, en barrios, en agrupaciones, en ferias de alimentación saludable y en celebraciones que buscan una raíz nativa. En este escenario, es evidente que el propósito de desarrollo sostenible, que está hoy instalado a todo nivel, aplica más al paradigma de Comunidad que al de Sociedad (fig. 4).



FIGURA 4 Prototipo de ecobaño en Codpa, hecho en tabiquería de tierra (quincha). Fotografía: Cristóbal Correa para Fundación Altiplano.

El ejemplo

La reflexión se intenta responder desde un modelo o ejemplo, que se nombra inicialmente "Porque me enamoré de ti," para luego tomar el pomposo nombre de "Conservación Sostenible en Comunidad." El ejemplo se sustenta en cinco ideas o piedras fundamentales.

1. Territorios Paisajes Sagrados. No hay recursos, hay tesoros, naturales y culturales, con comunidades que dan significado y sentido a su valor, para el buen habitar de las nuevas generaciones. Descolonización geopolítica y visión nativa del Territorio-Planeta (no étnica, sino ética, regalo de las comunidades).
2. La conservación patrimonial como necesidad humana. Se encuentra en relación directa con la necesidad de sostenibilidad: lograr que los tesoros naturales y culturales heredados estén disponibles para quienes vienen. Una necesidad no descrita pero que está asociada a todas las necesidades profundas que refieren economistas alternativos como Manfred Max-Neef (1993).
3. Diseño desde el valor. La conservación patrimonial exige una contemplación profunda del valor en riesgo, antes de idear soluciones. Se propone la fórmula básica de diseño: Valor + Necesidad (comunidad) + Riesgo = Iniciativa de conservación sostenible (Fundación Altiplano 2019).
4. La demanda responsable. La comunidad que ejerce la custodia de un tesoro en riesgo puede aprovechar la

demanda de industrias económicas que buscan "valor conservado," generándose sostenibilidad económica para la conservación. Aquí son relevantes industrias al alza como educación, vivienda, alimentación saludable, turismo responsable, biomedicina, industria cultural o economía creativa, tecnología, gestión de residuos y energías renovables.

5. La conservación como proceso adaptativo. En términos de liderazgo adaptativo (Heifetz y Linsky 2003) la conservación patrimonial no es un cambio técnico, sino un aprendizaje largo e incierto, con pérdidas, facciones enfrentadas y alto riesgo de fracaso antes de lograr el propósito o desafío de transformación que supone pasar de la actual economía insostenible a una economía sostenible.

Una de las aplicaciones interesantes de este modelo o ejemplo es la propuesta de criterios para el diseño de iniciativas de conservación. Se propone complementar los cuatro criterios tradicionales o recurrentes, recomendados desde la academia o el sector del patrimonio cultural (Investigación interdisciplinaria-intersectorial, Autenticidad/Originalidad, Mínima intervención y Reversibilidad), con otros cinco criterios que ayuden a orientar la conservación patrimonial al propósito de un habitar más responsable y un desarrollo más justo y sostenible:

- Comunidad. Lidera la valorización y custodia los tesoros en riesgo, desde su saber y necesidades. Reinstala a la academia y la institucionalidad del patrimonio en la situación de colaboración que le corresponde y reorienta la conservación hacia el habitar responsable.
- Territorio o Paisaje Sagrado. Visión holística, integradora y descolonizada del patrimonio natural-cultural.
- Sostenibilidad. La actuación patrimonial como parte de un propósito mayor de desarrollo sostenible de la comunidad que ha decidido conservar sus tesoros o herencias.
- Seguridad. La conservación exige prestar especial atención a los agentes de riesgo que afectan el uso seguro y responsable de los tesoros por parte de la comunidad, en una escala de tiempo adecuada a su evolución histórica.
- Aprendizaje/Escuela. La conservación como aprendizaje compartido, entre especialistas y comunidad, que comparten roles y beneficios en el proceso (fig. 5).



FIGURA 5 Señora de Tacora ingresando a su casa, preservada por el programa de capacitación. Fotografía: Cristóbal Correa para Fundación Altiplano.

Conclusiones

La pandemia covid-19 ha afectado todo lo que teníamos previsto, incluso este valioso encuentro Terra. Desde la pausa de la pandemia, la revisión del caso es especialmente interesante. El plan ha iniciado en 2019 un nuevo ciclo con una organización andina, que reúne a comunidades de los templos que se han ido conservando. La Fundación apoya en la formulación de un nuevo camino para los próximos años. Y se vislumbran cuatro cuestiones adaptativas complejas, que exigirán un nuevo proceso de aprendizaje compartido:

1. Lo económico. La cuestión de la sostenibilidad económica debe ser integrada con mucha mayor fuerza y profundidad en el ejercicio de la conservación patrimonial, desde la data de base a la formulación de las iniciativas y planes. ¿Cuánto valor hay en lo conservado? La Economía de la Conservación tiene un capítulo reservado para el patrimonio cultural. Y la conservación es parte de una nueva economía femenina, que se va instalando.

2. El habitar responsable como cuestión central. Conservar patrimonio es algo tan concreto y amigable que cuesta entender que su propósito esté entre libros y tratados, o en los planes de negocios de industrias de alto impacto como el turismo. Conservar para un mejor habitar. La contribución de la conservación para restaurar una vida más comunitaria, justa y responsable es real, desde las materialidades y sistemas constructivos que recuperan vigencia hasta la vocación de los pueblos y de la ruralidad frente al cambio climático y la custodia de los territorios.
3. Empleo + Aprendizaje. Como humanidad estamos en proceso de dejar muchas tareas en manos de la inteligencia artificial. Es un hecho. La conservación es uno de los sectores que valorará y preservará el oficio y saber artesanal, como un bien preciado, especialmente aplicable en educación complementaria y empleo digno.
4. Nativización. La palabra no está registrada en idioma español, pero está en uso. Hay algo esperanzador en la descolonización cultural y el reconocimiento indígena que se instalan con fuerza, masivamente, en las nuevas generaciones urbanas, que caminan en busca de origen y sentido. Las comunidades que conservan les estarán esperando…

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PART 6

Cultural Landscapes and Cultural Routes / Paisajes y rutas culturales

Qanat as Cultural Landscape in the Earthen Cities of Central Iran

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Abstract: *Qanats are human-made structures that, using gravity, conduct water from alluvial aquifers at the heads of valleys over long distances and along underground tunnels. In the dry and hot regions of Iran, they constitute one of the main infrastructures for the sustainability of historical cities, and thus their study helps outline regional dynamics and urban morphologies. The system, perhaps 5000 years old, has been respected and preserved in terms of design, technology, building materials, traditions, techniques, and management systems, as well as through intangible heritage knowledge of the natural environment, construction technology, and the Indigenous culture. This paper is a study of the effect of the human hand on the bare lands in and around the city of Yazd, Iran, that has shaped a unique cultural landscape. Yazd is a noteworthy case study as it evolved from a qanat settlement pattern with an urban core where the bazaar is the axis for social interactions. This core is then surrounded by central-courtyard houses and gardens, followed by farmlands with their own water organization systems that indicate the layout of the qanats. The mixed methodology of Yazd's qanatscape case study research consists of a survey of oral narratives, image analysis, and the interpretation of old maps, aerial photos, and satellite images in order to discover the patterns and values of these inherited structures in the arid and semiarid region of Iran.*

Resumen: *Los qanats son estructuras hechas por el hombre que utilizan la gravedad para conducir el agua por túneles subterráneos desde los acuíferos aluviales en la cima de los valles hasta lugares distantes. En las regiones secas y cálidas de Irán, constituyen una de las principales infraestructuras para la sostenibilidad de las ciudades históricas; por tanto, definen la dinámica regional y las morfologías urbanas. El sistema, que tiene unos cinco mil años de antigüedad, fue respetado y conservado en lo que respecta a su diseño, tecnología, materiales de construcción, tradiciones, técnicas y sistemas de gestión, al igual que como patrimonio intangible de conocimiento del entorno natural, la tecnología de la construcción y la cultura indígena. En este artículo, se analiza el efecto de la mano del hombre sobre las tierras desnudas de la ciudad de Yazd y sus alrededores, el cual dio forma a un paisaje cultural único. Yazd es un caso de estudio destacable, ya que evolucionó a partir de un patrón de asentamiento alrededor de un qanat con un núcleo urbano en el que el bazar es el eje de las interacciones sociales. Está rodeado, primero, por casas con un patio central y jardines, y más allá, por tierras de cultivo con su propio sistema de organización de agua que indica la distribución de los qanats. La metodología combinada que se implementó para investigar el paisaje de qanats de Yazd consiste en el estudio de narraciones orales y análisis e interpretación de imágenes en mapas antiguos, fotos aéreas e imágenes satelitales, con la finalidad de descubrir tanto patrones como valores de estas estructuras heredadas que se encuentran en la región árida y semiárida de Irán.*

Keywords: qanat (kariz), cultural landscape of the arid region, earthen architecture, qanatscape, water crisis, sustainable qanat-based towns, green infrastructure of desert cities, qanat network

Introduction

Considering the history of sustainable cities in the center of Iran, qanats contribute to a vital infrastructure that make possible the settlement of dry lands that are far from rivers. The paradise-model cities like Yazd, in central Iran, are situated in the dry plains between high mountains and two of Iran's largest deserts, Dasht-e Kavir and Dasht-e Lut. The region is characterized by a typical desert climate with cold winters and hot and dry summers, low relative humidity (about 60% in winter and 20% in summer), and low annual precipitation (Ghobadian 2009). Therefore, due to fast evaporation, there are no permanent rivers or lakes in central Iran. But ingenious Persian ancestors (3000 years ago) were the first to excavate the waterways beneath dry fountains to access fresh water, inventing the qanat, which became part of the main infrastructures of countless Persian settlements (Labbaf Khaneiki 2020).

Schematically, a qanat is a horizontal tunnel with vertical shaft wells that conveys groundwater from mountain slopes to plains that are suitable for settlements (fig. 1). The vertical shafts provide ventilation and access for cleaning, maintenance, and the immediate removal of spoil (Semsar Yazdi and Labbaf Khaneiki 2017) (fig. 2). Because of this development in construction, the qanat became a decisive part of the infrastructure that largely replaced nomadic herding with settled farming (Estaji and Raith 2016).



FIGURE 1 Goharriz qanat and Jupar city, Kerman, Iran, the typical landscape of qanat territory in central Iran, 2014. Photo: © S. H. Rashed.

A Brief History of Qanats

Qanat[1] technology was already known in Iran by the sixth century BCE, when Indo-Iranians began to settle as agriculturists (English 1998). They were crucial elements of the Persian landscape, described by the Greek historian Polybius (ca. 203–120 BCE). The technology spread well beyond the confines of the Iranian Plateau under the Achaemenids (550–331 BCE), when the Persian Empire extended from the Indus to the Nile. "The Achaemenid rulers provided a major incentive for qanat construction by allowing qanat builders and their heirs to retain profits from newly built qanats for five generations" (Semsar Yazdi and Labbaf Khaneiki 2017). Consequently, thousands of new settlements were established and others were expanded. Qanats were constructed from Mesopotamia to the shores of the Mediterranean and southward into parts of Egypt and Morocco. "They were particularly important sources of water in the foothills of eastern Iraq, the Syrian Desert, and the Hadhramaut. In Yemen and in Oman, qanats are locally called *Falaj* (pl., *Aflaj*)" (English 1998).

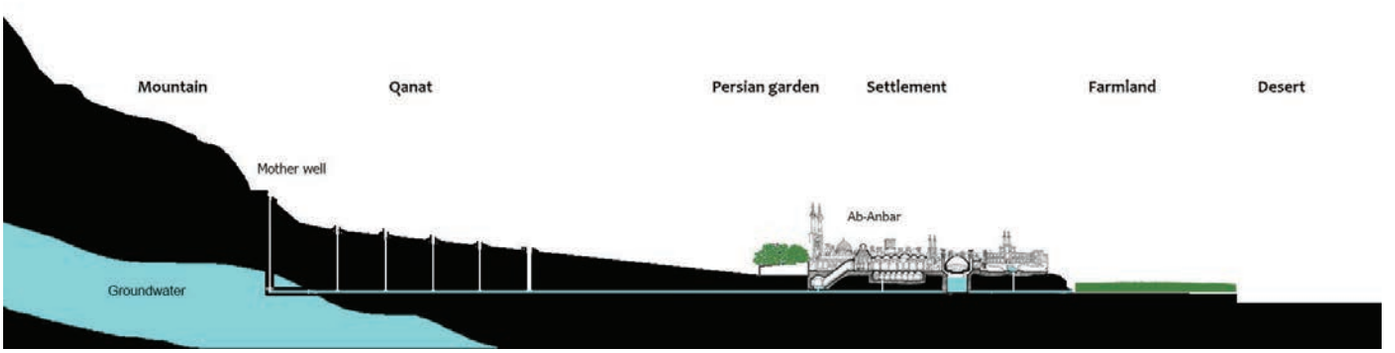


FIGURE 2 Profile of qanat and water connection under a city in an arid region. Illustration: Malihe Chamani, 2020.

The Four Elements of Earthen Architecture and Landscape

Qanats conduct water to dry lands to give form and meaning to the earth, helping to create sustainable cities and architecture and assisting settlements in their adjustment to harsh climate conditions. Four natural elements—water, wind, soil, and sun—integrate to generate new landscapes and architecture. Qanats were conceived as the means to conduct water, *Badgir* (windcatchers) were designed to move air naturally, soil is the vernacular building material, and the sun hardens earthen building materials and determines the architectural form and orientation of urban developments. The results are transformed vernacular landscapes, including architecture built according to geographic context and the arid nature of the land.

Registered in 2017 on UNESCO's World Heritage List, Yazd is an accurate example of a settlement in the desert that was formed based on those four elements. Despite the lack of permanent surface-based water sources in this region, fresh water is conducted by qanats from the underground water table for the supply and prosperity of *Abadani*[2] (Moeen 1972). *Badgir*, which circulate air above a qanat water pool (Honari 1989), are connected at the basement level of central-courtyard houses that are built from clay bricks, a vernacular material with a high heat resistance factor. This system brings earthen and natural-based architectural elements together with the environment to produce a zero energy, sustainable, and climatically pleasant city (figs. 3, 4).



FIGURE 3 A central-courtyard house in Yazd and, at upper left, a *Badgir* (windcatcher) that connects to the underground water canal and yard to circulate fresh air. Photo: Malihe Chamani, 2016.

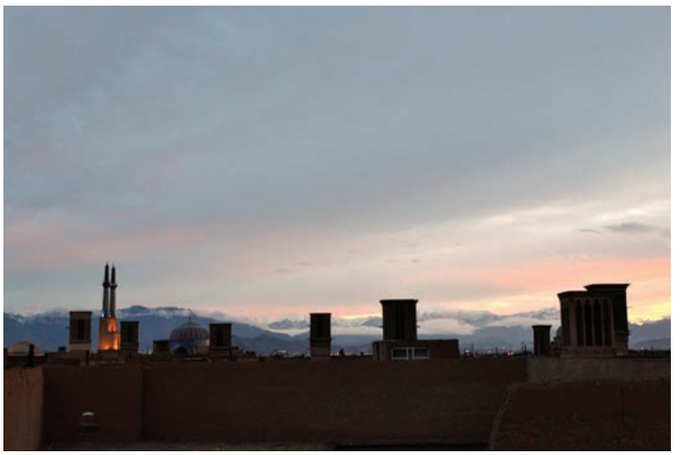


FIGURE 4 Historic cityscape of Yazd with Shir-Kooh Mountains in the background and windcatchers along the skyline. Photo: Malihe Chamani, 2016.

Qanat-Based Spaces

The core zone of Yazd is located on several qanats whose branches are connected to water spaces beyond the urban area, providing irrigation for the lower agricultural farmlands. The traces of some of these qanats, dating back to the fifth and sixth centuries, can be found in ancient quarters of the city and in neighboring towns and villages such as Zarch, 17 km away (Semsar Yazdi and Labbaf Khaneiki 2017).

The place where qanat water springs from the ground is the starting point for the generation of a variety of spaces with diverse functions and meanings. *Maqsam* (water distribution pools), *Ab-anbar* (water-storage spaces), *Meydan* (plazas), *Yakhchal* (icehouses), *Hoz-khaneh* (pool houses), *Hamam* (public baths), watermills, Persian gardens, and gray-water pools, among others, are the main qanat-based spaces in a city.

Spaces that have been created by water and qanats in desert cities have vital roles not only in the quality of the landscape but also in social cohesion and local identity. "Like all water technologies, qanats require a nexus of environmental and social conditions in order to be effective over time" (Majid Labbaf Khaneiki, pers. comm.) (fig. 5). On the Iranian Plateau, reliance on qanats promoted high levels of social and ecological adaptation. Qanats inspired a need for social cohesion that permeated virtually all areas of community members' lives.

Qanat as Cultural Landscape through Time

A cultural landscape is defined as an area, as perceived by people, whose character is the result of the action

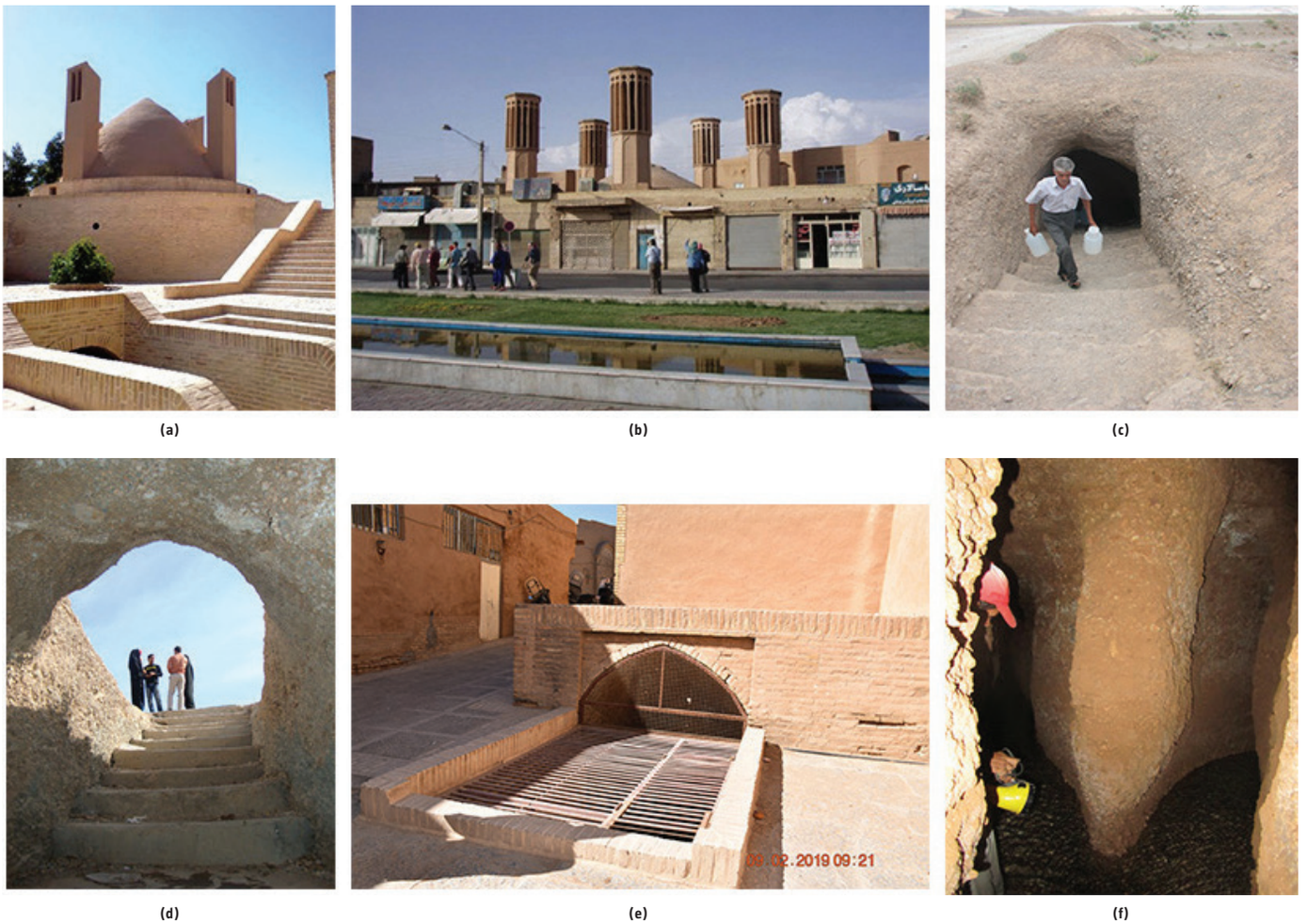


FIGURE 5 Spaces created by or around qanats: (a) *Ab-anbar* (water storage) in Meybod, (b) Amir-Chakhmagh plaza in the center of Yazd with water axis, (c) *Payab* (water access) for the Hasan Abad Mooshir qanat around Yazd, (d) view from water canal of Payab of Hasan Abad Mooshir qanat, (e) *Payab* in Yazd, and (f) the interior intersection of two qanats, Joopar, Kerman, Iran. Photos: Malihe Chamani, 2012–2019.

and interaction of natural and/or human factors (see the European Landscape Convention of the Council of Europe, 2000). Despite the existence of diverse cultural landscapes in Iran, this term was not part of Iran's conservation projects until the 2003 earthquake in Bam, which resulted in the inscription of Bam and its surroundings on UNESCO's World Heritage List as a cultural landscape in 2004. The vital role of qanats in the long life of Bam's cultural landscape was mentioned and published by the research committee in charge of the reconstruction of the ancient city of Bam (UNESCO 2008). However, there are no frameworks for including practical experiences in landscape and regional planning of Iranian cultural landscapes located in the arid zone. The old city of Yazd and its surrounding green qanat-based districts are paragons of live cultural landscapes, as yet unknown features for decision makers.

"It is undeniable that the existence of Yazd and its gardens are dependent on the presence and ability to distribute water of qanats" (Bharne and Bogosian 2010). Qanat canals, essential for the Persian gardens, urban forms, and quality of life, represent the concept of cultural landscape that also determines the ecological and green-area capacity of the city.

By 1500 CE, the historic city of Yazd had expanded to more than twice its original size, avoiding the northern desert and dissolving into the outer agrarian villages. Further growth continued toward the southwest until circa 1925, and by 1979 (nearing the end of the White Revolution in Iran) it

had enclosed the historic core to the east and west. Over the last three decades, rapid urbanization has transformed Yazd into a sprawling modern city about thirty times its original size (Kalantari and Hatami Nejad 2007).

The images in figure 6 demonstrate Yazd's development and the disappearance of qanat-based green areas from 1956 to 2016. The form and ratio of green spaces of the city demonstrate natural structures and a paradise-like settlement. Every qanat made the green spaces according to a pattern of hierarchy and distribution systems. However, population growth increased the demand for water and agricultural products, and the mismanagement of water made the situation more controversial. As locals have reported, these issues have resulted in the city becoming climatically less comfortable, especially in times of global warming.

In 1986, the vast garden area in the southeast disappeared as the water was diverted by electrical pumps to the city's industrial zone. Although all urban and rural households in present-day Yazd are supplied with drinkable water by conventional water pipes, the construction of dams and the vast digging of deep wells to catch water for agricultural and industrial purposes in such an arid region has caused irreparable damage to the environment and the context of qanats. Waterlessness is defined not only according to its climatic context but also by its socio-technological milieu.

The arid belt is expanding, and some predict that drier and drier seasons are on the horizon. In addition to the mismanagement and ignorance of cultural landscape issues in regional and urban planning for such developing and industrial Iranian cities, the economic situation and decision makers' short-term views have been a disappointment. These issues play out when considering the status of qanats' destruction, underground water drought, and surface cracks in the earth around cities.

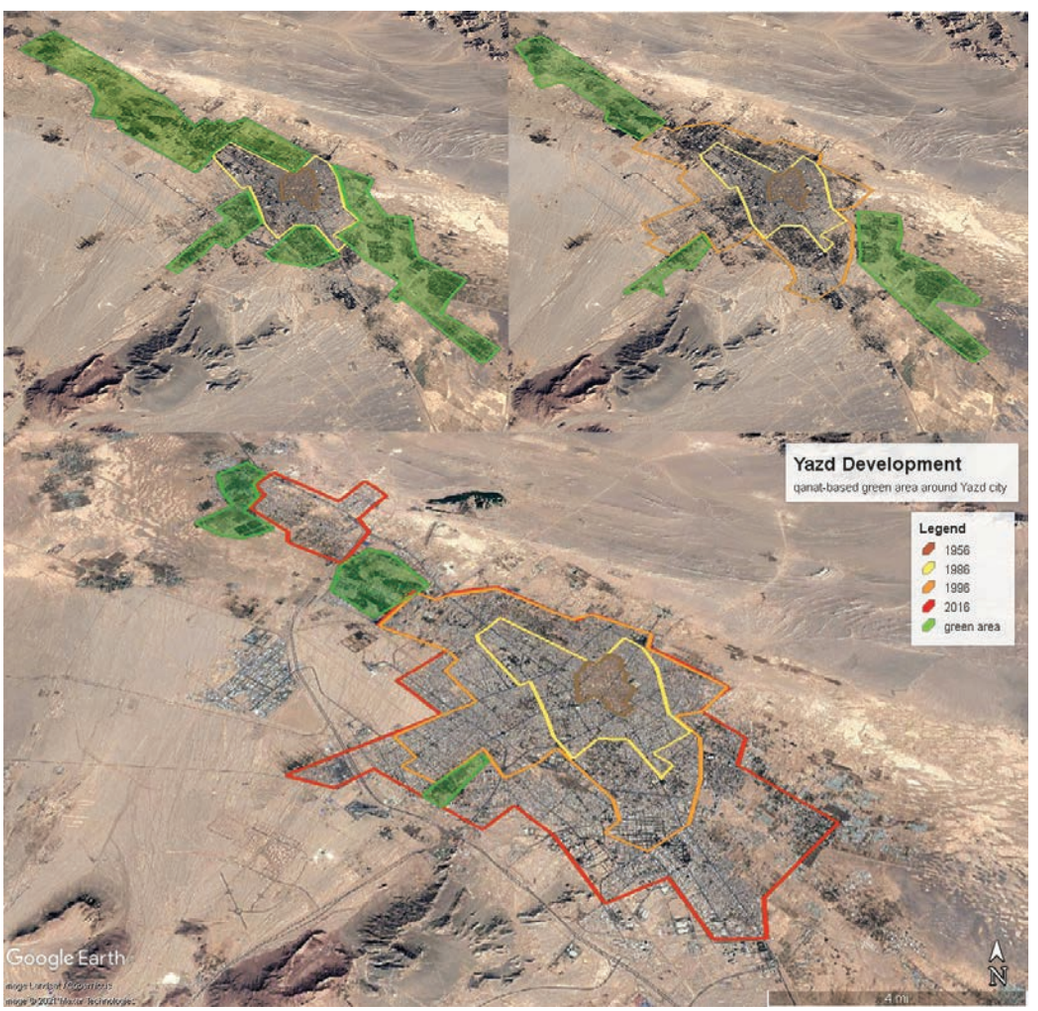


FIGURE 6 Aerial views of Yazd city development (1956–2016), showing the ratio reduction of green space to city development in the middle of the desert region. Photos: Google Earth Pro.

Qanatscape: The Archetypal Landscape in Arid Regions of Iran

Without the existence of qanats, the Iranian landscape would be dominated by vast dry lands. The oasis landscape that had been created by qanats is characterized by a common pattern. Located far away from natural rivers, the "hidden water" (Al-Karaji 1994) of the qanat infrastructure dictates a regional order and structure for the settlements. It establishes a system of landscape hierarchy through water cycles and social organization, collaboration, responsibility, cohesion, identity, and the sense of belonging to a place.

When considering Iranian landscapes holistically, we can begin to understand how they have been fundamentally shaped by the qanat system. We realize that qanats enable the habitation and cultivation of the land, and that the widespread pattern of such integrated landscapes follows a unique inner logic that serves as a tool for assessment, planning, decision making, and design. This all leads us to refer to these landscapes as qanatscapes. Taking all the natural conditions, the building techniques, and spatial effects of both agricultural land and settlements into account, the qanatscape needs to be explained across three scales: the regional, geographic scale (macro landscape); the scale of cultural landscapes (middle landscape); and the scale of sites (micro landscape).

Across Iran, several qanat territories are distinguishable by the sharp contrast of green and dry lands, and some well-ranges in plains are identified between high mountains and oasis-model cities or villages. In the regional view of the qanatscape, water and blue surfaces are not visible. But by zooming in to the area's middle scale, water is touchable and flows on the surface to create culture, life, and landscape. The middle scale of the qanatscape pattern is based on the green areas of vegetation, which are essentially the results of a conscious spatial ordering through the hierarchical distribution of water. The qanatscape pattern generally follows a quadrilateral model that is observed as a micro landscape of Persian architecture and urbanism.

Conclusion

Qanats define a settlement's lifeworld on the plateau by (1) determining settlement location, (2) structuring the built environments within settlements, and (3) requiring social cohesion for system maintenance, water allocation, distribution, and use (fig. 7). This lifeworld frames the horizon of everyday life in dry plateau settlements, encompassing residents' firsthand involvement with the practical world, the world of values, and the world of goods (Buttimer 1976; Seamon 1979).



(a)



(b)

FIGURE 7 (a) The qanat water mouth holy place made by locals and (b) the religious relationship of locals with qanat water, Gouharriz qanat, Joopar, Kerman, Iran. Photos: Malihe Chamani, 2012.

Today, without the vital, multifunctional landscape infrastructure of the qanatscape, places that are far away from permanent sources of surface water either are limited to low-yielding agriculture in villages or have been completely abandoned in cities. Several qanats are registered on the World Heritage List, such as those at Zarch and Qasabeh. These are conserved and rehabilitated partially to meet the basic criteria for maintenance, although they do not function in municipal and regional planning as paths to a sustainable future. As local residents have reported, this ignorance has resulted in the city becoming climatically less comfortable, especially in times of global warming.

The qanatscape forms a remarkable landscape typology. From its infrastructural qualities to its social sensitivity, it is an underinvestigated field of research. It provides a rich body of knowledge for both landscape research and practice and has the potential not only to rehabilitate an expansive and effective heritage infrastructure but also to inspire new investigations and landscape systems through design and planning principles.

Notes

1 From a Semitic word meaning "to dig," in Persian "Kariz" (Semsar Yazdi and Labbaf Khaneiki 2017).

2 *Ab* means "water," and *Abadi* in Persian refers to a dry land turned permanently green by water.

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Lo Manthang: A Cultural Landscape Surviving between Tradition and "Development"

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Abstract: *The earthen walled city of Lo Manthang, capital of Upper Mustang in northern Nepal, is strategically located on the ancient trans-Himalayan trade route between India and Tibet. This route was instrumental in the exchange of ideas, beliefs, commodities, and people that shaped the present cultural landscape of Lo. The Lo cultural landscape includes the walled settlement, farmlands, irrigation channels, ancient ruins, and living culture, an outstanding representation of the interaction between human and nature in a high-altitude arid environment. It is the only surviving medieval fortified settlement in the Tibetan region and one of the last remnants of traditional Tibetan life. The closure of Tibet due to the 1950s political conflict halted the trade and the economy of Lo Manthang until tourism was introduced in the early 1990s. Its remoteness and isolation for almost five decades allowed for the preservation of its unique heritage. However, Lo is changing at an unprecedented pace, which is having an impact on its historic, sociocultural, and physical settings. Until recently Lo was only accessible by a four-day hike, but now it can be reached in six hours by vehicle. Despite the changes, the cultural landscape of Lo Manthang still retains its major characteristics. This paper explores the impact of new "development" activities on the cultural landscape of Lo Manthang. Strategic planning is needed to ensure that any future development activity is planned with local participation to preserve the cultural landscape that attracts visitors and is a major source of the local economy.*

Resumen: *La ciudad amurallada de tierra de Lo Manthang, capital de Mustang Superior al norte de Nepal, se encuentra ubicada estratégicamente en la antigua ruta comercial que atraviesa el Himalaya para unir la India y el Tíbet. Esta ruta fue fundamental para el intercambio de ideas, creencias, productos y personas que dio forma al paisaje cultural actual de Lo. El paisaje cultural de Lo incluye el asentamiento, los campos de cultivo, los canales de riego, las ruinas antiguas y la cultura viva, una representación impresionante de la interacción entre el hombre y la naturaleza en un entorno árido de gran altitud. Se trata del único asentamiento medieval fortificado en la región del Tíbet y uno de los últimos vestigios de la vida tradicional tibetana. El cierre del Tíbet, a causa del conflicto político de la década de 1950, interrumpió el comercio y la economía de Lo Manthang hasta que se introdujo la actividad turística a principios de la década de 1990. La ubicación remota y el aislamiento de casi cinco décadas de este sitio patrimonial único permitieron su preservación. Sin embargo, Lo está cambiando a un ritmo sin precedentes, lo cual está teniendo un impacto en su entorno histórico sociocultural y físico. Hasta hace poco tiempo, solo se podía llegar a Lo después de una caminata de cuatro días, pero actualmente se puede llegar en un viaje de seis horas en vehículo. A pesar de los cambios, el paisaje cultural de Lo Manthang aún conserva sus características más importantes. En este artículo, se analiza el impacto de las nuevas actividades de "desarrollo" sobre el paisaje cultural de Lo Manthang. Se necesita una planificación estratégica para garantizar que cualquier actividad de desarrollo futura se planifique con la participación de la población local, con el fin de preservar el paisaje cultural que atrae a los visitantes y que es la principal fuente de ingresos de la economía local.*

Keywords: Lo Manthang, Mustang, cultural landscape, Nepal

Introduction

The strategic location of Nepal—between two larger and influential countries, India and Tibet (China)—has resulted in the growth of prosperous towns and important cultural centers along the ancient trade routes between these countries. The exchange of goods and culture also helped develop unique cultural landscapes that have withstood centuries of history. However, these historic towns are now transforming at an alarming rate, with this transformation threatening the natural environment, the built heritage, and the people in an irreversible process. In developing countries such as Nepal, little effort has been made to consider these unique landscapes as cultural centers or heritage worthy of conservation. This neglect and lack of appropriate development guidelines may have dire consequences, with under-resourced local authorities undertaking projects such as road construction. For example, the initial plan for the road to Lo Manthang widened the existing historic trail, bringing trucks within meters of the historic wall of Lo Manthang and ancient chortens (Buddhist votive structures), threatening their structural integrity. This road was later moved away from the historic walls after serious criticism from the tourism industry and conservation experts (Chapagain 2007).

Lo Manthang, Upper Mustang

Upper Mustang, once a cultural center, lies at the border of Nepal and Tibet (China) on the ancient trade route between India and Tibet. It lies in the rain shadow of the Himalayan range, with a desert-like climate that is cold and semi-arid with low annual precipitation. The combined effect of the intense sun and strong winds has resulted in the region's distinctive rugged and "lunar" landscape (fig. 1).

This region, also known as the Kingdom of Lo, covers an area of 2500 km^2. Its capital, the earthen walled city of Lo Manthang, lies at an altitude of 3900 m (fig. 2). Upper Mustang, along with its capital, Lo Manthang, was inaccessible to outsiders after China closed the Tibetan border following the 1950s political conflict. As a result, trans-Himalayan trade collapsed and the economy came to a standstill until the region reopened for tourism in the early 1990s. Its remoteness and isolation for almost five decades allowed for the preservation of its unique built form and a traditional way of life that have become major tourist attractions.

Historical Setting: The Kingdom of Lo

According to earliest available sources (Chinese Dunhuang annals, Tibetan white annals, and the chronicles of Ladakh), this region was under the Tibetan Empire in the seventh century (Dhungel 2002). After the disintegration of the Tibetan Empire in the tenth century, it became one of the districts of Nga-ri (Western Tibet). From the mid-fourteenth century, Lo gradually emerged as an autonomous power and ultimately became an independent kingdom in 1440, with Ama-pal as its first king. Strategically located on the major north–south trade route, the new kingdom quickly became a military power and religious center with a vibrant economy, establishing itself as a strong regional authority, a position it retained throughout the fifteenth and sixteenth centuries. From the mid-sixteenth century, Lo was under the kingdom of Jumla (western Nepal). In 1789, the Lo region was annexed into the greater Kingdom of Nepal and became known as Mustang under the newly established Shah dynasty. Despite its long-standing cultural and political links with Tibet, Lo became a part of Nepal. However, due to its remoteness from the central powers, the rulers of Lo maintained relative autonomy despite depending on other power centers, including Nepal.



FIGURE 1 Upper Mustang landscape, with ancient chortens in the foreground. Photo: Sirish Bhatt.

Culture and Society

The Lo area is inhabited by the Lo-pa people, who are culturally, linguistically, and ethnically related to the people of western and central Tibet and speak Lo-pa, a form of Tibetan dialect. The population of Mustang District is 13,452 (Central Bureau of Statistics 2012) and that of Upper Mustang is approximately 3834, a number that is decreasing.[1] During the winter months more than half of the population migrate to the southern lowlands to escape the harsh living conditions. These seasonal migrations are slowly turning into permanent shifts, with more opportunities to be found in the lower lands. In recent years, there is a growing trend of the

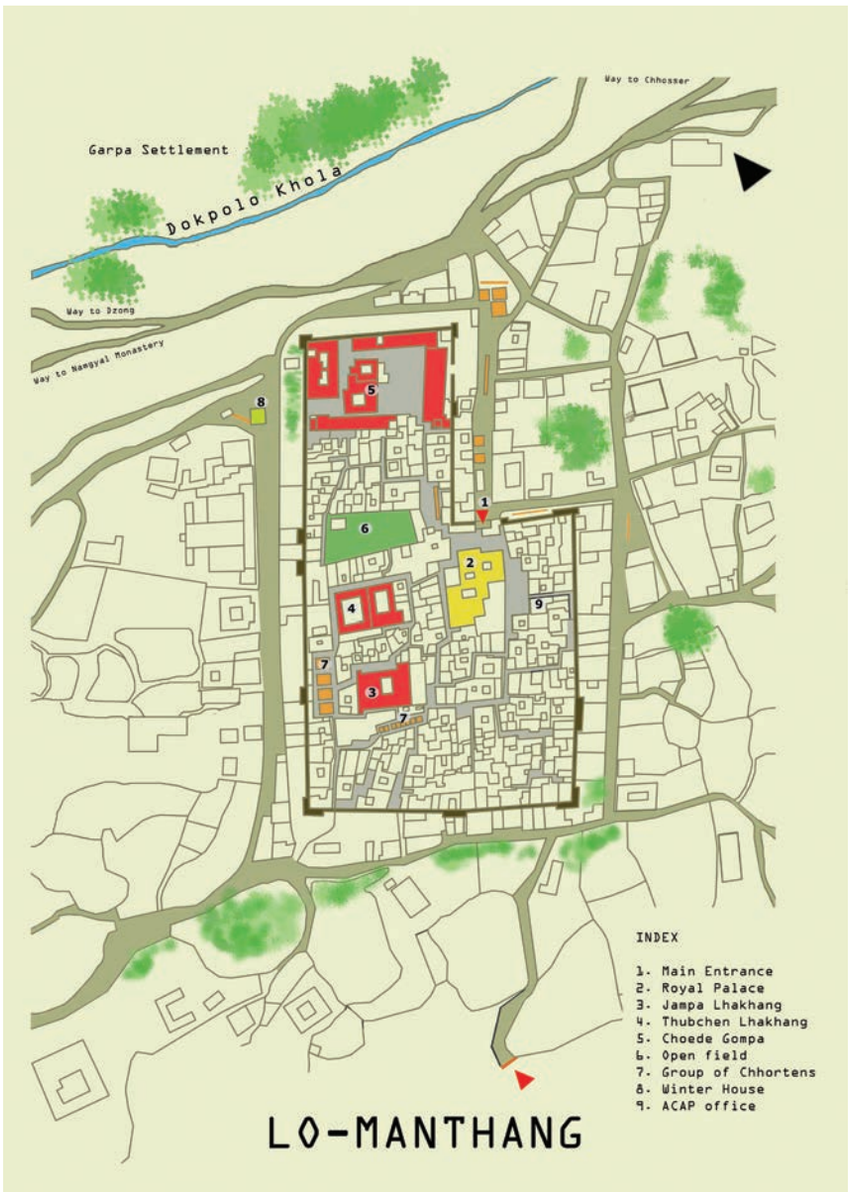


FIGURE 2 Map of Lo Manthang, showing the walled city and major monuments. Illustration: Sirish Bhatt and Aneisha Gurung.

younger generation migrating farther, to the US and Europe, primarily for economic opportunities (Khattri 2020). This permanent out-migration of youth is resulting in an aging population and a decline in the overall population of the region.

The Lo-pa ethnic and cultural links with Tibet are reflected in their way of life, language, festivals, and religious beliefs (fig. 3). Though the principal religion of Lo today is Tibetan Buddhism, the region is an amalgam of religious diversity, including pre-Buddhist Bon traditions that existed prior to the seventh century (Dhungel 2002). Despite Buddhism's strong influence, the deeply rooted Bon order was never completely eliminated, and an abundance of Bon elements and ancient sites are still found in the region.



FIGURE 3 A Lo-pa traditional festival celebration in Lo Manthang. Photo: Sirish Bhatt.

Table 1 Number of Trekkers in Mustang from 2001 to 2019 (Source: Ministry of Culture, Tourism and Civil Aviation 2020)

Year	Trekkers	Year	Trekkers	Year	Trekkers
2001	922	2002	536	2003	572
2004	825	2005	661	2006	248
2007	1,282	2008	838	2009	1,659
2010	2,162	2011	2,950	2012	2,965
2013	2,862	2014	3,883	2015	2,673
2016	3,984	2017	4,240	2018	4,116
2019	3,739	2020	62[1]		

[1] This sudden dip is due to the COVID-19 global pandemic and subsequent lockdown and travel restrictions.

The people of Lo have adapted to survive in the area's harsh environment by engaging in trans-Himalayan trade, together with herding and farming. Around 57% of the land in Upper Mustang is barren, with 30% of grassland used as pasture for livestock and only 1.64% for farming, which is made possible through an intricate hand-built irrigation system that channels snowmelt to fields located in the alluvial parts of the valleys (District Development Committee Mustang 2016). After the Tibetan border closed and trade was suspended, inhabitants' livelihood depended on livestock rearing, with a collective care system by rotation that is still in practice. Due to low annual rainfall, temperature, and the single growing season, agricultural productivity is extremely low. Since the reopening of the border and introduction of tourism, the additional income from a steady increase in international visitors, mainly for trekking from September through October and April through May, is emerging as a livelihood supplement for the Lo-pa (Ministry of Culture, Tourism and Cicil Aviation 2020) (table 1).



FIGURE 4 Ancient cave openings in Upper Mustang. Photo: Sirish Bhatt.



FIGURE 5 The cultural landscape of Lo Manthang. Photo: Sirish Bhatt.

Cultural Landscape of Lo Manthang

The ancient cave complexes dotting the high cliffs, as well as the petroglyphs found along the riverbed that date to prehistoric times, represent the oldest evidence of human habitation in the region (fig. 4). Some of the best-preserved monasteries (containing exquisite wall paintings and ornamentation) in the Tibetan region are found here, and they continue to have significance in the day-to-day lives of the local people. Lo Manthang is the only surviving example of medieval Tibetan compact settlements within a fortified wall, and the last remnants of authentic Tibetan life. Cultural traditions and belief systems that link to Tibetan Buddhism are still vibrant and permeate every aspect of life. Religious festivals and ceremonies are performed throughout the year, and traditional skills such as weaving and traditional healing methods are still practiced. The cultural landscape of Lo includes the walled settlement, monasteries, and ancient ruins as well as the surrounding natural landscapes and the ancient living culture that are outstanding representations of a harmonious coexistence between humans and nature in a high-altitude arid environment (fig. 5).

Current Context: Drivers of the Changing Landscape

The Road

New so-called development projects, such as road construction, are the main drivers of change taking place in Upper

Mustang (particularly in Lo Manthang) with devastating impact on its social, cultural, and natural settings. The vehicular dirt road that connects Lo Manthang to Tibet (north) and Kathmandu (south) is expanding the ancient trade route, threatening the tourism industry that depends on trekking and closing down tea houses and lodgings along the way. This road has cut down the four-day trekking time to Lo Manthang from Jomsom, the nearest airport and town, to six hours in a vehicle and is bringing a new type of tourist, mainly domestic visitors on short breaks. However, the new road is contentious, with most of the local people favoring it for a range of positive outcomes such as easier access to a greater variety of affordable food, reduced travel times, and easier access to health care facilities. This new connectivity is also bringing in imported commodities, including alien building materials, that are changing the unique built landscape heritage of Lo Manthang.

Tourism Development

The advent of tourism is another important impetus for change in Upper Mustang, especially Lo Manthang. In 1992, the government adopted a policy of restricted, high-value tourism and reopened the area to a limited number of tourists paying a permit fee. But although the government promised that 60% of the revenue from the permits would be returned to the region for local development, this has not materialized (Gurung 1998). Due to a decreasing population and the fact that farming in the harsh environment is limited and requires more people, the local economy increasingly depends on tourism as a convenient revenue alternative. This is transforming the physical environment as guesthouses, cafés, and souvenir shops multiply, creating urban sprawl and decreasing farmlands.

Expansion Outside the Town Wall

Prior to the introduction of modern-day tourism, the settlement of Lo Manthang was confined within the fortified earthen wall. With increased demand for tourism infrastructure and the need for larger spaces, the town has expanded rapidly outside the wall, with new structures added each year, many of them built directly against the ancient town wall, obscuring it from view. The expansion is occurring without any guidelines through the construction of amenities for tourists, most built in an incompatible style and with nontraditional construction materials. Such haphazard sprawl has a negative impact on the visual aesthetics of the ancient walled town and its surrounding landscape, with a gradual loss of farmlands and traditional lifestyle.

Kora-la Border (Nepal-China Border)

Kora-la, a mountain pass (4660 m) situated on the border between Mustang and Tibet, is being developed as a vehicle border crossing between Nepal and China. Once in operation, it will be the third most important border crossing between the two nations and one of the most accessible corridors in the Himalayas. When the border officially opens, there could be an influx of Chinese commodities, including construction materials and Chinese tourists, in addition to the increase in tourists from the south.

Threats to Natural Resources

The rapid pace of tourism and infrastructure development is straining the limited natural resources, especially water (Karli 2018). Traditionally, the size of a settlement in Upper Mustang depended on the availability of water and, subsequently, the number of fields that could be irrigated. The water needs for irrigation and domestic consumption had previously been met by snowmelt streams from the mountains, but with the growing number of new guesthouses with flush toilets (replacing the traditional dry toilet) and attached bathrooms, the demand has increased substantially. To minimize negative impacts, tourism development in Upper Mustang requires proper planning that bears in mind the region's limited resources, environmental fragility, and seasonal aspects.

New Administrative/Governance System

In the new political structure of Nepal, Lo Manthang is a rural municipality with an elected body led by a mayor and deputy mayor. The new constitution (2015) grants the local government autonomy of governance and management of local resources. In the traditional governance structure of Lo, the raja (king), village chiefs, and senior lamas were the head figures. With the declaration of Nepal as a federal republic and the abolition of the monarchy in 2008, Lo's status as a kingdom also ended. In practice, however, the king continued to exercise authority and remained powerful within Lo. After his death, his son inherited the traditional title of *gyalpo* ("king" in Tibetan) and continues to play a major role but in a more cultural and religious context. The long history of the traditional governing system that ties the people to the land and the king may potentially cause conflicts with the new elected government.

Lo Manthang: A Tentative World Heritage Site

Lo Manthang has been inscribed on the UNESCO World Heritage Tentative List as "The Medieval Earthen Walled City



FIGURE 6 The cultural landscape of Lo Manthang, with surrounding agricultural fields, ancient ruins, and the Himalayas in the background. Photo: Sirish Bhatt and Aneisha Gurung.

of Lo Manthang" since 2008. The nomination is limited to the medieval earthen walled city and does not adequately reflect the overall significance of the place. The nomination needs to take into account the built heritage, the surrounding landscape, and the living traditions (fig. 6). A broader cultural landscape approach is needed to take into account the "combined works of nature and of man" (UNESCO 2019, par. 47) that have shaped the landscape of Lo Manthang over time. There are a handful of ongoing restoration projects in Lo Manthang, mainly monasteries and cave paintings. However, the majority of the cultural sites in Upper Mustang remain undocumented. A systematic heritage resource database (one that includes the movable artifacts) is lacking and should be prepared to understand and protect the sites.

Conclusion

Lo Manthang is faced with similar challenges of other traditional societies that are struggling to adapt to rapidly changing conditions. Despite these shifts, the region still retains most of its unique natural and cultural landscape. However, immediate care is needed to ensure that any future development activity is thoughtfully planned with local participation to avoid the loss of the cultural landscape that is a part of the local identity and economy. The remote location and harsh climatic conditions limit the reach of federal or provincial governments and thus a communication mechanism between these, including the involvement of the local people in decision-making processes, is vital. With the increasing role of local governments, a robust communication with the federal government is essential to avoid delays and unnecessary expenditures such as realignment of the road. Any plans for Upper Mustang should take into consideration that the communities are changing from subsistence farming to tourism with a reach to modern technologies and road connections. As changes are inevitable, the success of future sustainable planning depends on adopting those that are acceptable to the locals and that address their contemporary needs. The federal government needs to conduct regular dialogue with the locals if Mustang is to be inscribed on the World Heritage List.

Note

1 Interview with Indra Dhara Bista, representative of Mustang in Gandaki Province.

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Value Interpretation and Conservation of Rural Earthen Landscape: The Case of Earthen Villages in the Loess Plateau in Central China

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Abstract: *Rural earthen landscapes are universal but unique cultural areas that reflect a long-term evolution from the natural state to cultural ecology. As an important type of cultural landscape, these areas reflect many aspects, such as architectural style, landscape environment, agricultural mode, land use, and cultural tradition. They also face severe social, economic, and technological challenges today. Since 2012, teachers and students from Tongji University and the École de Chaillot have been engaged in investigating, researching, and planning for the villages around Pingyao City, Shanxi Province, including the villages of Liang and Shuimotou. This paper examines these villages as case studies: (1) to identify and analyze the characteristics and components of the rural earthen landscape of this region, (2) to interpret the value of rural earthen landscape and to put forward the notion that distinctive rural earthen landscapes are capable of being an important resource for rural revitalization, and (3) to propose comprehensive strategies on conservation and restoration, as well as specific ecological technology measures, to solve the existing problem that rural landscapes are gradually being abandoned or destroyed.*

Resumen: *Los paisajes rurales de tierra son un paisaje cultural universal pero único, que refleja una larga evolución desde el estado natural hasta la ecología cultural. Como un tipo importante de paisaje cultural, los paisajes rurales de tierra reflejan muchos aspectos, como el estilo arquitectónico, el entorno paisajístico, el modo de vida agrícola, el uso de la tierra y la tradición cultural. Pero también enfrentan severos desafíos sociales, económicos y tecnológicos en el presente. Desde 2012, los maestros y estudiantes de la Universidad de Tongji y la École de Chaillot se han dedicado a investigar, estudiar y planificar las aldeas alrededor de la ciudad de Pingyao, provincia de Shanxi, incluyendo la aldea de Liangcun y la aldea de Shuimotou. Este artículo examina estas aldeas como casos de estudio: (1) para identificar y analizar las características y componentes del paisaje rural de tierra de esta región; (2) interpretar el valor del paisaje rural de tierra y proponer que los paisajes rurales de tierra distintivos pueden ser un recurso importante para la revitalización rural; y 3) proponer estrategias globales de conservación y restauración, así como medidas tecnológicas ecológicas específicas para resolver el problema del abandono y la destrucción gradual de los paisajes rurales.*

Keywords: earthen villages, rural landscape, value interpretation, conservation, rural revitalization

General Problems and Challenges of Rural Earthen Landscapes in China

Rural landscape should be understood as cultural landscape. Since 1992, the UNESCO World Heritage Committee has formally included "cultural landscape" as one specific type of world heritage, noting that cultural landscapes represent the combined works of nature and of humans. They are illustrative of the evolution of human society and settlement over time (UNESCO 2019). If we view the evolution of rural villages from the perspective of cultural landscape, we find that these settlements were gradually constructed by local people who adapted to their geographical, hydrological, and climatic environments, integrating cultural development.

In order to meet the requirements for agricultural production and daily life, people often transform their surrounding topographies and make use of local natural resources to create special land and agricultural landscape systems. In essence, the formation of rural landscape is the evolution from a natural state to a cultural ecology, the creative accumulation of generations, and the highly compounded outcome of the material and spiritual worlds (Shan 2010). This is exhibited in many aspects such as architectural settlement, landscape environment, production mode, land use, and cultural tradition.

Due to the continuous expansion of the dual urban-rural structure in China today, rural problems have become an important issue in the process of urbanization. Villages with relatively well-preserved features frequently experience the opposite in terms of location, transportation, and economic conditions, contributing to a large number of people moving to live and work in cities with better infrastructure. This has led to the decline in, and in some cases the disappearance of, rural landscapes, as rural areas face the compounded problems of a population that is aging or moving to urban locations, resulting in the subsequent abandonment of fields.

Changes in land use as a result of mechanized production also pose problems for rural earthen landscapes. In the traditional era, people followed the rules of nature or topography to create suitable farming methods. Examples are Hani terraces and Xinghua stacking fields, which are listed as World Heritage Sites. With the evolution of technology and tools, it is not difficult to open mountains and fill rivers. In order to improve output and meet the needs of large-scale mechanized production, traditional land use modes are easily erased in the effort to build homogeneous agricultural landscapes, which breaks the relationship with nature.

The development of tourism, and with it the need for the amenities of modern life, has resulted in construction that is destructive to rural earthen landscapes. Tourism is developing in some villages with rich cultural resources, good locations, and healthy economic conditions. The output of traditional agriculture is low in these locations, and extant vernacular architectural structures cannot meet the needs of modern life. Therefore, a significant amount of money has been invested to transform traditional rural landscapes from local buildings into unified brick houses without character.

Special Challenges Faced by Rural Earthen Landscapes

China has a vast territory of diverse rural landscapes, mainly distributed in the central and western regions of the country, with large climatic and geographical differences. The Loess Plateau is a region featuring typically characteristic rural earthen landscape in China.

Tectonic movement of the earth's crust over twenty million years ago combined with monsoon winds to transport the vast amounts of sediment that formed the Loess Plateau, an area of 150,000 square miles known for its unique dry climate and powdery, windblown soil. Erosion caused by water movement formed the special landscape of this area, including hundreds of mountain gaps and valleys (Xiao and Wang 2015). Today, the Loess Plateau covers the majority of the area of Shanxi Province, Henan Province, and several other provinces in central China. In such an environment, early humans often chose flat terrain to settle, and cave dwelling became an effective means of accommodation, utilizing the hill area while saving more flat land for agricultural uses.

Yaodong architecture includes earthen dwellings that use loess in their construction and maintenance. Most of the dwellings are excavated directly into the mountains, and their circular, arc-shaped interior structures help meet the requirements for lighting and aesthetics. With the development of building skills, *yaodong* gradually formed three types of structures according to different location and terrain conditions. These are a back-on-the-cliff type, an underground type, and a stand-alone type (fig. 1).

These stacked caves, just like earthen buildings rising on the mountain cliffs that formed an overall landscape in this area, constitute the local settlement space. In order to meet the communities' needs, residents reclaimed agricultural land in the valleys or gullies near the water and planted crops that adapted to the local dry climate and loess, such as apple, sweet potato, sorghum, and millet. To further increase the amount

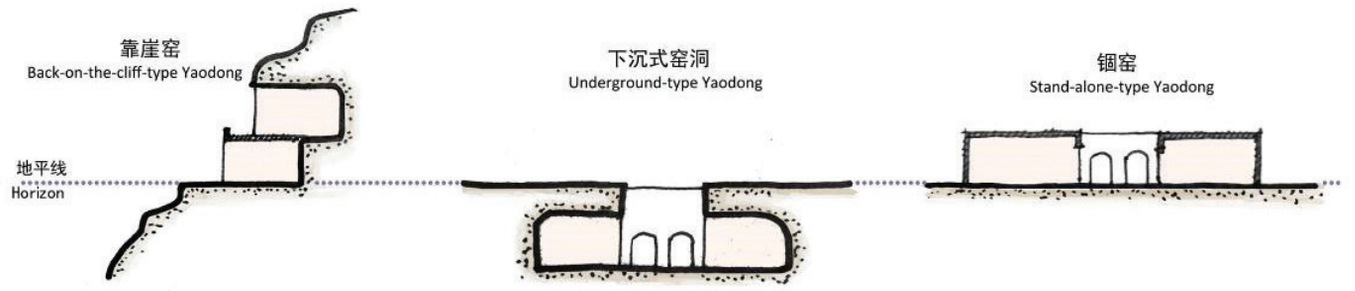


FIGURE 1 The three types of *yaodong* earthen architecture. Illustration: Shao Yong, Xu Kanda, © Tongji University.



FIGURE 2 Agricultural space in the valley in a rural earthen landscape. Photos: Shao Yong, Xu Kanda.

of land available for agriculture, ancestors dug terraces on the terrain and introduced a special water diversion system (fig. 2).

Such rural earthen landscapes are facing special challenges. From an architectural perspective, earthen materials are naturally loose in structure and weak in anti-seismic ability. Wind and rain significantly increase the moisture content of soil and erosion, and, although the *yaodong* do have timber support structures, they are still relatively vulnerable and easily damaged. The Loess Plateau region is often dry and lacks water, creating restrictions for the production of crops. In response, the traditional terraces based on earthen environments are gradually abandoned, and reclamation is carried out in flat land far from the village.

Important changes have taken place in the relationship between humans and land from the perspective of integrity. Natural space, and residents' access to it, becomes more and more restricted. Compared with the landscape in the South Yangtze River delta, typified by "flowing water and timber houses," the rural earthen landscapes are often regarded as backward, creating major resistance for comprehensive preservation projects.

Components and Values of Rural Earthen Landscape: Villages of Shuimotou and Liang

In this paper, we will take the villages of Shuimotou and Liang of Pingyao County in Shanxi Province in the Loess Plateau as examples to discuss the values and components of rural earthen

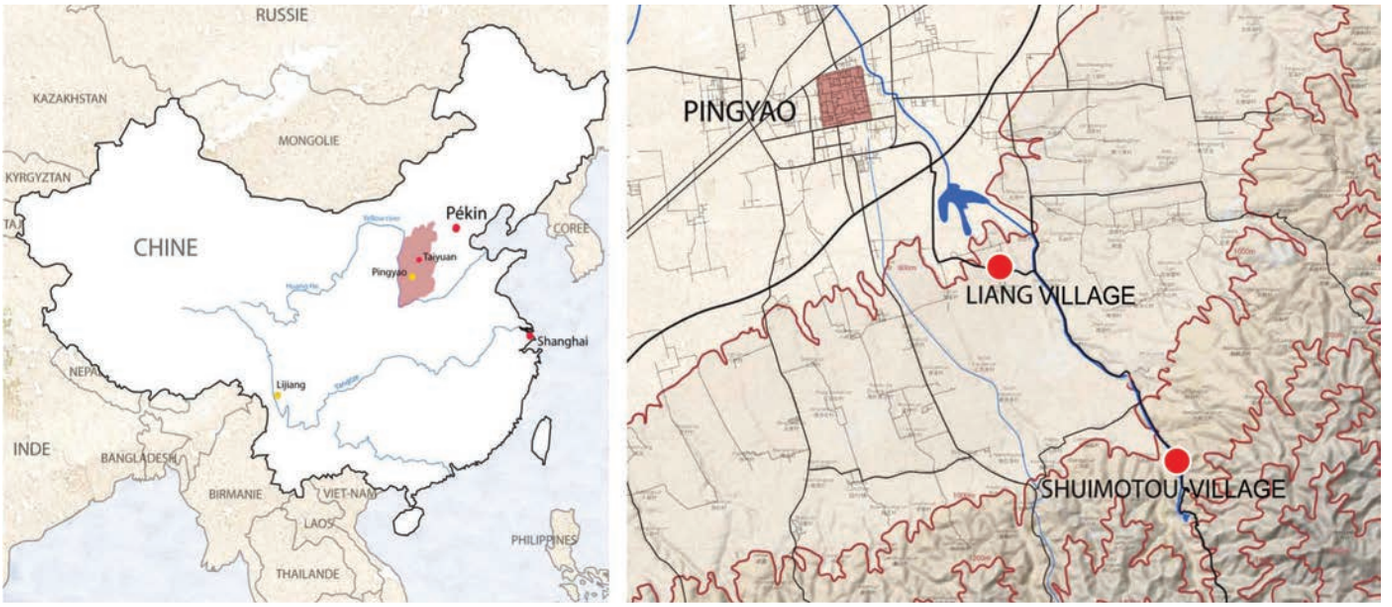


FIGURE 3 Map highlighting (a) area surrounding Pingyao and (b) location of Shuimotou village and Liang village. Illustration: Shao Yong, Xu Kanda, © Tongji University.

landscape and the methods of conservation and revitalization. Both villages were gradually constructed along the Huiji River over a period of more than several hundred years (fig. 3).

Shuimotou village is located in a mountainous area with a lake that flooded during the rainy season, making it impossible to live near the water. As the water level dropped, the area with slightly lower terrain gradually became suitable for human habitation. In order to adapt to the population surge in the fifteenth century, the territory of the village was extended to the current ancient village area. Additionally, inhabitants intelligently created a terrace system to deal with the problem of limited farming space. In the past several decades, with the water flow further reduced to contain more people, the tidal flats of the river valley also became arable, cultivated land. However, the fields were higher than the surface of the water. To deal with this problem and irrigate the farmlands, the villagers skillfully used the terrain elevation to draw two channels from the upper reaches of the Huiji River.

Because the province of Shanxi is located near the nomadic tribes of the north, the earthen villages here often have the need for defense. The topographical features of the hilly valley create some natural depressions and barriers, so the villages were built in these places close to the mountain, vertically overlapping the terrain so that the flat roof of one house became the ground floor of another family's home. *Yaodong*s are directly excavated into the cliff. The combined layout of earthen buildings and mountain background has created a special cultural landscape, and the loess plays a very important role in forming it (fig. 4).

Liang village is located in the plains area near the base of the mountain. The Huiji River and its tributaries pass through the village on both sides, and this abundant water system provided excellent production conditions for the village. Early villagers built back-on-the-cliff-type *yaodong*s along the river and used the middle valley area for agricultural cultivation. In some areas with micro-terrain changes, terraces were also adopted.

After the twelfth century, the village gradually developed into a settlement of "one street and five fortresses." The flat area was used to build stand-alone type *yaodong*s using adobe from loess; these had high earthen walls of about 5 m that were built around the community for defense. The settlement layout and defense system constructed of earthen materials has become the typical built-up landscape of villages in the plains area in Shanxi, which continues to today. The rural earthen landscape has different characteristics from that in the mountainous area, exhibiting regional diversity (fig. 5).



FIGURE 4 Rural earthen landscape of Shuimotou village. Photo: Xu Kanda, © Tongji University.



FIGURE 5 Typical layout of earthen villages in a plains area, Liang village. Photo: Xu Kanda, © Tongji University.

The need for water collection and utilization is a very important issue in the regional sustainable development of settlements built mainly with earth. Therefore, most of the earthen walls in Liang have been well preserved with rainwater channels.

In addition to the production and daily living areas, the special religious area in or around the village is also a vital part of the rural earthen landscape. For example, Liang was rich because of its water resources. Water was regarded as the "source of wealth," so early villagers chose the south end of the village with the most abundant water resources to establish a temple with an opera stage for the worship of nature. The temple and opera stage complex, as well as the huge water well that is located in the fields of the valley, use the natural mountains and rivers as a background, forming the unique landscape of this area (fig. 6).

As demonstrated by the examples of Shuimotou and Liang, the components of rural earthen landscape are abundant, comprehensive outcomes of the interaction between

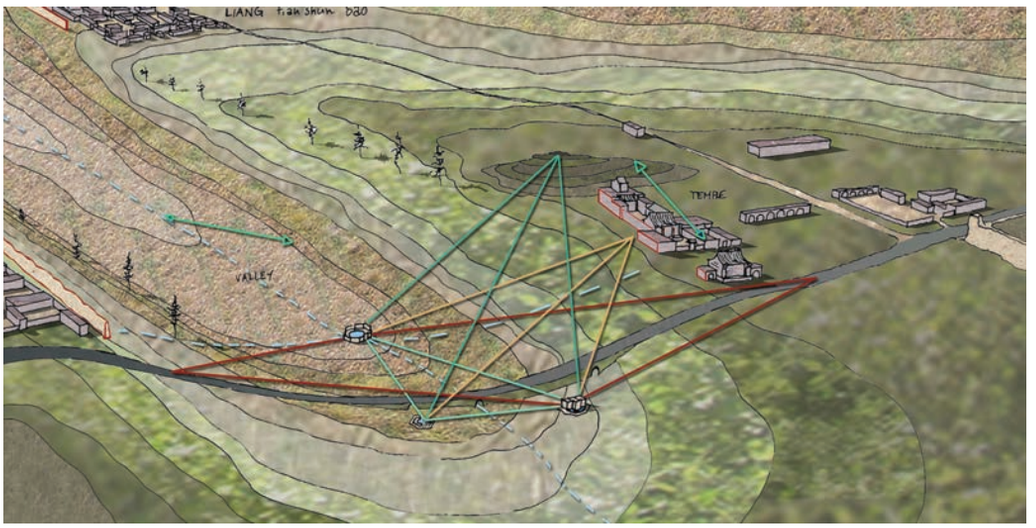


FIGURE 6 A landscape-relationship analysis of the water temple area in Liang village. Illustration: Tongji-Chaillot Joint Workshop, © Tongji University.

humans and nature. These include the built-up settlements, formed by earthen architecture, that conform to the terrain conditions and the intensive land use strategies under adverse conditions. They also include the agricultural space related to villagers' natural transformation of the land and their water utilization. In addition, the interaction is also reflected in religious and cultural spaces formed by the worship of nature.

Rural earthen landscapes, which have evolved for hundreds of years, exhibit significant historical value, and the layout of settlements and agricultural spaces that adapt to the earth and water environments have scientific value. The various details of construction created by the use of loess have formed a unique artistic value reflecting the regional identity. Rural earthen landscapes, in essence, are the reflection of vernacular wisdom that balance the relationship between humans and land, as well as an organic integration of tangible cultural heritage such as architecture, farmland, and the intangible heritage of living systems. Rural earthen landscapes are important cultural landscapes that have a significant reference for contemporary times and should be well conserved.

Rural Earthen Landscapes as Important Resources for Rural Revitalization

Earthen villages are mostly in areas with poor location, traffic conditions, and low agricultural efficiency. For example, the per capita disposable income of rural residents in Pingyao County in 2020 was only 42.5% of the income of urban residents,[1] which led to a hollowing of the community and abandonment of farmland. The quality of rural earthen landscape is changing.

However, the importance of rural landscape for village development has not been realized. For longtime city dwellers, these cultural landscapes not only provide visual beauty but also explain the local ancestral development. It is an important resource that helps to establish an emotional connection with the local natural environment, which is of great significance in heritage education and rural revitalization.

This emotional connection has brought big changes in tourism, especially in the post-pandemic era: on one hand, residents are increasingly pursuing more healthy and ecological modes of tourism; on the other hand, overseas vacations or long-distance journeys are restricted and short-distance, high-frequency leisure trips have become the new normal. Rural tourism has proven to be the main opportunity for the tourism industry's recovery, as these landscapes provide both natural and cultural resources that attract tourists with their unique characteristics and rare offerings.

We propose a series of comprehensive strategies for the conservation and revitalization of these landscapes. Emblematic of the longtime symbiosis between humans and nature, the conservation and revitalization of rural landscapes cannot be separated from the continuing impact of humans. Therefore, in the process of conservation, we should also maintain and improve villagers' life conditions and continue the traditional production style by building a living rural landscape.

Using earth as a construction material is a key strategy for conservation and revitalization. The core of rural earthen landscapes lies in the traditional features based on the regional earthen environment, including loess, as well as its vernacular

earthen architecture. Therefore, it is necessary to continue using earth in the construction of settlements while introducing modern technology and skills to improve and enhance the capability of earth to, for example, strengthen the material's seismic performance. To maintain the atmosphere and improve the quality of life, the existing decaying *yaodong* buildings should be restored using traditional architectural craft.

Agricultural space is another important component of rural earthen landscape. In order to realize the continuity of nature, we should repair or improve the agricultural space, enhance the value of agricultural products so that villagers can still benefit from the land, and continue the use and transformation of nature in an appropriate manner (Shao and Zhang 2018). Such strategies will maintain healthy human relationships with the land.

The conservation of rural landscape involves the living inheritance of its intangible cultural heritage, including spiritual beliefs and practices. Traditional handicraft skills or customs, along with specific cultural spaces, should be conserved as a whole. Additionally, the conservation of religious spaces can emphasize harmony with nature to avoid constructive damage. Meanwhile, strengthening the intangible culture based on rural earthen landscapes would not only provide diverse tourism elements but also raise awareness among villagers of conservation.

Attention must also be paid to the improvement of ecological technologies. In order to better conserve the rural earthen landscape, professors and students of Tongji University and the École de Chaillot took Shuimotou village and Liang village as case studies, putting forward improvement measures for ecological sustainable development.

For the terraces that have very close relationships with rural earthen landscapes, setting up new small irrigation systems inside the terrace to collect rainwater could prevent the terraces from being abandoned. Meanwhile, this system, borrowed from terraces, could also be implemented in the village areas. Small plant purification systems in villages are designed to use natural terrain, which plays a role in the improvement of the micro-environment by creating a more livable village (fig. 7).

For many of the abandoned back-on-the-cliff-type *yaodong*s, green roofs, solar water purification, wind energy ground source heat exchange systems, and built-in, sand-filled drainage systems would increase ecological energy saving and



FIGURE 7 Water recycling in the terrace system. Illustration: Tongji-Chaillot Joint Workshop, © Tongji University.

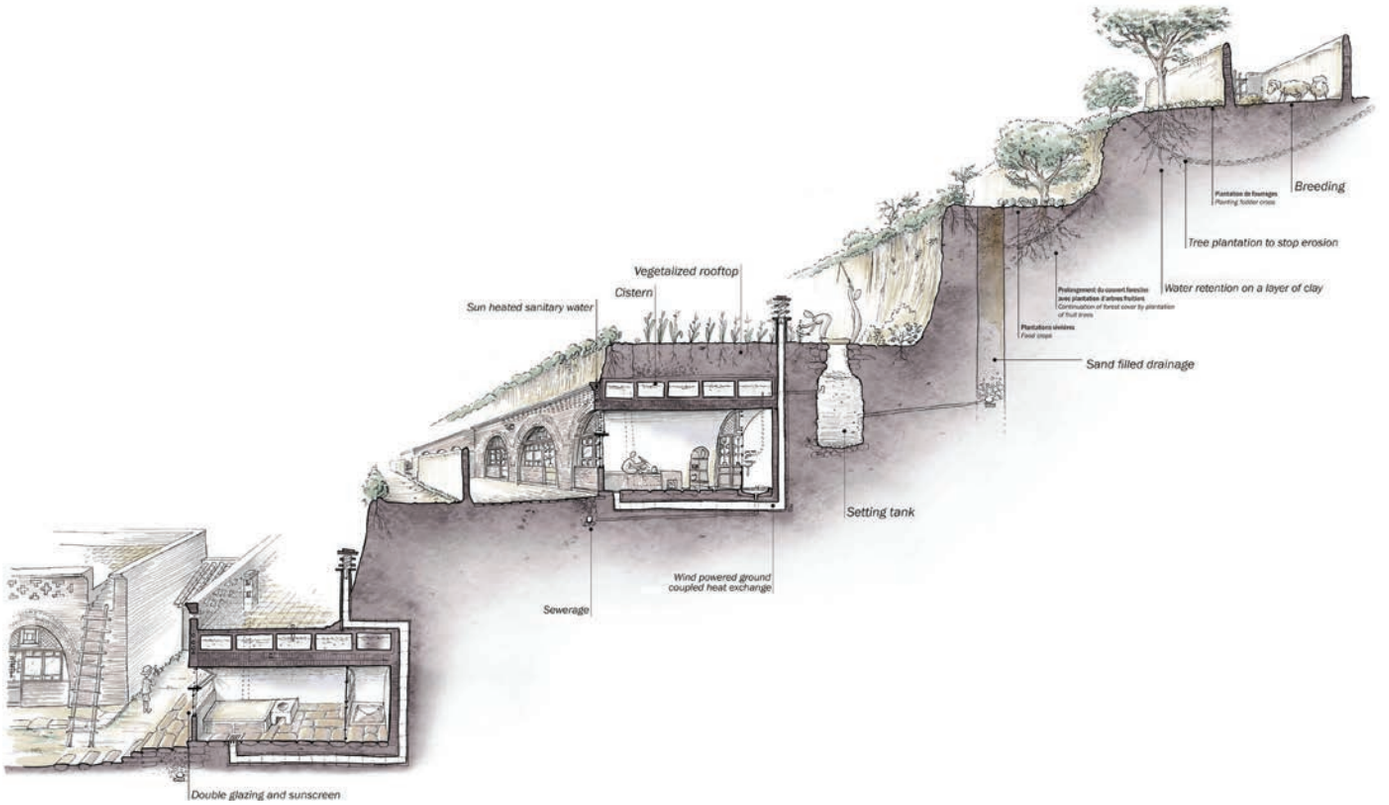


FIGURE 8 Ecological improvement strategies for back-on-the-cliff-type *yaodong*. Illustration: Tongji-Chaillot-Joint Workshop, © Tongji University.

retain the original earthen construction methods. The distinctive characteristics of rural earthen landscapes are preserved while living conditions are improved (fig. 8).

Conclusions

As a type of important cultural landscape that reflects local development, rural earthen landscape shows the interaction between humans and nature, embodies vernacular wisdom, and interprets multiple values that still reference significance for contemporary life. They are an important resource in the realization of rural revitalization, and we need to pay more attention to these landscapes, continuing to produce and live in spaces with earth as their core. Comprehensive strategies of conservation and revitalization should be considered in order to integrate humans, nature, architecture, and culture. To realize sound conservation methods while building harmonious relationships between these elements, improving villagers' lives should be set as one of the important targets along with conservation of the built heritage.

Acknowledgments

Since 2008, Tongji University in China and the École de Chaillot in France have conducted several Sino-French workshops in architecture and rural heritage conservation in villages around Pingyao and achieved solid outcomes. Shao Yong is the main Chinese instructor. All rights reserved by Tongji University and the École de Chaillot.

Note

1 Statistics are available from the Pingyao County Government on its official website (Pingyao County Government 2020).

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PART 7

Decorated Surfaces / Superficies decoradas

Enduring Connections: Science Supports Traditional Knowledge at Montezuma Castle National Monument

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Abstract: *This paper briefly explores the meaning of decorative yellow architectural finishes using an analytical approach that includes architectural and archaeological analysis as well as traditional knowledge. Recent collaborative research between the National Park Service (NPS) and the University of New Mexico has shown that earthen washes are the primary form of wall decoration at the Montezuma Castle cliff dwelling (AZ O:5:14 [ASM]). Yellow washes were first identified and analyzed by the University of New Mexico using a combination of optical microscopy, X-ray diffraction (XRD), and energy dispersive X-ray spectroscopy (EDS). These studies yielded important information on the ancient techniques used for processing, mixing, and applying earthen washes. Native American traditional knowledge provides additional evidence regarding the way in which materials were acquired, processed, and applied to wall surfaces. At Montezuma Castle, Hopi tribal members accessed this information by connecting with community members having specialized and expert knowledge on material sources and application techniques. This knowledge was acquired over many generations and requires discussion and thoughtful consideration before being shared with the NPS. In many ways, yellow washes are a proxy for the important relationship that descendant communities have with the Montezuma Castle cliff dwelling. By using a multiperspective research approach that includes scientific inquiry and traditional knowledge, the NPS learns more about how to appropriately manage the cliff dwelling, and tribal members are provided with an opportunity to share information on the significance of this important ancestral place.*

Resumen: *En este artículo se explora brevemente el significado de los revestimientos decorativos amarillos por medio de un enfoque analítico que incluye el análisis arquitectónico y arqueológico, y también el conocimiento tradicional. En una reciente investigación realizada en colaboración entre el National Park Service y la University of New Mexico, se demostró que las capas de tierra son la forma principal de decoración de las paredes de la vivienda en el acantilado del Castillo de Montezuma (AZ O:5:14 [ASM]). Las capas amarillas se identificaron y analizaron por primera vez en la University of New Mexico por medio de una combinación de microscopía óptica, difracción de rayos X y espectroscopía de rayos X por dispersión de energía. Estos estudios proporcionaron información importante sobre las técnicas antiguas de elaboración, mezcla y aplicación de las capas de tierra. Al utilizar los conocimientos tradicionales de los nativos americanos, se obtienen pruebas adicionales de la manera en la que se adquirían, procesaban y aplicaban los revestimientos en los muros. En el Castillo de Montezuma, los integrantes de la tribu Hopi accedieron a esta información al conectarse con los integrantes de la comunidad que tenían conocimientos especializados y con expertos en fuentes de materiales y técnicas de aplicación. Estos conocimientos se desarrollaron a lo largo de muchas generaciones, por lo que es necesario analizarlos y reflexionar sobre ellos antes de compartirlos con el National Park Service. En muchos sentidos, las capas amarillas representan la importancia de la relación que las comunidades descendientes tienen con la vivienda en el acantilado del Castillo de Montezuma. Al implementar un enfoque de investigación con perspectivas múltiples, que incluye la investigación científica y los conocimientos tradicionales, el National Park Service aprende más sobre la manera de gestionar adecuadamente la vivienda del acantilado, y los miembros de la tribu tienen la posibilidad de compartir información sobre el significado de este importante lugar ancestral.*

Keywords: Montezuma Castle National Monument, cliff dwellings, plaster, architectural analysis, traditional knowledge, National Park Service (NPS)

Background

This paper presents a brief discussion of a heritage preservation project at the Montezuma Castle cliff dwelling that utilizes a multiperspective approach including scientific inquiry and traditional knowledge. In this paper, we focus on the discovery of yellow plaster washes. These washes are a proxy for the complex connections that living people have with the site and the ability of collaborative research to identify and articulate those connections.

Montezuma Castle is a twenty-room cliff dwelling in central Arizona's Verde Valley (fig. 1). The dwelling consists of earthen architecture in a high alcove overlooking Beaver Creek, a perennial tributary of the Verde River. Recent research suggests that construction of Montezuma Castle began in the mid-twelfth century, with rooms being added over time. By the mid-thirteenth century, much of the dwelling had been built to its current architectural form (Hodgins et al. 2018). Archaeological evidence and oral histories indicate that the dwelling continued to be occupied until the late fourteenth century after which inhabitants left, eventually settling in villages on the Hopi Mesas (Guebard 2016; Kralj KenCairn and Randall 2007).

While the National Park Service (NPS) has maintained and interpreted Montezuma Castle for over a century, very little effort has been expended in research. Furthermore, Native American perspectives were not incorporated into the management and interpretation of the site. Until recently, much of what the NPS knew about the cliff dwelling came from archaeological projects that were completed in the 1930s.[1] By the 1990s, the NPS approach to the preservation of ancient architecture had drastically changed to include concepts of site significance using detailed data collection and the incorporation of tribal perspectives (Firor 1988; Metzger 1988, 1989; National Park Service 2002). Despite this important paradigm shift, the new approach was not immediately employed at Montezuma Castle and tribal perspectives on the importance of the cliff dwelling were ignored.



FIGURE 1 Montezuma Castle cliff dwelling, Camp Verde, Arizona, 2020. Photo: W. Navenma, courtesy of National Park Service, Montezuma Castle National Monument.

Multiperspective Research at Montezuma Castle

Beginning in 2012, park managers began an effort to study the cliff dwelling by partnering with architectural conservators at the University of New Mexico. This project was a response to the lack of past archaeological research at the site and an attempt to incorporate more sensitive preservation strategies in the future. The original intent of this project was to conduct research on the constituency of earthen building materials, identify areas of deterioration, and make informed treatment recommendations (Bass et al. 2015, 2017). During the project, NPS archaeologists and university conservators found that traditional knowledge could be used along with the results of scientific inquiry to create more robust and meaningful interpretations.

University and NPS professionals conducted in-depth visual inventories of building materials on every wall at the cliff dwelling. The inventory distinguished and documented earthen plasters by appearance and location. Samples of each plaster were then collected for analysis. The university developed an analytical method utilizing optical microscopy, X-ray diffraction (XRD), scanning electron microscopy (SEM), and energy dispersive X-ray spectrometry (EDS) to characterize these materials (see Bass et al., this volume). This method utilized small samples to limit impacts to architecture. Analytical techniques were used to identify clays and aggregates, secondary minerals, and soluble salts in earthen plasters (Bass et al. 2015, 2017; Guebard, Bass, and Porter 2018).

Information on the location, appearance, and constituency of extant plasters was interpreted by archaeologists and conservators to explain how earthen materials were processed, mixed, and applied. During the project, yellow, white, and red plaster washes were identified in three rooms (fig. 2). These washes consist of clays that were likely processed to remove large particles and obtain a uniform consistency. Mineral pigments were added to produce the desired color. Water was applied to the mixture and brushed or wiped onto wall surfaces. These washes adorned windows, doorways, and dados, resulting in brilliant decorative surfaces. Superimposed layers

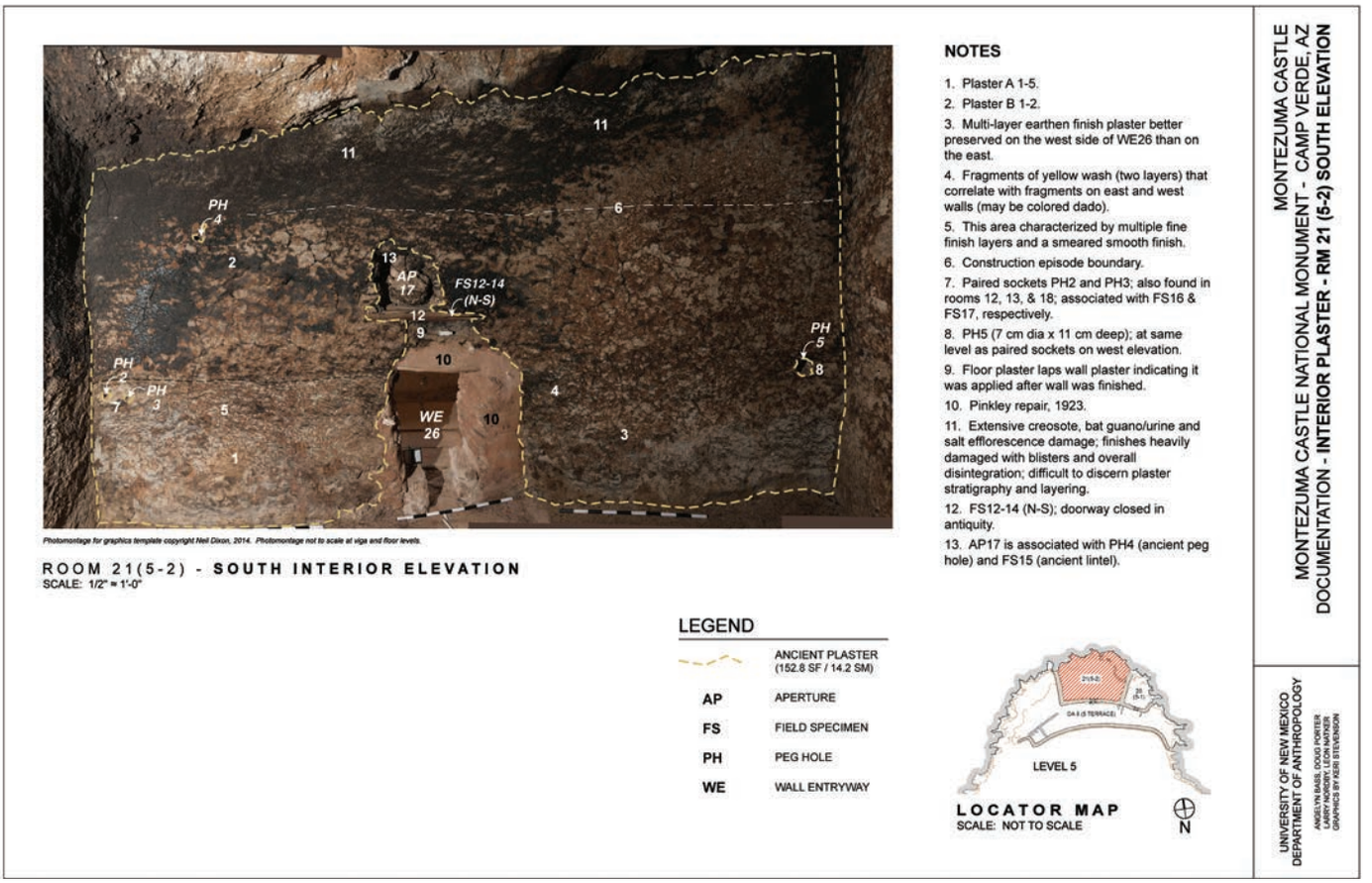


FIGURE 2 Results of plaster survey and condition assessment for Room 21 (5–2), south interior elevation. The locations of yellow plaster washes are annotated on the photo. Taken from Bass et al. 2015. Illustration: A. Bass, courtesy of National Park Service, Montezuma Castle National Monument.

of plasters and washes suggest that these colors were periodically changed or renewed (Bass et al. 2015).

While the results of this analysis were informative, many questions remained about how materials were collected, processed, and applied. To learn more about the application, long-term durability, and eventual deterioration of plastered surfaces, the park used an experimental approach in which white colored washes were replicated and applied to masonry test walls at Tuzigoot National Monument (fig. 3). The project was led by NPS preservation experts, all of whom live on the Hopi Mesas and have extensive knowledge of traditional building practices. By accessing their knowledge and connecting with other experts in their community, they were able to locate appropriate material sources and utilize traditional processing and application techniques.

Information on material sources and pigments is acquired through years of hands-on practice or through connections with family and community members who have specialized knowledge and expertise (Munson 2020). Additionally, certain types of information may belong exclusively to some individuals or are restricted to others. At Hopi, decisions about what information is appropriate to use in resource management applications or share with the public is vetted through processes that require discussion and thoughtful consideration. These review processes require extensive time and effort and can only be completed by tribal members with the appropriate connections and knowledge.

The result of test wall efforts at Tuzigoot confirmed what had been assumed during sample analysis: that builders had used expert knowledge to locate, process, and apply materials with a specific idea of how they would look and perform. The information on how to find and process these materials has been passed down through many generations. While this is not surprising, it does create an opportunity to investigate ancient building choices and learn about the significance of the site. As Nordby (2015) wrote, studies of well-preserved



FIGURE 3 Preservation experts apply white plaster washes on test walls at Tuzigoot National Monument, 2019. Photo: W. Navenma, courtesy of National Park Service, Montezuma Castle National Monument.

cliff dwellings "offer the opportunity to study the relationship between what people think about these buildings, and what they feel about them." The connection between how buildings are constructed and why they have meaning is powerful and provides insight into the lives of ancient builders and their descendants.

Past beliefs and ideals are encoded in ancient architecture (Cameron 1999). The study of architectural elements, such as colored plasters, establishes a basis for investigating the meaning of ancestral places and creates an opportunity to interpret the deep connections between present-day people and their ancestors. In the next section we briefly discuss the use of traditional knowledge and scientific inquiry to investigate the meaning of colored plasters. The information presented here is not the only way in which architectural analysis and traditional knowledge can be used. The following example is a proxy, however, for the potential that multiperspective research approaches have for understanding and interpreting important places.

Yellow Plaster Washes

Unlike other colors, yellow washes at Montezuma Castle contain approximately 12.5% albite, a mineral found in central Arizona (Bass et al. 2015). We do not yet know how albite was used in plaster washes, but we believe it was specifically added to help create a bright yellow hue matching the paste and surface color of Jeddito Yellow Ware ceramics. The similarities in plaster wash colors and ceramics are not a coincidence, and we believe the symbolic and ideological meaning of the color was intentionally referenced (Guebard, Bass, and Porter 2018).

Hopi scholars and archaeologists have discussed the meaning of the color yellow in multiple studies, noting that objects like ceramics denote important concepts associated with past and contemporary Hopi beliefs (Munson and Hays-Gilpin 2020). The color yellow is associated with the cardinal direction north, but it is also rooted in a concept that scholars have called the Flower World, a collection of shared visual concepts related to important beliefs (Hays-Gilpin and Schaafsma 2010; Munson 2020). For Hopi ancestors and their descendants, these beliefs are expressed in material objects, songs, and oral histories.[2]

Jeddito Yellow Ware is a ceramic type distinguished by its bright yellow color (fig. 4). The color is created by a combination of locally sourced clays and the use of an oxidizing

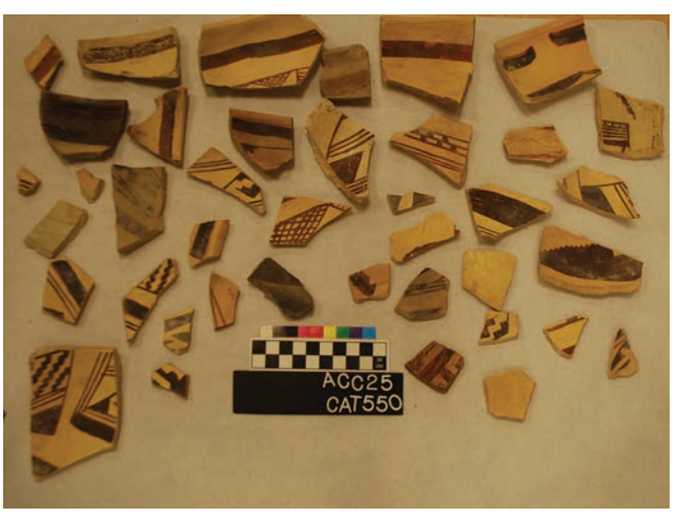


FIGURE 4 Examples of Jeddito Yellow Ware ceramics found at Montezuma Castle National Monument. Photo: M. Guebard, courtesy of National Park Service, Montezuma Castle National Monument.

environment for firing (Colton and Hargrave 1937). Jeddito Yellow Ware is a representation of Flower World ideology and is plentiful at Montezuma Castle, constituting approximately 69% of all fourteenth-century decorated ceramics recovered from archaeological contexts (Guebard, Bass, and Porter 2018; Jackson and Van Valkenburgh 1954). Neutron Activation Analysis (NAA) indicates that Jeddito Yellow Ware found in the Verde Valley was manufactured and produced only on the Hopi Second Mesa (Adams 2013). These vessels were then traded into the valley through existing social and economic networks.

Hopi tribal members from Second Mesa have collaborated with the NPS, sharing oral histories that recount important events emphasizing the connection that living people have with the cliff dwelling. These histories identify the ancestors of people on Second Mesa as the builders and inhabitants of Montezuma Castle and tell of how they eventually migrated north to settle at Hopi. Yellow plasters and artifacts are a tangible representation of Hopi history and part of a larger body of evidence that supports oral histories.

The ideological and physical connection between yellow objects and architecture at Montezuma Castle is a proxy for the relationship that living people have with important ancestral places. This transcendent relationship includes symbolism and ideology as well as spiritual and cultural significance. Sometimes known as footprints, objects and architecture are important representations of Hopi history and provide knowledge of what it means to be a Hopi today (Balenquah 2012; Kuwanwisiwma, Koyiyumptewa, and Poleahla 2012). While this connection is well known to Native people, many non-Native NPS archaeologists and preservationists are only now becoming aware of its importance. The complex relationship between past people, their descendants, and ancestral sites creates an obligation for the NPS to incorporate tribal perspectives into public interpretations and management practices.

At Montezuma Castle, the discovery of yellow plasters has the potential to drastically change the way in which the NPS understands and interprets the significance of the cliff dwelling. For instance, yellow plasters and their subsequent meaning are one way to illustrate the enduring and unbroken connection between ancestors and descendants. Evolving concepts of site significance are not exclusive to the NPS. Architectural studies that incorporate scientific inquiry and traditional knowledge also have the potential to affect the way that tribal governments, clan groups, or individuals define and articulate the significance of a place. This information can strengthen tribal perspectives by providing tangible examples of the significance identified in oral histories and other sources of important information.

Cooperative projects like this one create opportunities to reassess existing management practices and create new methodologies using traditional knowledge. Information on material sources and application techniques are just two examples of how this information might be used to develop appropriate management strategies. These strategies can only be created with the participation of tribal members and it is incumbent on the NPS to seek out partnership opportunities.

Traditional knowledge is vital to the management of ancestral places. At Montezuma Castle, the knowledge shared by members of the Hopi Tribe complements what we have learned through years of scientific inquiry. This cooperation creates avenues for Hopi tribal members to become active participants in the management of their ancestral places and will create space for their voices to become part of the site's public interpretation in the future. Despite these successes, there is still much work to do. The NPS will continue to find ways of incorporating traditional knowledge into the management of the Montezuma Castle cliff dwelling.

Notes

1 A short architectural study was conducted at the site by the Western Archaeological and Conservation Center in 1988 (Wells and Anderson 1988). This is an excellent source of information on the dwelling, but it does not include tribal perspectives.

2 There are a number of studies that support this statement; however, we have learned this important fact from working directly with our colleagues at Hopi.

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Stabilization of Buddhist Mural Paintings from Guru Lhakhang, Ladakh, India

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Abstract: *This paper presents the challenges of the wall painting conservation project at Guru Lhakhang, with emphasis on Himalayan earthen mural painting technologies, specific damage, and solutions. The main interventions include the stabilization of the architectural structure, the reattachment of the delaminating clay support, and paint exfoliation. Scientific analysis of the original wall painting components, understanding the causes and mechanisms of deterioration, and studying the local resources and their properties, together with evaluation of the intervention materials, have been the main steps in determining the most suitable conservation approach.*

Resumen: *En este artículo se presentan los desafíos del proyecto de conservación de las pinturas murales en Guru Lhakhang, con énfasis en las técnicas de las pinturas murales de tierra de la región del Himalaya, los daños específicos y las soluciones implementadas. Las intervenciones más importantes incluyen la estabilización de la estructura arquitectónica, la reinstalación del soporte delaminado de arcilla y la pintura exfoliada. Los pasos principales para determinar el enfoque de conservación más adecuado fueron el análisis científico de los componentes originales de la pintura mural, la comprensión de los motivos y el mecanismo del deterioro, así como el estudio de los recursos locales y sus propiedades.*

Keywords: Buddhist wall paintings, conservation, earthen heritage, Himalayan murals, Ladakh heritage

Introduction

Guru Lhakhang is a privately owned Buddhist temple, the only intact part of a ruined cliff-top palace complex located in Phyang Valley, 20 km northwest of Leh (Ladakh) at 3550 meters. The hamlet under the fort is the earliest settlement of old Phyang village (fig. 1).

The one-story temple is in a simple Himalayan vernacular style, built on a rocky foundation with stone lower walls, mud brick, and timber. It is square in plan (6.18 × 6.3 m) with a small entrance door on the south wall and without windows, just a lantern in the flat roof.

The interior walls (45 m²) are decorated with a valuable mural ensemble of contentious age placed by art historians somewhere between the fourteenth and fifteenth centuries (Vitali 2005; Lo Bue 2011). The Buddhist iconography includes a celebration of Sa kya pa masters and portraits of aristocratic figures attending the temple consecration ceremonies, all identified from their inscriptions beneath. The murals constitute important cultural and religious value to the community and a significant art-historical record of the place with educational and research value. Guru Lhakhang is still in use for religious practice and is regularly maintained by the caretaker and owner, Mr. Gasha, who invited Tibet Heritage Fund (THF) to survey the temple and recommend a plan for its safeguarding in 2016.



FIGURE 1 General view of the Guru Lhakhang temple location and the fort ruins. Photo: A. Nicolaescu.

Technical Details

The Guru Lhakhang mural follows a typical Himalayan painting technique: natural pigments with animal-glue binder on a clay support. The support is composed of a coarser mortar (soil, clay, gravel, straw, and sometimes twigs) to level out the irregular masonry, followed by a second, finer and compact mortar (*markalak*, soil, and animal hair) that provides a smooth, stable base for the kaolinite ground layer. X-ray diffraction (XRD) analysis established an illite-dominated clay mineral range for the render, giving desirable construction properties. Analysis shows that *markalak* ("oily sludge" in Ladakhi) is 80% clay (mainly illite 77.50%, kaolinite 1.80%, and montmorillonite 0.70%) with 20% silt (but zero sand), while all the other soil samples contain sand, silt, and some clay (Nicolaescu 2016).

The pigment range studied to date includes calcite for the white paint, vermillion, orpiment, an unidentified yellow lake, chalconatronite or similar copper green, and indigo.

The painting technique is complex; superpositions of different colors create different hues or shades, and glazes skillfully impart subtle volume.

Condition Assessment

A complete photographic and graphic documentation was compiled. Each deterioration type (including evidence of past treatments) was mapped in order to monitor its recurrence and location in the whole area, particularly for future reference. There appear to have been three previous interventions: two were directed toward the architecture with minor isolated interior interventions and a third was limited to assessment and a treatment testing campaign.

Modifications made during a 1998 intervention raised concerns about causing damage to the murals (Harrison et al. 2000). The traditional open lantern in the roof was changed and two outdoor spaces abutting the temple walls were filled with rubblestone. An environmental assessment was undertaken during our intervention in 2016 in order to determine the impact on the paintings from external forces. This has focused on solar impact through the lantern and the general environment affecting the walls and roof to help determine plaster instability. A data logger was installed close to the ceiling, to the west of the lantern, for a year. It recorded air

and wall temperatures, humidity, and light levels in order to provide information on the background moisture conditions within the temple and how they interact with the paint and plaster layers.

The temple is sound, and no severe structural damages were observed during the architectural survey. However, there are some deep cracks on the south–north axis, with cracks under the roof beam brackets that have bulged due to the heavy weight of the roofing soil accumulated through years of inadequate maintenance. Raking light reveals uneven wall surfaces with areas of severe bulging in the lower parts due to the irregularity of the stone masonry.

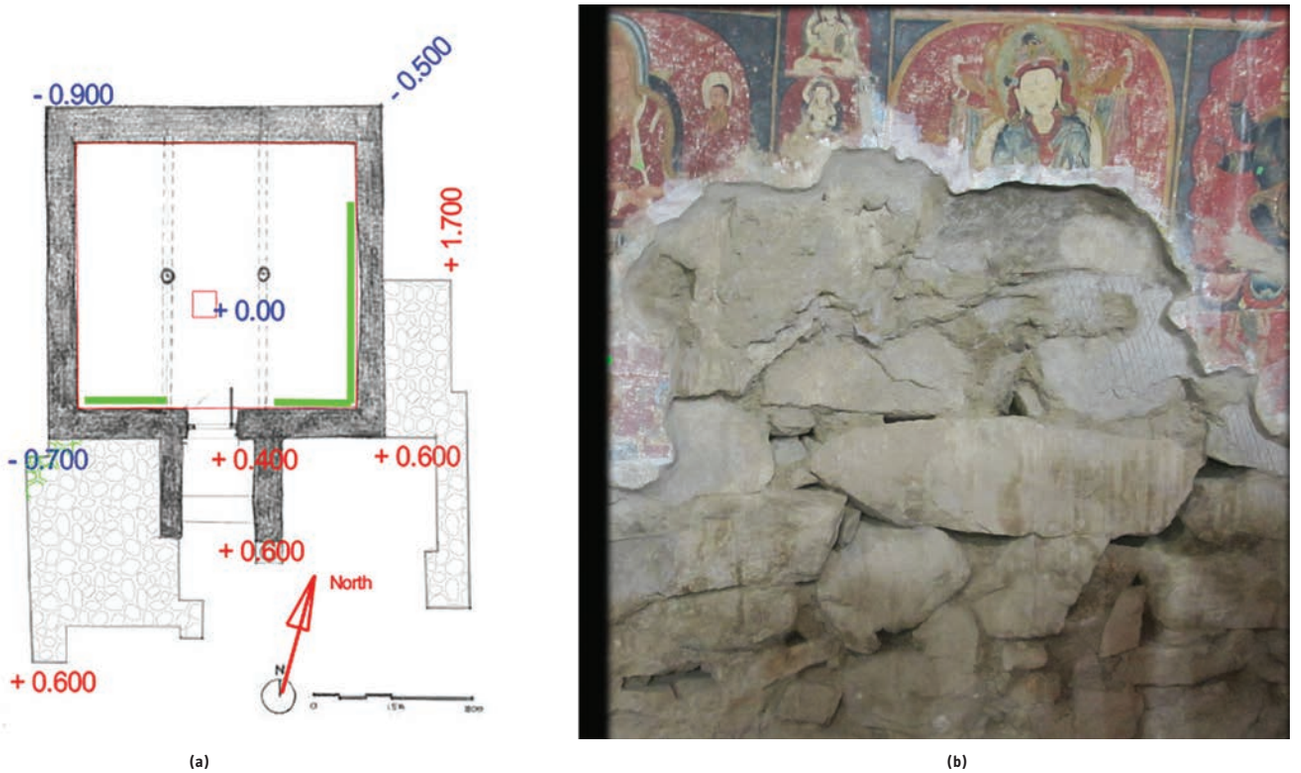
Render has been lost in two main areas, the largest of which is along the east wall that culminates in an area of loss toward its southern end below exterior ground level. This damage continues onto the south wall whose height is diminishing due to the lower wall not being buried. The second area of loss is on the south wall to the west of the door, where the abutting outer room has been filled with rubble (fig. 2).

Water entry through the roof perimeter has caused damage in three places: two wash zones on the west wall that are associated with the roof drainage (one of these has been previously rectified) and an area on the south wall where there is detachment from the support above the door due to structural movement. Also, the lower roof above the entrance has trapped water that has infiltrated through a visible crack, weakening the render and the painting on the south wall (fig. 3).

Water infiltration on the west wall provoked major damages to the painting, washing it off in some areas and producing plaster decohesion that caused further exfoliation and flaking of the paint layer. In the upper walls, the support has slid together with the paint layer, resulting in irreversible cupping/wrinkles that are most likely the result of prolonged water saturation in the wall (fig. 4).

The modified lantern has been studied to assess the impact of direct sunlight and its contribution to light levels. An insolation study using the model developed by Thorn (2005) determined that sunlight enters the lantern and falls onto the most affected area of plaster loss, but that overall recorded light levels during normal use are very low and are unlikely to dramatically alter the paintings.

However, the paintings contain light-sensitive pigments including indigo, orpiment, and yellow organic lakes, all of which fade in the presence of light regardless of UV levels.



(a) (b)

FIGURE 2 (a) Recording of the ground levels around the building, showing that in both render loss areas (marked in green), soil levels are higher than the internal floor height and (b) detail of the east wall render loss, revealing the irregularities of the stone masonry. Architectural plan : Y. Hirako, THF. Photo: A. Nicolaescu.



(a)

(b)

FIGURE 3 (a) General view of the temple and (b) water infiltration affecting the south wall. Photos: A. Nicolaescu.



FIGURE 4 Detail of the paint layer wrinkles on the upper west wall. Photo: A. Nicolaescu.

The study showed light levels remain below 50 lux throughout the year, with only the conservation program raising light levels to 350 lux. International standards advise light levels below 100 lux for sensitive paintings on permanent view. This has implications for future tourist visitation. In order to open the building to visitors, the light levels would have to be raised and these new levels could be deleterious to the wall paintings.

Loss of render appears to be mainly driven either by poor drainage of the flat soil roof or by high external soil levels. Sunlight falling on the paintings in the southwest corner is considered contributory but less significant than the wall being below outside ground level. Render losses predate the rubble filling in the side rooms, indicating that this work did not exacerbate damage and there is no indication that the render loss has expanded since the initial pre-1998 repairs.

Treatment

The main goals of the THF conservation project in Guru Lhakhang have been the urgent stabilization of the wall paintings to prevent further loss, as well as architectural interventions that aim to mitigate future deterioration. No retouching of the paint layer losses has been carried out at this stage, only mechanical cleaning tests of the adherent dust, soot, and clay deposits to assess the conservation condition of the paintings underneath.

The stabilization has required reattachment of render to masonry, ground, and paint layer exfoliations, and consolidation and reattachment of flaking and powdering paint. The treatment materials were selected both for compatibility with the original and for their long-term stability. The efficacy of these materials has been established over ten years of treatments on similar paintings in the region. Additional testing of specific materials and application methodologies was necessary at Guru Lakhang due to the site's severe and atypical damages, such as the buckled and detaching paint layer.

All the treatments have been documented, photographed, and mapped to periodically assess performance.

Paint Layer Treatments

Gelatin was selected as the adhesive for its compatibility with the original binder and its working properties (penetration, adhesion, and color stability). Published research (Soppa et al. 2014), together with initial tests of different animal glues including various local ones, proved less suitable for such applications.

Paint Flake Reattachment

A 2% gelatin solution was successfully used for the reattachment of paint flakes in our previous treatments of similar wall paintings. In paint and ground layer reattachment trials at Guru Lhakhang, however, this solution produced tide marks, stains, or paint layer disturbances during the adhesive injection, requiring adjustments to materials and methodology to avoid these issues.

A layer of menthol, dissolved in isopropanol and brushed on the surface to be treated, was found to create a protective dense film that was enough to block the migration of adhesive during its application. The protective layer sublimates after some hours without residues (Langdon, Skinner, and Shugar 2015). After the adhesive application, the paint flakes were pressed with a rubber roller through Japanese paper and a layer of Melinex film. The crystallized menthol layer continued to protect the paint surface during this process (fig. 5).

Treating the Paint Layer Exfoliation

Exfoliations are associated with the loss of plaster cohesion below the ground layer, causing a combined lifting of the paint layer, ground, and some fine plaster (fig. 6).

Previously successful treatments, similar to flake relaying, were insufficient even after repeated applications. Further testing developed different methodologies, adhesives, and concentrations, all recorded and assessed after a year but open to further refinement in future years.

In the new tests, gelatin was used in different concentrations (2, 2.5, and 3%) or in combination with other consolidants to address the plaster cohesion. Tests with different

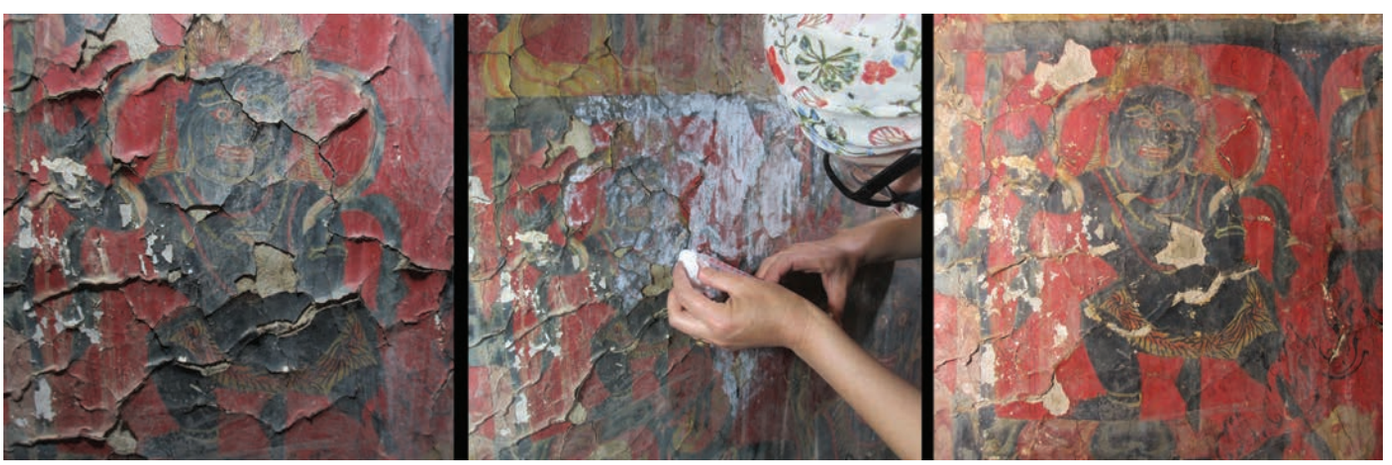


FIGURE 5 (a) Paint layer before intervention, (b) during the paint flake relaying using menthol protective layer, and (c) after fixation and edge pointing of the fragile paint layer. Photos: A. Nicolaescu.



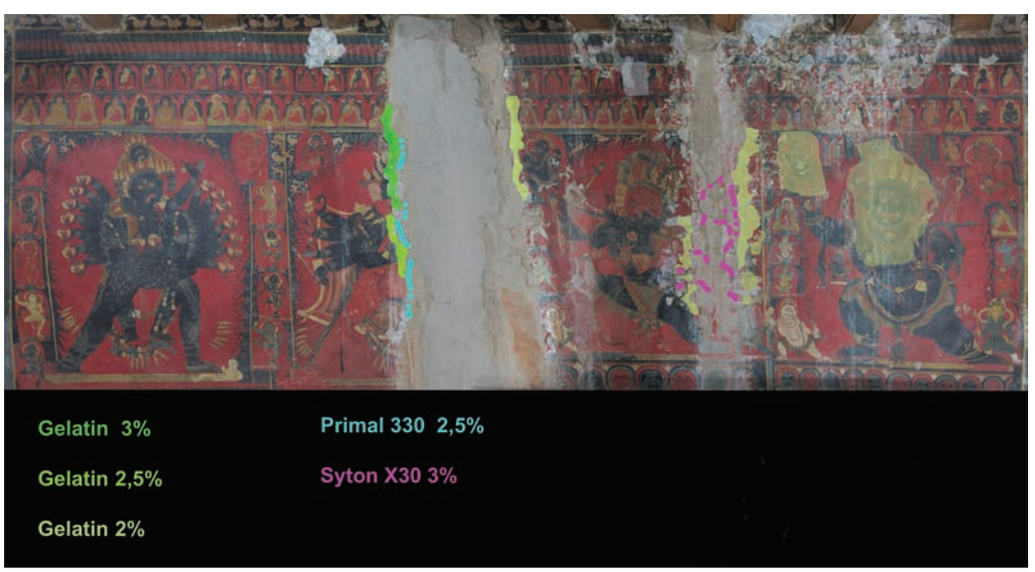
(a) (b)

FIGURE 6 (a) Macro photography of the exfoliating paint layer and (b) detail of the compression system for the paint layer reattachment. Photos: A. Nicolaescu.

concentrations of an aqueous silica emulsion (Syton X30) and an acrylic emulsion (PRIMAL E330) in ethanol to avoid water staining were also evaluated.

Tests were carried out on loose fragments of the support and on the lower part of the east wall with losses in the paint layer. These in situ tests compared the changes to the original material after the application of the consolidants: color change, water drop absorption, permeability changes (measurement of the capillarity coefficient determined by a contact sponge method [Vissac 2017]), and surface cohesion measured through contact with a cotton swab or soft brass brushes. After narrowing the selection to the better-performing consolidants and their concentrations, further tests were applied to severely damaged areas around the water leaks and areas of isolated paint fragments on the west wall to observe the outcomes after a year (fig. 7).

The application methodology was modified after evaluating these tests a year later. If the area was previously just pressed with a rubber roller, it was now held under a compression pad for twenty-four hours or ironed with a hot spatula and then pressed. An obvious outcome of the tests was that pressing the treated surface for twenty-four hours (or until



(a) (b)

FIGURE 7 The consolidation tests on the west wall. Photo: A. Nicolaescu.

completely dry) improves the reattachment. In addition, ironing with a hot spatula was beneficial in more severe cases of detachment as this method controls swelling of the clay substrate by speeding up the drying time.

Using the methodology described above, a 2% solution of warm gelatin, compatible with the original materials, gave very good results in areas with reasonably cohesive plaster. A 3% solution of Syton X30, applied in areas with less cohesive plaster, improved results without changing the original support properties. The only potential drawback was staining, and this was prevented by applying Japanese paper to the surface to create an outer evaporation layer. PRIMAL E330 improved the surface cohesion but produced unwanted changes in permeability of the original materials, even at lower concentrations.

The Treatment of Paint Layer Wrinkles

This type of damage could not be reversed without threatening the original surface. Therefore, these areas were preserved only with targeted paint reattachment.

Edge Pointing / Small Plaster Losses

In areas with losses of the support and paint layer exfoliation over friable plaster, the ground and paint layer edges often had no underlying support and remained very fragile even after consolidation.

A liquid clay mortar was developed to secure the delicate edge pointing areas and was applied by brush or by local injection in areas of plaster loss. The liquid clay composition is based on research for clay-based injection grout for support detachments (Nicolaescu 2016) and modified to achieve the fine stabilization of these ground and paint layer edges (see fig. 5).

The same natural local components (*markalak* and yellow soil) of the original render, chosen for their chemical and mechanical compatibility, were sieved (150μ) and mixed with 2% gelatin, rather than just water, for better cohesion and adhesion to the plaster edges. This mortar was tested first in 2007 at Red Chamba temple (Leh, India) where its performance (adhesion, shrinkage, and permeability) was assessed on purpose-made mud bricks and mock-up renders (Nicolaescu 2016).

Consolidating Support Detachments / Grout Injections

Our previous research showed earth-based injection grouts successfully stabilized paintings on mud renders. Systems for both grouting and surface repair that can be applied effectively have been developed, and these have remained stable for over ten years.

Critical requirements such as adhesion, shrinkage, and flow have all been refined during testing and consequent application, and it is critical to state that the tests themselves have been shaped by how the materials perform in real-world applications (Nicolaescu 2016). The treatment procedures involved complex preparations and methodology planning (fig. 8):

- Acoustic localization of the detached areas;
- Paint layer condition assessment before commencing grouting;
- Injection holes drilled into cracks or other damaged areas, as required;



(a) (b)

FIGURE 8 Images during support stabilization: (a) During grout injection, the protective Japanese paper layer covers the entire detached area and the quantity of injected grout is marked as the treatment progresses, and (b) during grout injection, using catheters for grout penetration. Photos: A. Nicolaescu.

- Mounting catheters for grout penetration where necessary;
- Surface dusting;
- Application of a Japanese paper facing with 3% Klucel adhesive for surface protection and occlusion of fissures;
- Mortar edging of delaminations before injecting to avoid grout flowing onto the painted surface;
- Filling fissures, including fine ones, adjacent to the intervention area;
- Temporary pressing with pads for plaster support during the injection and grout cure (at least 24 h);
- Pre-wetting of the consolidation area with a mixture of water and alcohol;
- Grout injection;
- Recording the quantity of grout injected;
- Removal of paper facing after complete drying;
- Repeating the operation if necessary.

Conclusion

The stabilization of the wall paintings from Guru Lhakhang required a reevaluation of the materials and methodologies used in the last ten years on similar murals with successful and stable results. The in situ evaluations represent the first step in choosing compatible intervention materials that can be refined after new assessments and laboratory evaluations.

The collaboration between architects, materials analysts, craftspeople, and wall painting conservators has been essential for designing interventions that address the stabilization of the structures themselves and protect the future deterioration of murals. And, because THF has a local branch and trainees, the conservation works are regularly surveyed, recorded, and maintained.

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Powers of Ten: Analyzing Ancient Earthen Architecture and Plasters in the American Southwest

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Abstract: *In the ancient architecture of the American Southwest, earth was used as a primary structural material for roof and floor surfaces, leveling and finishing walls, imparting color and sheen, and building in architectural features for domestic and ceremonial activities. These earthen materials are often well preserved in the arid climates and alcove sites of the region. Since 2013, the National Park Service (NPS) has collaborated with the Department of Anthropology at the University of New Mexico (UNM) to study earthen building materials at archaeological sites dating from the seventh through the fourteenth century. The use of earth for so many different architectural purposes means that in completing characterization studies, one is not focused solely on architectural finishes but is engaged at scales encompassing structure, decorative surfaces, utilitarian and special-use features, repurposed rooms and open areas, and the archaeological import of each. We are accustomed to thinking that the preservation history of many of these sites begins with the first federally funded repair efforts of the late nineteenth and early twentieth centuries, identifying preservation with direct intervention (when withholding treatment is often the better option). This paper illustrates how collaborative research and analyses conducted at different scales are changing this management paradigm, resulting in recommendations for fewer and more effective repairs that sustain and enhance the multiplicity of heritage values at these sites.*

Resumen: *En la antigua arquitectura del suroeste estadounidense, la tierra era el material estructural predominante que se utilizaba para construir las superficies de techos y suelos, nivelar y revestir las paredes, dar color y brillo, y elaborar elementos arquitectónicos para las actividades domésticas y ceremoniales. En muchos casos, los materiales de tierra se preservan bien en los climas áridos y los sitios en cuevas de la región. En los últimos tiempos, el National Park Service colaboró con el Departamento de Antropología de la University of New Mexico para estudiar los materiales de construcción de tierra en sitios arqueológicos que datan de los siglos vii al xiv. Ante el uso de tierra para tantos propósitos constructivos diferentes, al completarse los estudios de caracterización, se decidió no enfocarse solamente en los revestimientos arquitectónicos, sino también en aspectos a otra escala, que abarcan la estructura, las superficies decorativas, los elementos utilitarios y de uso especial, las habitaciones reutilizadas y los espacios abiertos, además de su importancia arqueológica. Se suele pensar que la historia de la preservación de muchos de estos sitios comenzó con las primeras acciones de reparación financiadas por el gobierno federal a finales del siglo xix y principios del xx, y se tiende a relacionar la preservación con la intervención directa (cuando la conservación preventiva es la mejor opción). En este artículo, se muestra la manera en la que los análisis realizados a varios niveles cambian este paradigma de gestión. A partir de investigaciones recientes, realizadas en colaboración con integrantes de las comunidades de descendientes, arqueólogos, conservadores, científicos de materiales e ingenieros, se obtuvieron recomendaciones para realizar reparaciones en menor cantidad y más eficaces, que mantengan y mejoren la multiplicidad de valores patrimoniales de estos sitios.*

Keywords: earthen plasters, archaeological sites, conservation, cliff dwellings

Introduction

For decades, archaeologists have regarded the detailed characterization of earthen materials used in the construction of ancient southwestern sites as hardly worth the trouble, unlikely to accomplish more than confirming that soil from the site was mixed with water and smeared on the surface. Unless plasters were decorated with painted or incised designs, they were, generally, deemed unworthy of close study. Recently, our characterization of earthen plasters from several Ancestral Pueblo and Ancestral Sonoran Desert sites in the American Southwest has revealed that earthen building materials were selected and manipulated for specific architectural purposes, providing glimpses into a sophisticated ancient plaster craft that conveys some of the builders' design intents.

The practice of archaeology in the US has changed fundamentally since the sites discussed here were excavated a century or more ago. Now, excavation is rarely undertaken outside the context of salvage, and the built environment, primarily masonry walls left exposed from past excavations, has become a primary node of archaeological analysis. With the focus now on architecture, attention to ancient earthen plasters was inevitable. This is especially true of cliff sites, where spatial constraints imposed by the alcoves meant that dwellers repeatedly adapted existing rooms to changing needs, often repurposing them by replastering. Because of the natural protection provided by the rock outcrops, many of these subtle changes survive in legible form (fig. 1).

Threats to the preservation of these sites occur at several scales, including degradation of the earthen finishes, but also involve structural threats such as subsidence and rotation of walls due to changing support conditions, exposure to weather, visitor traffic, inappropriate past stabilization, and the vulnerability of slender wall segments that are unbraced by roof and floor construction and isolated from intersecting walls by large vertical cracks (fig. 2). To address the complexity of these issues at each site, we adopted a multiscale and multicomponent assessment strategy consisting of (1) field survey, site documentation, and archival research to determine the site's history; (2) materials characterization to better understand the building technology, assign allowable design values, and identify appropriate repair materials; (3) architectural and archaeological analyses to develop a construction chronology and use history; and (4) structural analysis to evaluate current structure capacity, as well as the loads to which the construction is likely to be exposed. Pursuing these studies simultaneously has advanced our knowledge of the diverse values inherent in these sites, provided measures of the vulnerabilities to be addressed, and allowed for the tailoring of treatments to address specific inadequacies so that unnecessary alterations are avoided. This paper focuses on the methodology of our assessment strategy and summarizes the results of our characterization studies; more detailed discussions, along with the results of our architectural analyses and engineering assessments, are cited in the References section of this paper.



FIGURE 1 Upper and Lower White House, Canyon de Chelly National Monument (ca. 1000–1280 CE). The shelter afforded by the alcove has resulted in a remarkable state of preservation of the earthen construction materials, including mortars for unit masonry, roof and floor surfaces, wall plasters, and decorative finishes that include wall paintings and incised glyphs. Photo: Angelyn Bass.

Characterization Studies

In characterizing the earthen materials at these sites, analyses were conducted at multiple scales, making use of instrumental analyses to minimize sample sizes. Macroscopic features were characterized in situ, including identification of functional material groups, coarse fraction granulometry, and the documentation of surface features including color, surface texture, stratigraphy, and the presence of glyphs and other embellishments. Where larger samples were available, we evaluated physical properties using standard soils analysis techniques, which provided information on particle size distribution, fracture porosity, and Atterberg limits. In most cases, however, our sample sizes were intentionally small (≤ 1.5 g); using scanning electron microscopy (SEM), we obtained information on porosity, binder/aggregate proportions, and particle size/



FIGURE 2 A partially intact roof with an earthen roof plaster covering the closing materials, Upper Cliff Dwelling (ca. 1325–1450 CE), Tonto National Monument. In the preparation of the plaster, attention was paid to aggregate grading and premixing of the dry ingredients to insure the density and durability of the final product. In other roof plasters at the Upper Cliff Dwelling, we found that the builders used woven vegetal fiber mats to reinforce the plaster. Photo: Angelyn Bass.

morphology. In identifying clay and aggregate minerals and characterizing the microstructure of the mixes, we largely relied on X-ray diffraction (XRD), light microscopy, and scanning electron microscopy with energy dispersive spectrometry (SEM-EDS). Porosity measurements and phase analysis were done on backscattered electron (BSE) micrographs using image analysis software based on threshold analysis of gray-level images (fig. 3). Additional enhancement of the micrographs with ImageJ software yielded information on particle morphology and size distribution. By combining instrumental analyses, we have been able to produce detailed characterizations using micro-samples (Bass et al. 2017).

In the sites we examined, where the primary periods of occupation date prior to ca. 1450 CE, earthen materials were classified according to functional groups: (1) *structural*, either as one of the primary load-bearing materials or as bedding mortar for unit masonry. Construction was typically phased to minimize slump, and construction episodes (lifts) are typically 0.5–1.0 m high; (2) *leveling plasters*, often applied as the finishing stage of each construction episode and used to establish the wall planes on interior and exterior surfaces and can account for up to 30% of wall thickness; (3) *margin plasters*, used for closing wall penetrations around roof frames and where masonry walls meet alcove surfaces. These typically have a distinctive fingerprint texture from pushing the plaster into voids and, because they were renewed when roof frames or hatches were repaired, they sometimes have "not before" dates derived from dendrochronology; (4) *roof plasters*, used to fill gaps and cover the vegetal closing material and provide

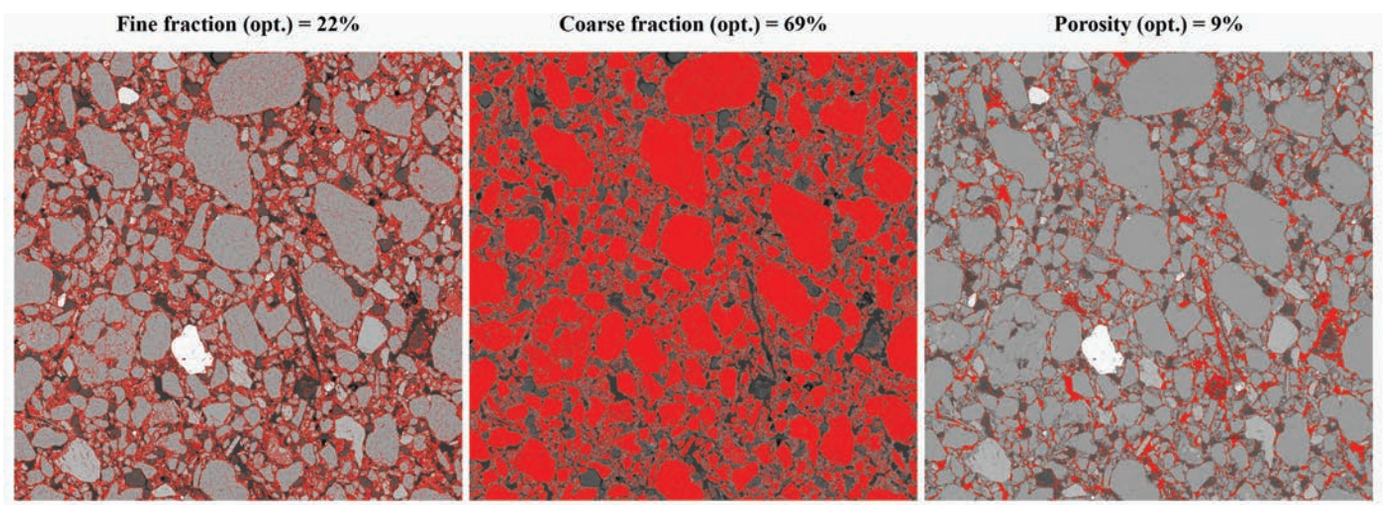


FIGURE 3 Image analysis of SEM micrographs yields information on the groundmass of the mix and the ways in which the coarse and fine fractions are combined. These include binder/aggregate ratios, the degree of blending, whether the aggregate fraction can be considered well graded or well sorted, and the porosities that typify the mix. This sample is from a roof plaster collected from Stack 3 at Antelope House, Canyon de Chelly National Monument. Photos: Mike Spilde, Institute of Meteoritics, UNM.

a water-resistant surface for the roof, or a substrate for floor plasters. Roof plasters were typically applied in a single thick (8–15 cm) coat; (5) *floor and feature plasters*, used to create surfaces at grade and over roof plasters in upper levels, as well as to form built-in architectural features in floors and walls such as raised platforms and floor ridges, mounded collars around hearths and mealing bins, loom anchors (coiled willow loops and corn cobs set in earthen plugs), and molded doorway surrounds, to name a few. These frequently consist of 2–10 cm of fine-grained plaster; in floors, at least some of these plasters were applied in thin (≈1 mm) layers as part of a simultaneous renewal of floors and walls; (6) *finish plasters*, 1–10 mm thick, used to smooth wall surfaces (including alcove walls incorporated in room construction) and to impart color; and (7) *washes*, <1 mm thick, used for renewing wall finishes, layering color or sheen, and executing painted designs (fig. 4).

Not every site includes all these functional groups, but most have a majority of them. These materials are distinguished not only by function but also by differences in particle size distribution, surface texture, mixing strategies (blending level, water content), and methods of application or construction. While the mineral constituents vary according to site geology, there are generalizations that can be made:



FIGURE 4 Interior wall plasters at Montezuma Castle (ca. 1125–1390 CE), Montezuma Castle National Monument, display a typical horizontal division of the wall: a multilayered dado on the lower half, a single-layer, handprint-textured leveling plaster on the upper half, and margin plasters filling voids around primary ceiling vigas. There is a yellow wash under the sooted surface that may signal economic and social connections to the Hopi and Flower World concepts that inspired the Jeddito Yellow Ware ceramics found at Montezuma Castle (Guebard, Bass, and Porter 2018). Photo: Neil Dixon, The Front Standard Photography, for the Department of Anthropology, UNM.

- Particle size distribution was manipulated in most of the mixes depending on the thickness of the layer(s) to be applied. Structural materials and leveling, margin, and roof plasters were installed in relatively thick coats and, in most cases, included coarse sands and/or fine gravels in the aggregate fraction. Floor and finish plasters and washes were applied in thinner coats. Finish plasters frequently incorporate fine and medium sands; floor plasters and washes are often composed primarily of clay and silt-size particles.
- For materials installed in thicker lifts or coats, the proportion of water in the mix seems to have been controlled, likely to reduce slumping, as indicated by the abundance of underhydrated clay lumps, packing voids, and polyconcave vugs in the mixes. These are mostly absent from finish and floor plasters. Washes, which were often applied by brush, seem to have been tempered frequently, based on the variability of the binder proportion throughout the layer and the relatively open porosity of the hardened material, presumably left by the evaporation of water in the mix.
- Extra attention was paid to aggregate gradation and premixing of dry ingredients in roof plasters and other materials exposed to the elements. These mixes are more apt to be well graded and thoroughly blended (a condition difficult to achieve except by premixing the dry ingredients). Well-graded mixes can result in denser packing of the particles, providing volumetric stability, increased load-bearing capacity, and reductions in the volume of pore space, minimizing interactions with water and frost.
- Color played a central role in the organization of Pueblo life (Munson and Hayes-Gilpin 2019), and at all the sites earthen finishes of varying colors (predominantly white, yellow, black, and red) were used to embellish surfaces. Micaceous washes at Canyon de Chelly were used to contribute sheen, while at Casa Grande thin (<200 μm), translucent washes of red micaceous earth and gypsum applied over all the interior walls impart a reflective quality thought to symbolize water (Guebard, Bass, and Porter 2018). In cliff dwellings at Canyon de Chelly and Tonto National Monuments, white finish plasters and washes figure prominently on both interior and exterior surfaces. Their placement on exterior walls, especially around

openings, helps to light interior spaces. Whitewashes, used in geometric designs on interior walls and public spaces (including rock faces), and the use of different pigments to achieve the same effect, suggest that the craft knowledge was well developed, and that pigment choice may have been particular to the context (fig. 5). Embellishments were also incised and sometimes combined with colored washes in wet finish plasters; they can be geometric or representational like the sandal patterns at Bare Ladder (fig. 6).

- At several sites, including the great house at Casa Grande, both cliff dwellings at Tonto, and Montezuma Castle, builders sourced structural and plaster materials from calcic horizons of caliche beds. Given the quantity of carbonate materials in some of the wall materials and plasters (calcite accounts for up to 50% of the binder fraction in some samples), the selection of this material is considered deliberate. Wall materials and plasters with significant calcite cement proportions are likely to be more durable than clay-based plasters alone.

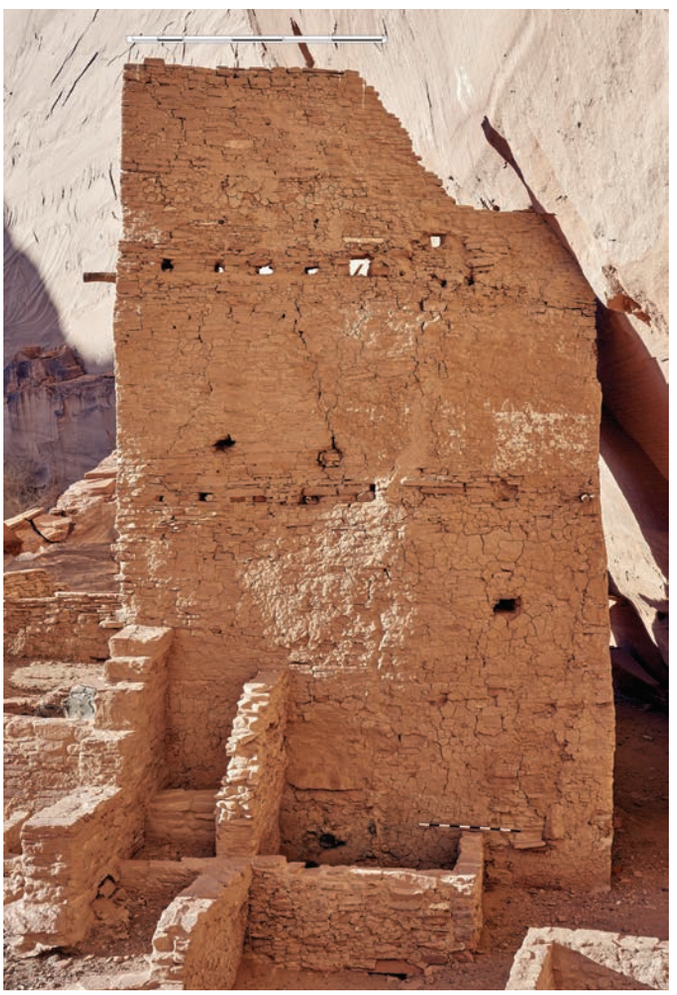


FIGURE 5 This wall painting on a four-story tower at Antelope House (ca. 700–1280 CE), Canyon de Chelly National Monument, features a triangles-and-dots design, a motif that also appears on the bench and wall of Room 23, to which the tower is connected. Its placement on the third story of an exterior facade made it clearly visible by the entire community. White plasters and washes, used liberally in this and neighboring cliff dwellings, were composed of several white pigments, including kaolinite, calcite, gypsum, and pulverized potassium feldspars. Photo: Neil Dixon, The Front Standard Photography, for the Department of Anthropology, UNM.



FIGURE 6 Incised sandals in Structure 14, Bare Ladder (ca. 1142–1250 CE), Natural Bridges National Monument. This room has more than 150 incised embellishments in the earthen wall plaster related to textiles, and holds woven goods and more than 25 different sandal patterns. In the floor are several intact loom anchors for securing vertical looms, along with weaving tools and remnants of human hair cordage embedded in the floor surface. Photo: Neil Dixon, The Front Standard Photography, for the Department of Anthropology, UNM.

Methodological Approach to Architectural Analyses and Engineering Assessments

Provenience-based, multiscalar architectural investigations complement characterization studies and are essential to understanding how ancient structures were built, used, and changed over time. These investigations address many of the same larger study units that were the focal points of earlier investigations—individual rooms or room groups, larger public spaces, single villages or grouped sites, etc.—but also smaller units of architectural production, including construction episodes (construction completed in a single event), bonding and abutment patterns, sealed doorways, and changes in building materials and surface finishes. In more recent work, the list of room types has been expanded to include functional-use open areas (rooftop terraces, ramadas, and other partially delineated outdoor spaces) where many day-to-day activities likely took place. In these provenience-based studies, results are expressed in detailed plan and elevation drawings, often using templates produced from Light Detection and Ranging (LiDAR) scans, annotated to identify and interpret this material (fig. 7). Architectural analyses also capture ancient and more recent repair campaigns, incorporating the results of visual inspections with data from excavation/preservation treatment reports. They are often the only description we have of interventions now hidden from view.

To address larger-scale threats that include structural movement, loading eccentricities resulting from changes in support conditions or the loss of key structural elements, visitor impacts, and the effects of overly aggressive treatment, our projects included engineering studies focused on quantifying current capacity and loads and identifying vulnerabilities. Advances in nondestructive testing technology and computer modeling have resulted in powerful tools for assessing current condition and capacity. Mobile laser technology, infrared thermography, surface penetrating radar, and resistance drilling determine existing conditions nondestructively. LiDAR scans capture the imperfect current geometry of structures that are no longer complete. Scan data can be used for evaluating structural displacements and deformations, as well as for creating structural models with accurate geometries (fig. 8). Such models can be used for seismic vulnerability studies. By quantifying residual capacity and current demands on the structure, modeling and analysis help to identify its most vulnerable elements so that interventions can be focused where they are needed most, reducing unnecessary treatment.

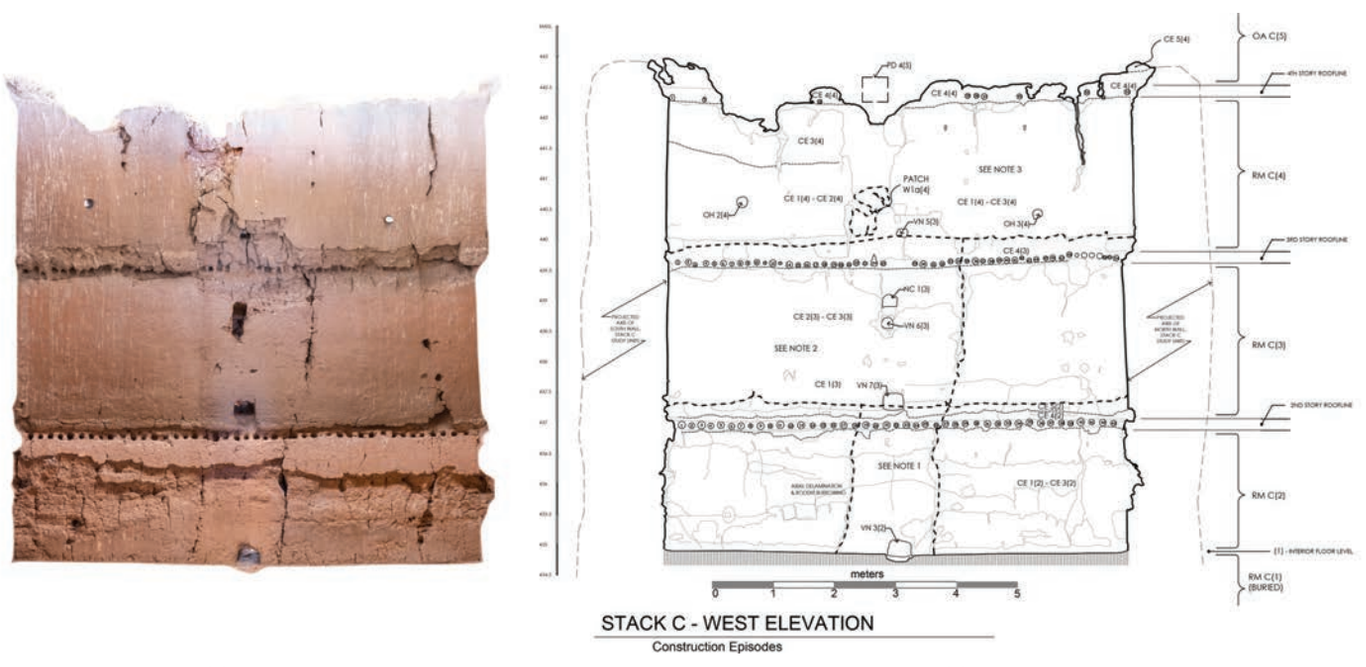


FIGURE 7 At Casa Grande (ca. 1350–1450 CE), Casa Grande National Monument, architectural analysis of the great house included production of photo composites of stack elevations and annotation of architectural sheets derived from LiDAR scan data to show (a) wall sectors, (b) construction episodes, and other features of archaeological significance. Illustrations: Larry Nordby, Jeremiah Gwin, and Angelyn Bass for the Department of Anthropology, UNM.

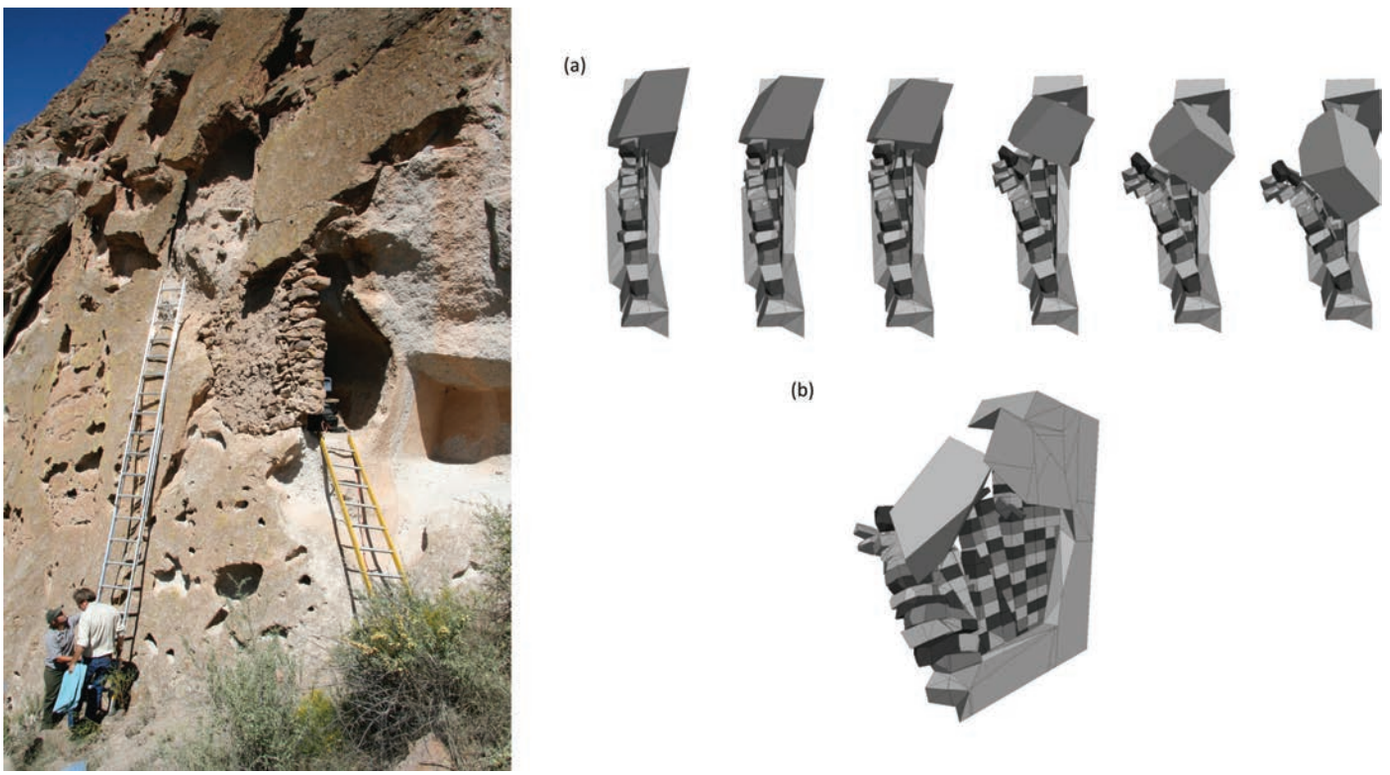


FIGURE 8 Left: Cavate B-2 at Bandelier National Monument (ca. 1100–1725 CE) has one of the last intact, plastered masonry partition walls in situ. It is threatened by detachment of the tuff boulder at the top and by erosion of the tuff at the base of the wall. Right: Ochsendorf DeJong & Block constructed this discrete element model (based on LiDAR data) to capture wall and outcrop geometry and explore collapse scenarios virtually. The modeling sequence depicts a collapse resulting from reducing joint strength and frictional capacity, viewed in (a) profile and (b) inside. Illustration: Ochsendorf DeJong & Block for the School of Engineering, University of Vermont.

Conclusion

Ancient builders and plasterers used earthen materials for multiple purposes, creating structural materials and surface finishes through binder/clay selection, aggregate gradation, premixing of dry ingredients, and control of mix-water proportions. Characterizing these materials contributes to our knowledge and understanding of ancient craft practices and provides information on the physical properties of the materials that can be used in many ways—from structural analysis to the design of appropriate conservation treatments to changing site management practices. Understanding the behavior of these materials and their architectural roles is essential to evaluating their performance; failure to apprehend the design intent can result in unnecessary treatments that are disfiguring and damaging and that alter the authenticity and spirit of these places. Combined site investigations, materials characterization, archaeological analyses, and structural assessments conducted through these collaborative UNM projects have expanded our awareness of the many diverse and dynamic site values that must be protected and managed for specific culture groups as well as the broader public, and has significantly increased interest, awareness, and financial support, which are essential for the sustainability of the sites (Lipe 1974; Demas and Agnew 2013).

For most of the western states where these sites are located, climate models show future increases in the number of wildfires that are likely to be followed by flash flood events (Touma et al. 2022). This significantly increases the likelihood of devastating floods in many of the watersheds where these sites are located. In times of catastrophic loss, cultural places become even more powerful symbols of connectedness, resilience, and recovery. At the same moment, the sites are threatened at scales that far exceed the reach of our current management efforts. The documentation of these sites, including the characterization studies presented here, is a reasonable but insufficient response to the risks.

We have reached a point where cultural resource protection must be focused on climate advocacy and action as a matter of necessity.

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Lecciones aprendidas sobre la conservación en México de bienes culturales prehispánicos elaborados con tierra

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Resumen: *La revisión de seis casos de patrimonio cultural que presentan elementos decorativos adosados a estructuras prehispánicas mexicanas cuyo componente principal es la tierra permite reconocer las estrategias empleadas para su conservación y, consecuentemente, proponer mejores prácticas. Se trata de bienes culturales relevantes que se ubican en la región central de México e incluyen cuatro murales, un relieve y una combinación de mural y relieve. Los casos de estudio corresponden a un periodo entre el 200 a. C. y el 1521 d. C. Estos vestigios arqueológicos han sido intervenidos con diversidad de tratamientos, estrategias y gestión, cuya comparación ha servido para reconocer prácticas acertadas y otras no recomendables. En todos los casos se implementaron medidas de tratamiento directo e infraestructura para protección y acceso. La intervención hizo uso de polímeros sintéticos y, gradualmente, adquirió un carácter más preventivo, que integra materiales y técnicas con comportamiento similar al de las técnicas constructivas originales. Igualmente, se han privilegiado en fecha reciente otras estrategias de conservación como capas y recubrimientos de sacrificio, procesos de reenterramiento y herramientas digitales o réplicas para el acercamiento y disfrute por parte de la sociedad. Los casos de estudio muestran que, cuando las acciones son asertivas, el patrimonio cultural hecho en tierra es duradero. Sin embargo, la reducida presencia de este tipo de bienes de tierra registrados, en comparación con los de otros materiales, enfatiza la importancia de ser especialmente cuidadosos con la conservación de estos elementos, y lo que significa involucrar a la sociedad en su conservación; lecciones a considerar para la futura toma de decisiones.*

Abstract: *The review of six cases of built heritage that exemplify decorative elements of Mexican pre-Hispanic earthen architecture allows for the recognition of strategies used for their conservation and, consequently, the opportunity to propose best practices. The cases are relevant cultural heritage structures located in the central region of Mexico and include four murals, a relief, and a combination of mural and relief. The case studies correspond to the period between 200 BCE and 1521 CE. These archaeological remains have undergone diverse treatments, strategies, and management, the comparison of which has enabled the authors to rank their levels of effectiveness and good practice. In all cases, direct treatment measures and infrastructures for protection and access were implemented. The intervention made use of synthetic polymers and, over time, acquired a more preventive character, integrating materials and techniques with behaviors similar to those of the original construction methods. Other conservation strategies such as sacrificial layers and coatings, reburial processes, and digital tools or replicas for the rapprochement and enjoyment by society have also been prioritized. Case studies show that when actions are proactive, earthen cultural heritage is durable. However, the reduced presence of registered earthen material examples compared to other materials emphasizes the importance of being especially careful with the preservation of these elements and the significance of involving society in their conservation. These are lessons to consider for future decision making.*

Palabras clave: tierra, bienes culturales, conservación, intervenciones, aprendizaje

Introducción

La tierra ha sido y continúa siendo un material de construcción ampliamente utilizado en México. Desde la época prehispánica fue empleada para la construcción de templos y ciudades, así como para la decoración de edificaciones, material que, dependiendo de los recursos y avances estilísticos en cada región, se integró o fue substituido por uso de piedra y cal.

Un primer análisis regional realizado por el Proyecto de Conservación de Bienes Culturales Muebles Asociados a Inmuebles Arqueológicos en la Región Centro-Sur-Golfo de México del Instituto Nacional de Antropología e Historia de México muestra que, en todos los estados ubicados en la región correspondiente al altiplano central y hacia las costas del Golfo y Pacífico del país[1], hay bienes muebles adosados a las estructuras arqueológicas cuyo componente principal es la tierra, siendo su presencia menor que la de elementos decorativos en piedra o elaborados con cal (fig. 1). Los ejemplos van desde el 200 a. C. hasta el 1521 d. C., lo que refleja que el uso de este material se dio a lo largo de todo el desarrollo de las culturas prehispánicas.

Los hallazgos de vestigios arqueológicos construidos con tierra han sido intervenidos con diversidad de tratamientos y estrategias, de ahí el propósito del presente trabajo que revisa y analiza las prácticas de conservación realizadas en seis casos de estudio para destacar las experiencias anteriores que nos permiten aprender, y proponer mejores prácticas para su conservación.

Metodología

Se eligieron seis bienes muebles asociados a inmuebles arqueológicos como casos de estudio, en donde la tierra es el elemento primordial de la técnica constructiva y decorativa: cuatro de pintura mural, uno de relieve y uno más que combina pintura mural y relieve.

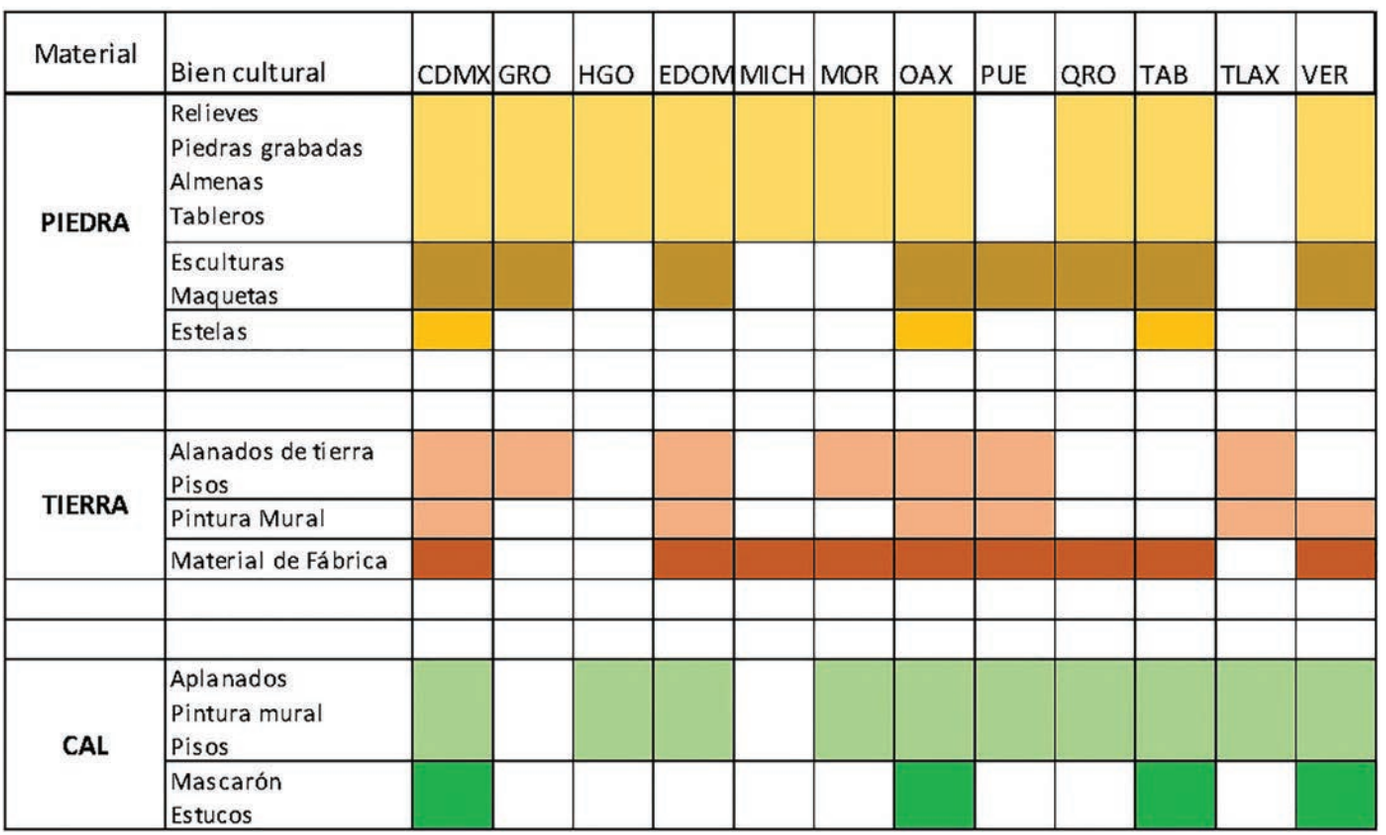


FIGURA 1 Comparativo de la presencia de bienes muebles asociados a inmuebles arqueológicos elaborados con piedra, tierra o cal, en la Región Centro-Sur-Golfo de México. Gráfico: Proyecto de Conservación de Bienes Culturales Muebles Asociados a Inmuebles Arqueológicos en la Región Centro-Sur-Golfo de México, CNCPC-INAH, México. 2020.

Los datos presentados se reunieron por las restauradoras que aquí suscriben, vinculadas en fecha reciente con el diagnóstico o conservación de dichos casos, tomando en cuenta la siguiente información: técnica constructiva del soporte y capa pictórica, relevancia histórica y social, fecha de su descubrimiento, características de la intervención inicial y de las subsecuentes, características del contexto donde se encuentra, apertura a visita pública, mantenimiento después de su hallazgo y hasta nuestros días, así como el estado de conservación reciente.

A pesar de que cada caso guarda características particulares que ameritan un análisis puntual, la información se analizó conjuntamente en busca de patrones similares de tratamiento y manejo, lo que permitió identificar aciertos y errores para su posterior análisis.

Casos de estudio

Los casos seleccionados provienen de diversos estados del país: Mural de los Chimales, Zona Arqueológica de Tehuacán Viejo, Puebla (Sisson y Lilly 1994) (fig. 2); Mural de los Bebedores, Zona Arqueológica de Cholula, Puebla (Rodríguez 2006) (fig. 3); Mural arriba del Basamento de Volutas, Zona Arqueológica de Teotihuacán, Estado de México (Cabrera 1995) (fig. 4); Mural del Templo Rojo, Zona Arqueológica de Cacaxtla, Tlaxcala (Lombardo 1986) (fig. 5); Relieve de Batracio en el Templo de Cha´a Chaak, Zona Arqueológica de Comalcalco, Tabasco (Armijo 2003, 2016) (fig. 6); Altar a Mictlantecuhtli, Zona Arqueológica de Zapotal, Veracruz (Miramontes 2015) (fig. 7). El mapa (fig. 8) ubica todos estos sitios.



FIGURA 2 Mural de los Chimales. Zona Arqueológica de Tehuacán Viejo, Puebla, México. Fotografía: Marcel Reichert, INAH-SECUL, México. 2020.



FIGURA 3 Mural de los Bebedores. Zona Arqueológica de Cholula, Puebla, México. Fotografía: Proyecto de Conservación de la Pintura Mural de la Zona Arqueológica de Cholula, CNCPC-INAH, México. 2019.



FIGURA 4 Mural arriba del Basamento de Volutas. Zona Arqueológica de Teotihuacán, México. Fotografía: Rosa Liliana Alfaro, INAH, México. 2020.

Cada caso presenta particularidades; sin embargo, para el presente estudio la información general de los mismos se resume en el Cuadro 1.

Para el análisis propuesto, es importante señalar las intervenciones y el estado de conservación de los casos, cuya información se presenta a continuación (cuadro 2).



FIGURA 5 Mural del Templo Rojo. Zona Arqueológica de Cacaxtla, Tlaxcala, México. Fotografía: Mónica Vargas Ramos, Proyecto de Conservación de Bienes Culturales Muebles Asociados a Inmuebles Arqueológicos en la Región Centro-Sur-Golfo de México, CNCPC-INAH, México. 2020.



FIGURA 6 Relieve del Batracio, Templo 1. Zona Arqueológica de Comalcalco, Tabasco, México. Fotografía: Mónica Vargas Ramos, Proyecto de Conservación Zona Arqueológica de Comalcalco, CNCPC-INAH, México. 2017.

Resultados

La técnica de elaboración de los murales y de los elementos con volumen muestra una diversidad de opciones y soluciones locales del uso de tierra, como resulta evidente en el Mural de los Chimales a partir de la integración de fibras orgánicas de la región en su revoque.

La fecha de descubrimiento de los ejemplos expuestos varía considerablemente. Destacan tres momentos: el



FIGURA 7 Altar a Mictlantecuhtli. Zona Arqueológica de El Zapotal, Veracruz, México. Fotografía: Ana Bertha Miramontes, INAH, México. 2015.

primero, a más de 100 años de la actualidad; el segundo, alrededor de 50 años; y el tercero, entre 30 y 35 años. A pesar de la diferente temporalidad entre estos hallazgos, el criterio empleado en su conservación fue similar: se implementaron medidas de tratamiento directo (de mayor o menor impacto) y de adecuación del entorno encaminadas a la presentación del bien cultural a un público visitante (en la mayoría de los casos) o a los investigadores académicos. A la par, se colocó infraestructura para protección del bien cultural: túneles, cubiertas y edificio tipo museo (esto último en el caso del Altar a Mictlantecuhtli). En general, estas estructuras no han funcionado del todo adecuadamente; un ejemplo de ello son las cubiertas de protección que se han sustituido a lo largo del tiempo, cambiando diseño y materiales, y transitando en la actualidad hacia soluciones más modernas, pero no necesariamente más acertadas.

Las intervenciones registradas responden a momentos específicos en la historia de la restauración. Aquellas realizadas a comienzos del siglo XX, principalmente encaminadas a consolidar las edificaciones, utilizaron cemento y elementos de metal relativamente modernos para su época. Para los bienes adosados, las intervenciones fueron escasas y de importancia secundaria, para lo cual aprovecharon materiales fácilmente accesibles. La mayoría de las intervenciones de hace ±50 años tuvieron un carácter igualmente estabilizador para la edificación; en ellas se empleó cemento extensivamente, considerado invasivo para el bien mueble adosado. Asimismo, se caracterizaron por emplear elementos estructurales (como en el caso del Altar del Mictlantecuhtli) y hacer

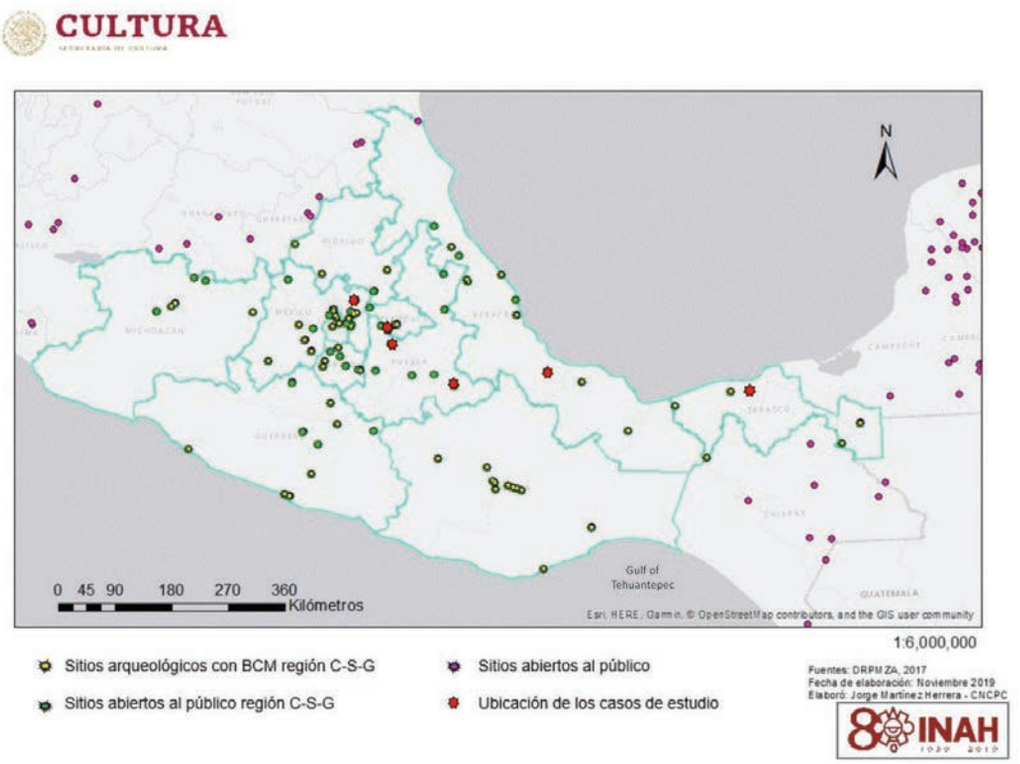


FIGURA 8 Ubicación de los casos de estudio que contienen bienes culturales muebles (BCM) dentro de la Región Centro-Sur-Golfo de México (C-S-G). Plano: Jorge Martínez Herrera, CNCPC-INAH, México. 2019.

Cuadro 1 Información de los seis casos de estudio.

Zona Arqueológica	Cacaxtla	Teotihuacán	Tehuacán Viejo	Cholula	Comalcalco	El Zapotal
Tipo de elemento	Pintura mural	Pintura mural	Pintura mural	Pintura mural	Relieve	Escultura y pintura mural
Extensión	2 muros completos	Fragmento	Habitación con muros	Muro de 62 m de largo	Esquina de basamento inferior	Escultura, cuatro muros en escuadra y jambas
Nombre	Mural del Templo Rojo	Basamento de Volutas	Mural de los Chimales	Mural de los Bebedores	Batracio o Templo de Cha´a Chaak	Altar a Mictlantecuhtli
Temporalidad	650–950 d. C.	300 d. C.	1200–1521 d. C.	200 d. C.	200 a. C.–900 d. C.	300–900 d. C.
Técnica constructiva	Muro de tepetate y adobe: revoque de tierra, arena y cal, enlucido fino de arena y cal, policromía	Cajones de tepetate rellenos de piedra y tierra: revoque de tierra, policromía	Muro de adobe: aplanado rugoso de tierra y fibras orgánicas, revoque fino de tierra, policromía	Muro de adobe: revoque de tierra, policromía	Cajones de tierra: capa de cal de concha, policromía	Arcilla con arena y limo: enlucido fino de arena y cal, policromía

uso de polímeros sintéticos de tipo acrílico, acetato y alcohol polivinílico, que igualmente reflejaban la modernidad de ese momento (cuadro 2). Para las intervenciones que siguieron, hace alrededor de ±30 años, gradualmente los polímeros sintéticos se dejaron de lado e inició una tendencia por el uso de materiales más compatibles con el original. Sin embargo, frecuentemente se empleó la cal como material afín, en lugar de las mismas tierras. A principio de este siglo, las intervenciones se transformaron, enfocándose a un carácter más preventivo, que integra materiales y técnicas compatibles de comportamiento similar al de las técnicas constructivas originales. También se han explorado otras estrategias de conservación que incluyen acciones como las capas y recubrimientos de sacrificio, así como los procesos de reenterramiento, en las

Cuadro 2 Intervención y estado de conservación de los casos de estudio.

Zona Arqueológica	Cacaxtla	Teotihuacán	Tehuacán Viejo	Cholula	Comalcalco	El Zapotal
Nombre	Mural del Templo Rojo	Basamento de Volutas	Mural de los Chimales	Mural de los Bebedores	Batracio o Templo de Cha´a Chaak	Altar a Mictlantecuhtli
Descubrimiento	1985	1907	1990	1969	Década de 1970	1971
Intervención inicial	Década de 1980 tierra + polímeros sintéticos	Ribetes de cemento	Sin intervención	1969–1971 polímeros sintéticos / cemento para estructura	1978–1980, polímeros sintéticos y caseinato/ cemento, varilla metálica y ladrillo para estructura	1972 y 1974, elementos de hierro aislados para refuerzo estructural, polímeros sintéticos
Intervenciones posteriores	1990–1991 cal e hidróxido de bario; 1996–1999, 2002 tierra y cal	Sin intervención	Sin intervención	1982 polímeros sintéticos; 2003, 2009–2021 tierra y reenterramiento de sector	2017 tierra y cal	2013 y 2015 tierra, cal y tepetzil
Infraestructura	Cubierta amplia	Cubierta amplia	Cubierta	Túnel para acceso y visita con recubrimiento de cemento	Cubierta limitada al elemento	Edificio tipo museo con piso de cemento
Proceso activo de deterioro	Estable	Estable	Estable	Inestable, asociado a presencia de humedad (excepto en área reenterrada)	Inestable, asociado a problema estructural del edificio	Inestable, asociado a presencia de humedad
Deterioros observados	Oquedades, fisuras, capa blanquecina superficial no salina	Pérdida puntual de soporte	Ataque biológico*, oquedades y abombamientos	Ataque biológico*, disgregación de soporte y capa pictórica, oquedades, desprendimiento de fragmentos, sales en superficie	Ataque biológico*, disgregación de soporte, oquedades, desprendimientos de revoque original y capas de recubrimiento	Exfoliación del enlucido, pérdida de cohesión, eflorescencias salinas (sección baja), erosión basal
Visita pública	Sí (alejada)	Sí	No	No	Sí	Sí

*Ataque biológico= presencia de iguanas, avispas, hormigas y otros insectos, ratas, crecimiento de raíces y proliferación de hongos.

cuales se pondera principalmente la conservación del bien cultural y la búsqueda de otras herramientas para permitir el acercamiento y disfrute por parte de la sociedad.

Tres de estos ejemplos encontraron una estabilidad al paso del tiempo, sin desestimar la presencia de deterioro de carácter puntual y acotado (el Mural del Templo Rojo, el fragmento de mural del Basamento de Volutas y el Mural de Chimales). Ello se ha visto asociado a contextos donde la presencia de humedad no es significativa debido a un clima mayormente seco y por el funcionamiento aceptable de sus respectivas cubiertas e infraestructura de protección. Los otros tres casos se han caracterizado por presentar procesos activos de deterioro que a la fecha no han logrado controlarse. Estos procesos activos están asociados a insuficiente mantenimiento de las estructuras que les contienen o al mal funcionamiento de la infraestructura colocada para su protección y exhibición, que ha generado procesos de filtración y flujo de humedad. En estos casos, el proceso activo de alteración ha obligado a implementar repetidas intervenciones de conservación.

Discusión

Los casos presentados son muestra del dominio de la técnica y versatilidad en el manejo de la tierra que lograron las culturas de esta región. La presencia de un menor número de bienes culturales en tierra en comparación con otros materiales puede responder a un uso menos frecuente, o bien, nos habla de un material de menor resistencia ante la intemperie que requiere de puntual y constante mantenimiento. Los tres casos de estudio que reportan inestabilidad (Mural de los Bebedores, Relieve de Batracio y Altar a Mictlantecuhtli) reflejan ausencia en la gestión necesaria para un adecuado mantenimiento del bien cultural y de la infraestructura colocada, resultando un efecto negativo a partir de los materiales empleados o del desgaste al paso del tiempo de dicha infraestructura. La presencia de procesos activos de alteración resalta la necesidad de brindar adecuado mantenimiento desde una perspectiva integral que aborde la estructura, el bien mueble adosado y la infraestructura colocada.

La intervención directa y la colocación de infraestructura ha respondido a la aplicación de criterios de conservación asentados a lo largo del siglo XX en diversas cartas de consenso internacional, pero se traducen en acciones que reflejan las tendencias de cada momento; todas ellas de buena intención, pero no siempre asertivas. La infraestructura preferida fue la colocación de cubiertas de protección. A pesar de los beneficios que estas cubiertas han brindado para la conservación, en todos los casos hay problemas asociados a su funcionamiento. Ello se incrementa cuando el clima favorece la presencia constante de humedad y las dimensiones de la cubierta abarcan exclusivamente sectores limitados al bien cultural, sin contemplar el contexto al que pertenece. Sin embargo, las otras opciones de túnel de acceso o edificio a manera de museo tampoco se presentan como soluciones ideales, como es el caso del Altar de Mictlantecuhtli, donde la falta de consideración del contexto geológico y ambiental resultan en un funcionamiento inadecuado del edificio de protección, mientras que el bien cultural que se intenta proteger se convirtió en el frente de desarrollo de los procesos de alteración.

Las intervenciones aplicadas a partir de la mitad del siglo XX respondieron al objetivo de brindar una solución duradera, tanto para el elemento decorativo como para el soporte y edificio que le contiene. La modernidad en ese momento se encaminó al uso de polímeros sintéticos, cuya aplicación modificó las características de comportamiento y composición de los bienes culturales. Ello refleja el descuido hacia los sistemas tecnológicos de tierra y su comportamiento a largo plazo. De esta forma, los ejemplos más intervenidos respondieron a casos donde los restauradores percibieron mayor riesgo a partir del entorno. Sin embargo, una intervención invasiva no aseguró la preservación del bien cultural (Relieve del Batracio; Mural de los Bebedores), pues el contexto al que pertenecen es determinante para su conservación. Caso contrario, el Mural de Chimales ha logrado estabilidad en un medio mayormente seco.

Las intervenciones con cal también han presentado efectos negativos al ser este material ajeno al comportamiento y composición propios de la tierra. Los malos resultados de las intervenciones registradas por años han favorecido un cambio gradual en los recientes tratamientos de conservación, donde se trata de tomar decisiones de intervención basadas en la comprensión de las características y comportamiento de cada caso particular elaborado en tierra. Por ello, se procura el empleo de materiales compatibles, retratables y que tengan comportamiento similar al original. También se observa la búsqueda de intervenciones que priorizan la conservación, sacrificando en ocasiones la visita abierta al público o el acceso de los académicos. Ejemplo de ello es el Mural de los Bebedores, en el cual se reenterró el sector de mayor afectación logrando con ello controlar las condiciones negativas provocadas por un pobre mantenimiento.

El mal estado de conservación de algunos de los ejemplos observados ha propiciado, entre especialistas y sociedad en general, la pérdida de valor de la técnica constructiva con tierra. Durante el sismo del 2017 acontecido en México –a la fecha, el de mayor impacto en el patrimonio cultural del país– algunos pueblos sufrieron la destrucción de sus viviendas de construcción tradicional en tierra por considerarse de baja seguridad. Esta postura, impulsada por los gobiernos locales, que denota la ignorancia acerca de las características de los materiales, se ha visto reforzada por la mala conservación de los ejemplos prehispánicos. La oportunidad de reforzar un conocimiento tradicional y fortalecer el involucramiento de la comunidad en la valoración de este tipo de patrimonio debe capitalizarse. Es por ello que la conservación de tales bienes debe de ir de la mano de la difusión y capacitación en los sistemas tradicionales de construcción y decoración con tierra, a fin de que la puesta en valor incluya todos los aspectos asociados al bien cultural tangible.

Conclusiones

La reducida presencia de bienes de tierra registrados, en comparación con los de otros materiales, enfatiza la importancia de ser especialmente cuidadosos con la conservación de estos elementos, por lo que las lecciones aprendidas de los casos presentados pueden ser una referencia para las tomas de decisión en un futuro. Estas lecciones se resumen en los siguientes enunciados:

- El contexto que rodea a los bienes muebles de tierra adosados a inmueble será determinante para su conservación, por lo que debe ser considerado prioritario para el tipo de tratamiento y medidas de protección a implementar.
- Priorizar la preservación del bien cultural por encima de otros criterios como la presentación al público.
- Las medidas de protección, sobre todo de la instalación de infraestructura, deben corresponder a la certeza con que se cuente respecto al futuro manejo y solvencia para el mantenimiento del bien cultural y de dicha infraestructura.
- Basar la intervención en el conocimiento del comportamiento y respeto a las técnicas empleadas originalmente.

- Favorecer tratamientos preventivos, de carácter puntual y no invasivo, de empleo de materiales compatibles y retratables, que aseguren un comportamiento similar al original y mantengan las características de la tierra.
- Los tratamientos y estrategias que se implementen, como las capas de protección y sacrificio o el reenterramiento, deben ser cuidadosamente monitoreados para evaluar su efectividad para este tipo de materiales.
- Considerar estrategias de difusión digital para este tipo de bienes culturales que no impliquen la necesidad de instalación de infraestructura invasiva.

Los casos de estudio muestran que, cuando las acciones son asertivas, los bienes muebles adosados construidos con tierra son duraderos. Ello es alentador para continuar preservando su valor como manifestación de momentos específicos del desarrollo tecnológico y estético de las civilizaciones de la región en estudio.

Nota

1 El proyecto regional comprende 62 zonas arqueológicas abiertas al público que se distribuyen en 12 estados del país. Incluye cuatro zonas patrimonio de la humanidad: Monte Albán, Teotihuacán, Tajín y Xochicalco.

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PART 8

Education / Educación

International Course on the Conservation of Earthen Architecture, Abu Dhabi: Development of a Comprehensive Regional Training Initiative

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Abstract: *The International Course on the Conservation of Earthen Architecture (EAC) is a one-month training initiative organized by the Getty Conservation Institute (GCI) in partnership with the Abu Dhabi Department of Culture and Tourism (DCT) and the Oman Ministry of Heritage and Tourism (MHT). First held in 2018, the course aims to improve the practice of earthen heritage conservation by providing practical training for mid-career professionals from the Middle East, North Africa, and South Asia. While these areas retain much of the world's earthen heritage, there are few regional training opportunities for professionals working on the conservation of earthen sites. Al Ain in Abu Dhabi and the Nizwa region in Oman were chosen as the locations for the course because of their rich heritage, diversity of earthen sites (from earthen archaeology to dense urban settlement), and the variety of conservation approaches and examples implemented by the partners. Led by local and international experts, participants utilized Al Ain and Nizwa as open-air laboratories to learn practical, hands-on methods for preserving earthen sites as well as fundamental theories of conservation and recent advances in technology that have influenced the preservation and management of earthen heritage. This paper describes the development and execution of the course, including curriculum design, participant profile, and field and laboratory activities, in addition to providing a critical evaluation of the course's strengths and weaknesses with considerations for future courses.*

Resumen: *El Curso Internacional de Conservación de la Arquitectura de Tierra es una iniciativa de capacitación de un mes de duración que organiza el Getty Conservation Institute junto con el Departamento de Cultura y Turismo de Abu Dabi y el Ministerio de Patrimonio y Cultura de Omán. Este curso se organizó por primera vez en 2018, y su objetivo es mejorar la práctica de la conservación del patrimonio de tierra por medio de la capacitación práctica de profesionales con cierta experiencia en Oriente Medio, América del Norte y sur de Asia. Aunque en estas regiones se encuentra gran parte del patrimonio de tierra del mundo, las oportunidades de capacitación regionales para los profesionales que trabajan en la conservación de los sitios de tierra son escasas. Al Ain, en Abu Dabi, y Manah, en Omán, fueron las ubicaciones elegidas para el curso, debido a la riqueza de su patrimonio, la diversidad de sus sitios de tierra (desde la arquitectura de tierra hasta los asentamientos urbanos densos) y la variedad de enfoques y ejemplos de conservación que implementaron los socios. Bajo la dirección de expertos locales e internacionales, los participantes utilizan los sitios de Al Ain y Manah como laboratorios a cielo abierto para aprender métodos manuales y prácticos de preservación de los sitios de tierra, al igual que las teorías de conservación fundamentales y los últimos avances tecnológicos que tuvieron un impacto en la preservación y la gestión del patrimonio de tierra. En este artículo, se detalla el desarrollo y la ejecución del curso, lo que incluye el diseño del plan de estudios, el perfil de los participantes y las actividades de campo y laboratorio, además de ofrecer una evaluación crítica de los puntos fuertes y débiles del curso con aspectos a tener en cuenta para futuros cursos.*

Keywords: earthen architecture, conservation, training, archaeology, Abu Dhabi, Oman

Introduction

Earth has been used as a construction material on the Arabian Peninsula for millennia. The World Heritage Site of Al Ain, UAE, contains numerous earthen archaeological sites dating from the Bronze and Iron Ages as well as Islamic period houses, forts, and mosques built in mud brick (fig. 1). While these significant sites are being preserved, earthen structures around the world are rapidly disappearing due to abandonment, demolition, and loss of traditional knowledge.

The Getty Conservation Institute (GCI) has been working in the study and conservation of earthen architecture for over thirty years. Between 1996 and 1999 GCI, with ICCROM and CRAterre, co-organized the Preservación de Arquitectura de Tierra (PAT) courses in Peru, which focused on training Latin American conservation professionals in the conservation and management of earthen buildings and archaeological sites. Following recent GCI projects in the region, including the rehabilitation of Kasbah Taourirt in Ouarzazate, Morocco, a need was identified to further develop training curricula and include different approaches for the conservation and reuse of historic sites and urban settlements in the region.

Development of the Course

Following a series of strategic planning meetings in 2015 related to built-heritage conservation, GCI identified renewed



FIGURE 1 Examples of earthen archaeology and historic buildings at Al Ain UNESCO World Heritage Site. Clockwise from upper left: Hili 17 Iron Age archaeological site, Jahili Fort, Bin Ati tower and archaeological site, and Bin Hadheibah Al Dhahiri fortified house. Photos: Benjamin Marcus.

training activities in the conservation of earthen architecture as a priority. A series of meetings and reconnaissance visits was carried out to identify a suitable location and partner. Al Ain was identified as a potential location for a regionally focused earth course because of its central location in the region, its rich earthen heritage, and the variety of conservation approaches, including successful adaptive reuse projects, implemented by the Department of Culture and Tourism–Abu Dhabi (DCT). Furthermore, Oman was selected to conduct part of the course on urban conservation due to its exceptional historic urban settlements constructed in earth and numerous conservation activities carried out by the Oman Ministry of Heritage and Tourism (MHT).

Following a reconnaissance visit in spring 2017, a Memorandum of Understanding (MOU) between GCI and DCT was drafted, and plans for the first earth course commenced in the fall of the same year. Two course-planning meetings were held with core instructors to develop and review didactic materials for the course and to plan site and laboratory-based activities.

Curriculum and Instructors

The course was envisioned as a comprehensive summary of earthen architecture practice, from documentation and assessment to treatment and maintenance. The long-term goal of the course is the improved practice for the conservation of earthen buildings and sites. More specific short- and medium-term goals include:

- Build the capacity of mid-career conservation professionals (architects, conservators, engineers, archaeologists, and scientists) from key areas with earthen heritage in the region including North Africa, the Middle East, and South Asia;
- Provide a biennial training opportunity that balances a theoretical foundation in earthen heritage conservation and management with an emphasis on practical methods and hands-on experiences;
- Build a regional professional network of course alumni dedicated to the conservation of earthen architecture;
- Disseminate didactic materials for earthen architecture conservation that reflect advances in conservation practice and can be adapted to other languages and formats, including online learning;
- Promote best practice in the conservation of earthen architecture.



FIGURE 2 Participants conducting structural assessment of an earthen building at Al Ain. Photo: Benjamin Marcus, © J. Paul Getty Trust.

The course is divided into four weeks, each covering different thematic areas of a typical earthen architecture conservation project. Through lectures, discussions, laboratory sessions, demonstrations, site visits, and field exercises, participants study fundamental theories of conservation as well as advances in technology and research that have influenced practical approaches to earthen architecture conservation. Group fieldwork at several worksites provides participants with the opportunity to address actual work scenarios (fig. 2).

Participants

Applications for the course were disseminated in January 2018 on the GCI and DCT websites, through professional organizations such as ICOMOS, ICCROM, and IIC, and to a list



FIGURE 3 Group photo of EAC18 participants and organizers. Photo: Nicole Declet, © J. Paul Getty Trust.

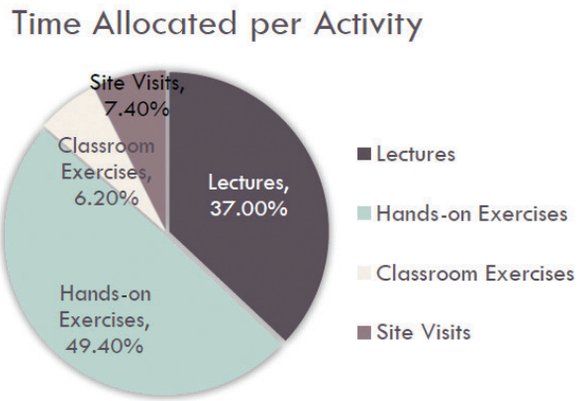


FIGURE 4 Chart showing breakdown of course activities. Illustration: Nicole Declet, © J. Paul Getty Trust.

of approximately fifty affiliated professionals. Applications were received by March 1, 2018, and following review by the partners, nineteen participants were selected and seven were placed on a waitlist. Of the final course attendees, seventeen participants were selected from applications, two were appointed by MHT, one was appointed by DCT, and two were appointed by DCT via the Saudi Commission for Tourism and National Heritage. The twenty-two participants were primarily mid-career professionals from eleven regional countries with earthen architectural heritage: Morocco, Egypt, Sudan, Oman, UAE, Saudi Arabia, Jordan, Afghanistan, India, China, and Zimbabwe (fig. 3). The selection process strove for an inclusive and equal balance of gender as well as a diversity of professional backgrounds, reflecting the multidisciplinary nature of the conservation field. Most participants completed an extensive application that required prerequisites including English proficiency, two to five years of professional experience, earthen architecture project work, and a master's degree or a qualifying bachelor's degree. To provide opportunity to a diverse number of participants, more than half of the course attendees received full scholarships that included travel, course fees, lodging, and a modest stipend to cover living costs while residing in the UAE and Oman.

Site Work, Laboratory Activities, and Course Materials

One of the central goals of the course was to provide a practical, hands-on learning platform grounded in sound scientific and theoretical methodology. The course utilized Al Ain and its historic sites as an open-air laboratory to emphasize hands-on learning. Over 50% of the course consisted of practical activities, including site visits, laboratory activities, and site work such as documentation, condition surveys, materials testing, and hands-on treatment interventions (fig. 4).

Didactic materials were shared with the participants in advance through the open-source learning platform Moodle. The EAC18 Moodle homepage included an introduction as well as a table of contents that linked to useful materials for the course, including orientation information, instructor and participant biographies, course curriculum, and teaching materials. A hard copy of all the material was made available to the participants as well.

The curriculum followed a "project approach" sequence meant to mimic the steps necessary to carry out a fully developed conservation project for an earthen building or site. This included three weeks of modules at Al Ain focused on various themes such as conservation theory, values and significance assessments, documentation, laboratory analysis of earthen materials, earthen construction techniques, decay mechanisms, and condition assessments. Practical conservation methods, including structural interventions, conservation of archaeological sites and decorated surfaces, and maintenance and monitoring, were also covered (fig. 5).

The final week of the course focused on developing adaptive reuse plans for earthen heritage. This was a week-long study tour held in Nizwa and Manah, Oman, two large seventeenth-century urban centers constructed in earth (fig. 6). This component also covered cultural landscapes and



FIGURE 5 Participants engaging in a laboratory exercise on sedimentation. Photo: Benjamin Marcus, © J. Paul Getty Trust.



FIGURE 6 Bird's-eye view of EAC18 course study site at Harat at-Bilad in Manah, Oman. Photo: Benjamin Marcus, © J. Paul Getty Trust.

conservation planning for urban settlements through a studio exercise. The week began by introducing the Omani cultural landscape to familiarize participants with the region. The sessions that followed focused on understanding methods for surveying urban settlements and principles of conservation and heritage management plans. These were complemented by a field exercise at Manah, where the participants completed a detailed survey of building conditions and usage and documented the tribal histories of the settlement (fig. 7). The final exercise consisted of a detailed design plan for the designated



FIGURE 7 A former resident of Manah being interviewed by participants on the uses and tribal history of buildings. Photo: Richard Ross, © J. Paul Getty Trust.

areas in Manah, taking into consideration the principles of intervention and the nature of contemporary demands.

Course Evaluation Methods

Various evaluation methods took place throughout the course. A traditional questionnaire was given to the participants at the end of weeks two and four, which included both scale-based ratings and open-ended questions. The following topics were evaluated: overall content, structure and sequence, and clarity of materials presented, followed by an individual session evaluation per week. Also evaluated was the usefulness of resource materials (Moodle), relevance of sessions, time allocation for lectures versus site exercises, most and least useful sessions, and topics the participants found new to them (Marcus and Declet 2019).

Another method used for the course evaluation was to have a final group discussion with the participants in which they answered three questions and shared their responses with the rest of the group. The last two methods for evaluation included instructors' feedback and the course coordinator's summary.

Critical Evaluation

In general, the course was well received by participants, instructors, and course partners. Participants felt that the practical focus of the course, intensive site work, and experience with real heritage objects and sites provided an exciting and effective learning experience that built skills that could

be applied at their own sites. Through surveys and discussions, several strengths were identified as well as areas for improvement, including course logistics, curriculum content, and methods of course delivery.

Participants highlighted the following course strengths:

- Earth as a building material was a popular topic; participants enjoyed the field exercises and work in the laboratory where they learned how to analyze soil from a molecular level. Hands-on learning of different earthen construction techniques was also very popular;
- Similarly, participants discussed how they benefited from the site work and fieldwork, especially hands-on interventions at the course's designated repair testing site, a reconstructed house that was used for learning all manner of repairs (fig. 8). Intervention planning and implementation lectures as well as structural analysis and seismic testing topics were also clear favorites;
- A large number of the participants encountered issues while documenting heritage in the countries where they work. Therefore, techniques like photogrammetry and photo scanning proved to be very relevant and useful;
- Some mentioned conservation and heritage management planning sessions as one of the most valuable aspects of the course;
- Many participants valued how the course provided cultural exchange and an opportunity for networking.



FIGURE 8 Participant executing a crack stitch in an earthen wall. Photo: Nicole Declet, © J. Paul Getty Trust.

In terms of areas for improvement, the majority of participants thought they needed more time in the final week to develop and design a proper management strategy. While the class had been divided into groups to develop reuse plans for individual areas of the site, many felt that a more comprehensive strategy that took overall values and conservation policies into account was needed. Similarly, a few sought a more systematic conservation planning exercise. Within the detailed design process of the Oman exercise, participants suggested having more structural and materials science involvement, as well as a repair and consolidation plan.

Due to its popularity among the participants, some suggested making the structural intervention exercises longer. Also requested was more focus on structural repair case studies and more time on intervention exercises with increased focus on repair methods. Attendees desired more discussion on sourcing repair material and the main criteria to understand how to choose appropriate materials for repairs, perhaps as an in situ exercise where students could develop different mixes while having materials scientists on site to explain behaviors. A few students wanted more detailed information about consolidants for earth. Some students thought there were too many "introductions" between lectures, which led to repetition. Others felt that the more specialized topics, such as the conservation of wall paintings or archaeological sites, were not applicable to the heritage in their countries, though many appreciated the new information.

Future Challenges and Considerations

Feedback from organizers and participants was incorporated into a revised curriculum drafted during an instructors'

meeting in London, February 2020. Instructors and course partners gathered to discuss changes to the course content and to coordinate and hone their didactic materials. These changes included redesigning the final week in Oman to focus less on developing detailed adaptive reuse proposals and more on developing holistic conservation policies applicable to the entire site. Another adjustment was to remove overlaps such as repeated information on decay mechanisms, structural interventions, and similar discussions of values relevant to both conservation theory and archaeological site management.

While the subsequent iteration of the biennial EAC was scheduled for February 2021, the course was postponed due to the COVID-19 pandemic and finally held October 22 to November 19, 2022. This second course hosted participants from fourteen different countries and included improvements such as a new course intranet site, new instructors to expand coverage of earthen materials testing and urban heritage issues, and a revised workshop in Oman on the conservation of earthen sites in urban contexts. In the second iteration of the course, this five-day workshop was held in Nizwa's ancient Harat al Aqr neighborhood, a bustling seventeenth-century city center constructed in earth that hosts an important market, shops and hotels, and a fort that is frequented by tourists and Omanis alike. With an additional local expert and a revised curriculum, this workshop provided participants the opportunity to apply UNESCO's Historic Urban Landscape (HUL) framework to the development of conservation policies for the preservation of the city center.

Incorporating these improvements in the curriculum, a third iteration of the course is planned for February 2025. In concert with the course planning, the course partners and organizers are compiling an illustrated handbook to accompany the course. The handbook presents the course content, bibliography, and appendices, including technical protocols and laboratory notes, in a narrative format that can be distributed to participants. Developed in English with translation in Arabic, the handbook will be disseminated via the GCI and DCT websites in order to reach a wider audience of conservation professionals, students, and the general public interested in the region's earthen heritage.

For more information on the International Course on the Conservation of Earthen Architecture, visit https://www.getty.edu/conservation/our_projects/field_projects/earthen.

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Stimulating Eco-Responsible Architecture and Conservation through Education: The DSA on Earthen Architecture Postgraduate Diploma at the Grenoble National School for Architecture (ENSAG)

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Abstract: *The Grenoble School for Architecture has run the DSA for Earthen Architecture, Building Cultures and Sustainable Development, a post-master's degree program in architecture and heritage, since 1984. Several independent surveys affirm the relevance of this training and the high applicability of the courses for various professions such as architect-craftspeople, development experts, heritage managers, and lecturers. The challenge of the DSA training is to supply graduates with the tools to intervene in a constantly changing world by providing relevant and responsible responses to ecological imperatives, the challenges of social inequalities, and the management of multiplying hazards. This paper queries the implemented strategies, tools, and lessons learned since the beginning of the DSA program, based on bibliographical studies and recent interviews with both teachers and students. It provides information about the pedagogical techniques used to enable young professionals to acquire working methods that will help them work in varied and complex contexts. In particular, the paper presents the implemented pedagogical modalities to reach the learning outcomes defined by the European Qualifications Framework (EQF): knowledge, skills, responsibility, and autonomy. It also highlights the way that this training has been enriched by social and cultural dimensions, enabling students to draw inspiration from vernacular architecture, to master the tools that promote adaptability and participatory management in conservation and contemporary architecture, and to adopt an eco-responsible attitude throughout the entire life cycle of buildings, from their construction to their conservation and final dismantling.*

Resumen: *Desde 1984, la Escuela de Arquitectura de Grenoble ha organizado el DSA: arquitectura de tierra, culturas de construcción y desarrollo sostenible, un título de posmaestría en Arquitectura y Patrimonio. Numerosas encuestas independientes confirman la relevancia de esta capacitación y la alta aplicabilidad de los cursos para varias profesiones, tales como arquitectos artesanos, expertos en desarrollo, gestores de patrimonio y profesores. El desafío de la capacitación del DSA es proveer a los graduados de herramientas para intervenir en un mundo en constante cambio, brindando respuestas relevantes y responsables a los imperativos ecológicos, los desafíos de las desigualdades sociales, la gestión de los peligros en aumento y mucho más. Este artículo cuestiona las estrategias y herramientas implementadas y las principales lecciones adquiridas desde el inicio del programa de DSA, basándose en estudios bibliográficos y entrevistas recientes con los profesores y los estudiantes. Brinda información sobre las técnicas pedagógicas empleadas para permitir que los profesionales jóvenes adquieran métodos prácticos que los ayuden a trabajar en contextos variados y complejos. En particular, el artículo presenta las modalidades pedagógicas implementadas para alcanzar los resultados de aprendizaje definidos por el Marco Europeo de Cualificaciones (EQF): conocimiento, habilidades, responsabilidad y autonomía. También destaca la forma en que esta capacitación se ha nutrido con las dimensiones sociales y culturales, permitiendo que los estudiantes se inspiren en la arquitectura vernácula, dominen las herramientas que promueven la adaptabilidad y la gestión participativa en la conservación y la arquitectura contemporánea, adoptando una actitud ecorresponsable durante todo el ciclo de vida de los edificios desde su construcción hasta la conservación y desinstalación final.*

Keywords: knowledge, skills, competencies, professional ethics, eco-responsible, participatory management, earthen heritage conservation, earth construction

Introduction

The DSA Earthen Architecture, Building Cultures and Sustainable Development (DSA-Earthen Architecture) course, focusing since its creation in 1984 on earthen building techniques, has evolved in order to allow students to acquire the necessary skills to intervene in extremely various contexts, providing relevant and responsible answers to the environmental imperatives and to the challenges caused by social inequalities and natural hazards.

This article is based on bibliographical studies and surveys among teachers and students who were asked about the implemented pedagogical strategies of the DSA. It is structured in two parts: (1) a general presentation of the training and (2) a reflection on the implemented pedagogical modalities and their interest for the students and the professional context.

The DSA-Earthen Architecture

Official Framework

The DSA-Earthen Architecture is a specialization diploma in architecture and cultural heritage. As such, the training is accessible to post-master's students willing to specialize in operations linked to architectural, urban, and landscape heritage in order to conserve, restore, enhance, and make sites that are useful in today's society (République française 2015). The training is accredited by a national diploma qualified by the French Ministry of Culture and organized by the Grenoble National School for Architecture (ENSAG).

Brief History

Following the first energy crisis of 1979, a group of students of the ENSAG carried out a study on the universality of earthen architecture and founded the research laboratory CRAterre-ENSAG, drawing vital lessons from their research that resulted, in 1984, in the first session of this specialization in earthen architecture. The pedagogical team was composed of architects, engineers, geologists, and sociologists. Like apprentice masons, they have all strived to imitate the master craftspeople working with them on various earthen building sites all over the world. The diversity of contexts they were exposed to enabled them to assimilate the very rich environmental, cultural, economic, and social approaches that distinguish vernacular architectures. In thirty-seven years of education, the contents of the training have evolved, but the pedagogical approach emphasizing the context remains at the heart of the curricula. The evolution of the DSA is due to a permanent reflection within the pedagogical team based on evaluations of each training module and an enrichment of the contents fed by field projects. All lecturers are professionals who share their practices with students through internships and seminars. Feedback from the field is integrated with research programs and course contents, resulting in up-to-date training for the students.

Variety of Intervention Contexts

This focus on the field is essential as earthen architecture is present in a variety of territories, and it is important to take into consideration their specific contexts. Raw earth, used for eleven millennia, is one of the most widely used building materials in the world. It takes the form of monumental heritage, private houses, and sites (including cultural landscapes and archaeological sites). Almost 20% of the properties inscribed on UNESCO's World Heritage List contain earth (UNESCO 2013). It is also present in the form of vernacular heritage, constituting the habitat for numerous populations in the world up to today. Earth can be the major constituent in these vernacular architectures, but it can also be complementary to other materials such as fiber, wood, or stone, or used as a mortar or binder. Earthen architecture is also present in urban human settlements. Actually, in an ecological dynamic, the material earth reintegrates modern architecture.

Earthen structures exist in more than 150 countries. In these contexts, they are subject to various pressures such as poverty, development of industrial materials, wars, and the effects of natural hazards (floods, earthquakes, etc.) on which the DSA students should reflect. As such, according to a survey conducted in 2015, the majority of the DSA graduates working in France have professional activities abroad (42%). However, a market exists in France with 22% of the graduates working exclusively in this country (Guillaud, Joffroy, and Rakotomamonjy 2016).

Structure of the DSA-Earthen Architecture

In accordance with the legislation, DSA trainings deliver professional diplomas with the primary objective of meeting the challenges of the diversification and evolution of architectural practice. Regarding the DSA-Earthen Architecture degree program, the challenge is to provide graduates with the tools they need to intervene on earthen architecture in this heteroclite and constantly evolving world.

The DSA-Earthen Architecture program includes nine teaching units spread over two years, for a total of 2400 training hours that include 890 supervised hours, 800 personal working hours, and 710 professional experience hours (Guillaud, Joffroy, and Rakotomamonjy 2016).

Through lectures and practical work, students examine five education units in the first seven months: (1) earthen architecture and building cultures; (2) specific scientific, technical, and methodological bases to earth material; (3) earthen heritage-related jobs; (4) modern earthen habitat-related jobs; and (5) exercises and implementation within the framework of a festival through experiments, exchanges, and meetings with building professionals, enterprises, craftspeople, researchers, and others. The remaining months are dedicated to the consolidation of knowledge through the last four education units: (6) real-life professional situation, (7) practical works and implementation, (8) in-depth seminars, and (9) writing and thesis defense.

Pedagogical Approach

Skills-Based Approach within the DSA

The DSA-Earthen Architecture adopts a skills-based approach supported by Marianne Pournay (Pournay, Tardif, and Georges 2017). Within this framework, learning is an active, constructive, cumulative, and dynamic process under the supervision of the students. Everyone builds their knowledge and skills by making connections between new and acquired knowledge, formulating and testing hypotheses, resolving concrete problems, enriching and organizing their own knowledge repository, and exchanging information with their peers.

This approach correlates with the structure of the European Qualifications Framework (EQF) of the European Higher Education Area (European Union 2017). The EQF defines three types of learning outcomes: (1) knowledge, (2) skills, and (3) responsibility and autonomy. During the DSA-Earthen Architecture, these learning outcomes are integrated into authentic professional situations in order to develop true management skills in various contexts.

Knowledge

We will present hereafter the different learning outcomes that are required for a post-master-level training (Level 8), reflecting briefly on how these outcomes are transmitted within the DSA-Earthen Architecture.

According to the European Commission, Level 8 knowledge is defined as the "knowledge at the most advanced frontier of a field of work or study and at the interface between fields" (European Union/Europass 2017). Within the DSA-Earthen Architecture, the methods for the empirical transfer of ancestral knowledge through experience and practice (Correia 2012) are complemented by a scientific knowledge of materials science. The chosen pedagogy assumes that it is not possible to understand the properties of a building material without manipulating it and vice versa. Therefore, three weeks of practice in building with earth are followed by three weeks of analyzing the material earth and understanding its physical-chemical properties (fig. 1).



FIGURE 1 Analysis of earthen materials in the CRAterre/ENSAG laboratory in Grenoble, France, 2018. Photo: S. Moriset, © CRAterre.

Historically, earthen architecture has shown us that bad soil does not exist, but bad architectural structures do. Earth allows a variety of sustainable constructions, for example, the Great Wall of China, that have been built with various soils found along the way. In this sense, the DSA-Earthen Architecture proposes a range of tools to the students, allowing them to adjust their intervention approaches according to the diversity of soils they encounter. Students learn to understand the properties of the material: how to modify its grain-size distribution if necessary, create building elements out of raw materials, adapt the architectural design to the specificities of the material, organize a construction site according to the available resources, and ensure the lifelong maintenance and conservation of the building. As such, the DSA is the link between the disciplines of engineering, architecture, and heritage conservation.

Skills

According to the European Commission, Level 8 skills are further defined as "the most advanced and specialized skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice" (European Union/Europass 2017).

The majority of earthen constructions are informal. In light of this observation, the educational practices of the DSA



FIGURE 2 Experimentation at scale in Grands Ateliers in Villefontaine, France, 2017. Photo: S. Moriset, © CRAterre.



FIGURE 3 Public demonstration of maintenance practices and scientific behavior of earthen material in the Village of Four, France, 2018. Photo: S. Moriset, © CRAterre.

include tools that allow the apprentice to adapt to different sociocultural contexts and to build on existing knowledge while proposing qualitative improvements. To this end, a two-week module prepares the students to understand the context through a territorial diagnosis and Strengths, Weaknesses, Opportunities, and Threats (SWOT) analyses. They are also trained in project design using logic frameworks and participatory management tools.

Moreover, the teaching carried out by the DSA addresses the entire life cycle of buildings through the following education modules: (1) laboratory and field tests; (2) earth, raw material; (3) production and implementation techniques; (4) surface treatment; and (5) architecture, structure, and building systems. The integration of the building life cycle concept in the training provides tools to the students that enable a complete management of architectural projects while ensuring a consideration of the environmental, economic, and social impacts of the actions undertaken.

During education unit 5, the students experiment at a 1:1 scale and meet and exchange ideas with building professionals, governmental authorities, artists, and researchers (fig. 2). Through this unit, the students are challenged to implement experimental research and to innovate. Additionally, they become part of and learn to work with a network of professionals.

Responsibility and Autonomy

According to the European Commission, Level 8 responsibility and autonomy is defined as the ability to "demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity, and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research" (European Union/Europass 2017).

During the DSA, the four months of compulsory real-life professional training equips students with the methodological tools necessary to define a project and analyze its context. They are also tasked with developing innovative solutions that are adapted to particular contexts. The DSA students must continuously research a specific topic related to the different earthen architecture professions. They are required to perform an in-depth survey on this topic, make assumptions, and demonstrate these by research or practice. In this way, they contribute to the production of new ideas or new processes in the field of environmentally friendly building and heritage conservation (fig. 3).

Personal Skills

Further to the learning outcomes defined by EQF, the DSA emphasizes personal skills. It is fundamental to developing students' personal skills in listening to others and respecting cultural diversity. Via critical analysis, understanding, and interpretation of vernacular architectures, the DSA allows students to reuse the intelligence demonstrated by different building cultures, pushing them further in a spirit of collective evolution and adaptation to the present and the future.

Since its creation, the DSA-Earthen Architecture has trained more than 350 architects, engineers, archaeologists, teachers, historians, and graphic designers from sixty different countries. By having students of different backgrounds work together, the DSA-Earthen Architecture encourages



FIGURE 4 Conservation works organized within the DSA-Earthen Architecture, in Saint-André-le-Gaz, France, 2021. Photo: S. Moriset, © CRAterre.

open-mindedness, creativity, capacity of adaptation, and the development of ideas and original concepts. This process allows the students to better adopt the principles of sharing knowledge in a participative approach inspired by traditional building cultures.

The valorization of manual work also fosters the respect that those invested in architecture have for those producing it (fig. 4), and it is not uncommon that many graduates go on to become craftspeople. In that respect, a huge heap of earth becomes architecture and, as noted by Patrice Doat, one of the founders of CRAterre, "Architecture [. . .] naturally finds its order through the scale of the gesture and the rhythm of work."

Opportunities

Surveys demonstrate the relevance of the DSA-Earthen Architecture. According to the Ministry of Culture and Communication (Ministère de la Culture et de la Communication-DGPAT 2012), the knowledge acquired during the DSA-Earthen Architecture is "useful or very useful" for 100% of students interviewed. Moreover, 79% of the students attest that their professional activity is linked to their earthen architecture specialization.

A survey carried out in 2015 (Guillaud, Joffroy, and Rakotomamonjy 2016) shows that graduates from the DSA-Earthen Architecture have found work in international organizations (UNESCO, UN-Habitat, Shelter, and NFI); in ministries of culture, urbanism, architecture, and foreign affairs; and in NGOs, universities, research laboratories, and enterprises. They provide their consultancy expertise in numerous fields: context analyses, inventory, documentation, conservation and enhancement of cultural heritage, quarry identification, earth analysis, implementation in the building and conservation sector, architectural design and construction, and university and professional training. Finally, 40% of the students have received an award or recognition after graduation, of which approximately 77% credited this specialization.

Conclusion

A skills-based approach has several advantages, in particular because it allows the development of critical thinking and promotes multiple interpretations of a problem. It is relevant for future societies that will have to manage increasingly complex challenges. The organization and pedagogical methods practiced in the DSA-Earthen Architecture help train professionals whose abilities exceed purely technical skills in order to be able to meet the challenges of today's society. The DSA-Earthen Architecture also highlights the strong link between the education in heritage conservation and the development of modern architecture.

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La enseñanza de la construcción con tierra y la conservación de monumentos en una facultad de arquitectura en Perú

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Resumen: *El Perú es un país con una milenaria tradición constructiva con tierra que abarca desde la época prehispánica hasta el siglo XXI. Actualmente, gran parte de las construcciones rurales siguen siendo en tierra, especialmente por las ventajas de aislamiento térmico que ofrecen y la economía de su construcción. Dado el rico patrimonio construido en tierra y la presencia de una tradición viva en la construcción de viviendas, en el Perú se ha desarrollado una serie de estudios sobre sistemas mejorados para construir con tierra y para la conservación de monumentos, conocimientos que tienen en los estudiantes de arquitectura un importante público objetivo. Este artículo muestra una experiencia formativa singular que se desarrolla en la Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC) de Lima, Perú, donde se han implementado asignaturas obligatorias para el estudio de construcción con tierra, de arquitectura peruana y de conservación del patrimonio edificado en el Perú.*

Abstract: *Peru is a country with an earthen building tradition that has existed for thousands of years, from pre-Hispanic times to the twenty-first century. A large number of rural constructions are still fabricated in earth today, especially due to the advantages of thermal insulation that they provide and the economy of their construction. Given this rich heritage, one that includes the presence of a living tradition for house construction, a series of studies on improved systems for earthen buildings and the conservation of monuments has been carried out in Peru, information that has a significant target audience in students of architecture. This article describes a unique training experience that takes place in the School of Architecture at the Universidad Peruana de Ciencias Aplicadas (UPC) in Lima, Peru, where compulsory courses have been established for the study of earthen construction, Peruvian architecture, and the conservation of built heritage.*

Palabras clave: enseñanza, construcción con tierra, historia de la arquitectura, conservación del patrimonio

Construcción con tierra en el Perú: Una actividad milenaria

El ser humano llegó al Perú hace aproximadamente dieciséis mil años (Lumbreras 2019, 73) y constituyó una de las seis culturas originarias del mundo junto con Mesopotamia, Egipto, China, India y Mesoamérica (Shady y Leyva 2003). Perú cuenta con una geografía que genera una enorme biodiversidad (INEI 2014) propicia para la formación y desarrollo de diversas culturas (Lumbreras 2013).

En Perú la relación del hombre con la tierra no ha sido sólo utilitaria, sino que es vista como deidad capaz de procrear y proteger. Se le conoce como "Pachamama," en una íntima relación que aún subsiste (Chambi 2018, 43–47) y que ha sido particularmente intensa en construcciones prehispánicas donde los muros de adobe o tierra compactada, los relieves de barro y tierras de color estaban impregnados de espiritualidad debido a la naturaleza sagrada atribuida al material.

Los restos culturales más antiguos en Perú son aproximadamente del 10 000 a. C.; las primeras viviendas, de juncos y ramas, se habrían realizado entre el VI y V milenio a. C., y hacia el 4000 a. C. se usó la tierra como mortero para unir piedras en un recinto en la localidad de La Paloma, a unos 65 km al sur de Lima (Agurto 1984, 39–52). El adobe más antiguo hallado en Perú, en el Complejo Arqueológico Sechín Bajo, en el Valle de Casma, en Ancash, es del 3500 a. C. (Fuchs *et al.* 2006, 126).

En el periodo prehispánico, las construcciones en tierra fueron las más abundantes en la costa peruana debido a la aridez del territorio (fig. 1) y a su escasa pluviosidad (Espinoza 2017). La tierra fue el material más usado para viviendas en Lima durante el virreinato (Cancino 2011) y aún lo es en las viviendas rurales en todo el país (INEI 2019).

Según información brindada por la Dirección General de Patrimonio Histórico del Ministerio de Cultura del Perú, al 27 de julio de 2021 el Estado Peruano tenía registrados 5192 inmuebles históricos patrimoniales en el país, gran parte de ellos construidos en tierra. Asimismo, el Sistema de Información Geográfica de Arqueología (SIGDA) tiene hasta el año 2021 aproximadamente 13 140 monumentos arqueológicos prehispánicos declarados como patrimonio cultural de la nación, aunque se trata de un inventario en constante actualización.

Edificación actual

La construcción con tierra actualmente es una realidad en el Perú, sobre todo en zonas rurales, ya que permite edificar a bajo costo con bajo impacto ambiental, utilizando recursos accesibles y propios de la zona, y ofrece propiedades acústicas e higrotérmicas favorables (MVCS 2010).

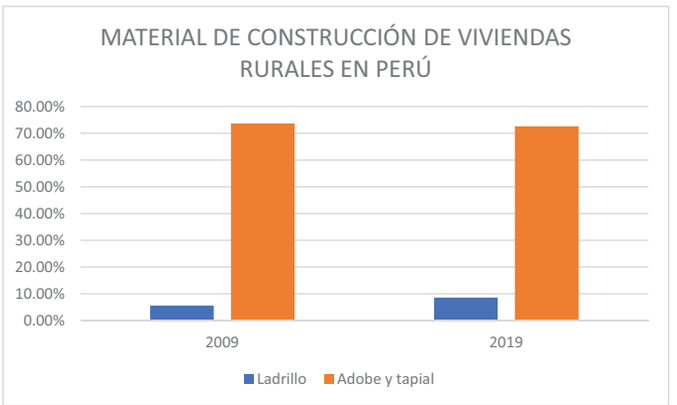


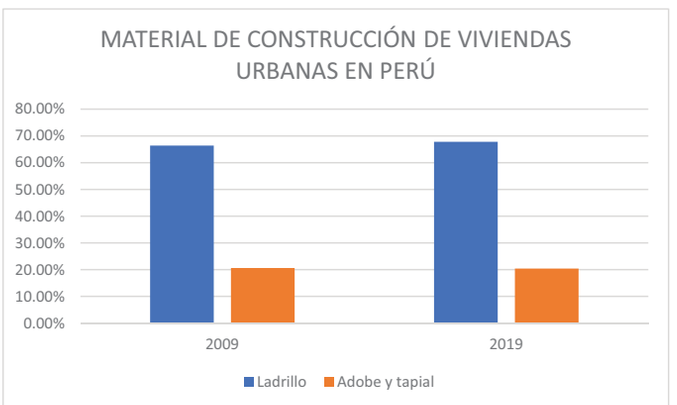
FIGURA 1 La tierra ha sido por miles de años el material de construcción más utilizado en la costa peruana y en gran parte del Perú. Vista de Huaca Pucllana, Lima. Fotografía: Luis Alberto Rengifo Zevallos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).

El censo de vivienda realizado por el Instituto Nacional de Estadística e Informática (INEI 2019) señala que en el año 2009, el 50,10 % de viviendas particulares en el Perú eran de ladrillo o bloque de cemento, mientras que el 34,80 % eran de adobe o tapial. El resto eran de madera (6,6 %), quincha (1,8 %), piedra con barro (0,90 %) u otros materiales (6,7 %). Diez años más tarde, en 2019, las viviendas de ladrillo o bloque de cemento habían aumentado al 54 %, mientras que las de adobe y tapial constituían el 32,6 %; es decir, la tierra cruda seguía siendo el segundo material más usado en viviendas en el Perú, porcentaje que aumentaba enormemente en el área rural. Según el mismo censo, en 2009 el ladrillo era el material del 5,6 % de las viviendas rurales, mientras que el adobe y tapial lo eran del 73,7 %; en el 2019 el ladrillo se presentaba en el 8,6 % de las viviendas rurales mientras que el 72,6 % era de adobe o tapial. En diez años se registra un ligero descenso, pero la tierra sigue siendo usada masivamente por la población rural.

El uso del adobe y tapial es también significativo en las ciudades. Mientras que en 2009 el 66,4 % de viviendas urbanas eran de ladrillo o bloques de cemento, el 20,6 % de las viviendas eran de adobe y tapial; en 2019 el 67,8 % de viviendas urbanas eran de ladrillo o bloque de cemento, y el 20,4 % era de adobe y tapial (cuadro 1).

Cuadro 1 La tierra (adobe o tapial) es el material más usado en la construcción de viviendas rurales en el Perú. Fuente: Censo Nacional de Vivienda INEI 2019. Elaboración: Mirna Soto Medina





Riesgo sísmico e investigaciones para el reforzamiento

Perú está en el cinturón de fuego del Pacífico (López *et al.* 2017). El Instituto Geofísico Nacional ha determinado cuáles son las áreas del Perú más expuestas a sismos (Tavera 2017); se constata que toda la costa, algunas zonas de los Andes centrales y la vertiente oriental de la ceja de la Sierra Norte son las regiones de más alto riesgo sísmico.

En Perú se han desarrollado, en las últimas décadas, investigaciones sobre técnicas de refuerzo sísmico tanto para viviendas contemporáneas (construcción con tierra mejorada, elementos de refuerzo, geomallas, etc.) como para edificaciones históricas de tierra (Cancino 2011).

Las principales entidades que han desarrollado investigaciones y técnicas de refuerzo para construcciones con tierra son el Instituto Nacional para la Investigación y Normalización de la Vivienda, que funcionó entre 1975 y 2005 (SENCICO 2020); el Servicio Nacional de Capacitación para la Industria de la Construcción (SENCICO 2021); el Centro Peruano-Japonés de Investigaciones Sísmicas y Mitigación de Desastres (CISMID 2021) y la Pontificia Universidad Católica del Perú (PUCP 2021). El proyecto de investigación más importante en Perú para la conservación y refuerzo estructural ante sismos de edificaciones históricas de tierra es el que realiza desde 2011 el Ministerio de Cultura del Perú en convenio con el Getty Conservation Institute: el Seismic Retrofitting Project (GCI 2021).

Una propuesta formativa integradora

Estas investigaciones realizadas en las últimas décadas brindan una cantidad de conocimientos que bien puede ser incorporada en los planes de estudio de los futuros arquitectos en Perú. Presentamos a continuación la experiencia que desde 1996, dos años después de su inicio de actividades, se desarrolla en la Universidad Peruana de Ciencias Aplicadas (UPC), una propuesta integradora que relaciona la construcción con tierra y la conservación de monumentos a partir de la articulación de tres asignaturas: "Obras Preliminares," "Arquitectura Peruana" y "Conservación del Patrimonio Cultural Inmueble."

Obras Preliminares

Se trata de una asignatura obligatoria de cuatro horas semanales que se imparte en el cuarto semestre. Dictada por primera vez en 1996, es la primera de las cuatro asignaturas del área de construcción. Se inicia el estudio del proceso constructivo a través de técnicas de construcción con tierra, desde cimientos, fabricación de adobes y bloques de tierra comprimida, levantamiento de muros con técnicas mejoradas (adobe reforzado con caña, adobe reforzado con geomalla, tapial reforzado), construcción de sistemas entramados como la quincha y la tierra aligerada y techos de madera, considerando códigos, normas, reglamentos y estándares nacionales (figs. 2, 3 y 4).

Se recurre a una "metodología activa" con un 30 % de clases teóricas y un 70 % de lecciones prácticas, en un taller de cerca de 600 m^2 que cuenta con el equipamiento necesario, herramientas, almacenes y oficinas. Por cada grupo de 20 estudiantes hay dos profesores y varios operarios que asisten en el proceso práctico de aprendizaje. Al final del semestre los estudiantes habrán construido un módulo previamente diseñado.

Esta facultad fue la primera en Lima en implementar una asignatura obligatoria de construcción con tierra.

Al finalizar, los estudiantes están familiarizados con el material, conocen su comportamiento estructural, valoran tecnologías tradicionales, han investigado sobre su uso en



FIGURA 2 Pruebas de ensayo de tierra antes de la preparación de adobes en la asignatura "Obras Preliminares." Fotografía: Johan Pinillos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).



FIGURA 3 Demostración de elaboración de un adobe en la asignatura "Obras Preliminares." Fotografía: Johan Pinillos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).



FIGURA 4 Estudiantes construyendo un muro de adobe en el taller de la asignatura "Obras Preliminares." Fotografía: Johan Pinillos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).



FIGURA 5 Estudiantes construyendo un muro de adobe reforzado con caña en el taller de la asignatura "Obras Preliminares." Fotografía: Johan Pinillos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).

el pasado y se aproximan a la problemática de su mantenimiento y conservación (figs. 5, 6 y 7).

Arquitectura Peruana

Es una asignatura obligatoria de cuatro horas semanales que se dicta en el sexto semestre; impartida desde 1997, se enfoca en la arquitectura peruana prehispánica, virreinal y republicana identificando las principales obras y sus características en su contexto cultural, económico, ambiental y territorial y permitiendo al estudiante reconocer que la tierra ha sido uno de los materiales de construcción más utilizados en Perú hasta inicios del siglo XX.

La asignatura presenta los sistemas constructivos prehispánicos con énfasis en técnicas sismorresistentes como



FIGURA 6 Un grupo de estudiantes construye el techo de una habitación de adobe mientras otro grupo trabaja en un muro de adobe reforzado con geomalla en el taller de la asignatura "Obras Preliminares." Fotografía: Johan Pinillos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).

las shicras y la quincha en Caral, los muros y rellenos Moche, las técnicas constructivas Nasca, los adobes Chimú y la practicidad constructiva Inca. En lo virreinal y republicano se destacan las técnicas constructivas con adobe y quincha para la construcción de muros, arcos, bóvedas y cúpulas.

Conservación del Patrimonio Cultural Inmueble

Es una asignatura obligatoria de tres horas semanales que se dicta en el séptimo semestre; impartida desde 1997, busca promover la reflexión crítica, análisis y discusión sobre el patrimonio monumental en el Perú y el mundo.

La metodología es teórico-práctica: en aula se tienen clases expositivas, estudio de casos locales y extranjeros, y lecturas que permiten desarrollar una base conceptual consistente, orientando a los estudiantes a asumir un interés y compromiso por la salvaguardia de los monumentos y sitios



FIGURA 7 Módulo terminado: el primer piso es de muros de tierra, mientras que el segundo piso es de madera. Asignatura "Obras Preliminares." Fotografía: Luis Alberto Rengifo Zevallos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).

históricos. En el aspecto práctico, cada estudiante selecciona una obra histórica en la ciudad y elabora un expediente técnico general que incluye el diagnóstico y la propuesta. Dadas las características de las construcciones históricas en Lima, muchas de las obras estudiadas son de tierra.

Se ofrecen además dos asignaturas electivas: "Restauración de Edificaciones," que permite ampliar los conocimientos en conservación con un estudio pormenorizado de los monumentos arquitectónicos, y "Restauración Urbana," que se enfoca en los espacios públicos con valor histórico.

En todas las asignaturas se propicia el trabajo en grupo a fin de preparar a los estudiantes a formar parte de equipos de trabajo multidisciplinarios.

El plan de estudios considera además asignaturas electivas vivenciales que pueden ser cursadas a partir del sexto semestre y que permiten a los estudiantes profundizar simultáneamente en los temas de construcción con tierra, historia de la arquitectura y restauración. Ellas son:

a) "Ciudad de Lima." Asignatura electiva de tres horas semanales que permite estudiar y analizar *in situ* las obras de arquitectura más relevantes del Centro Histórico de Lima, declarado Patrimonio de la Humanidad, así como algunas zonas arqueológicas fuera del centro histórico, haciendo énfasis en los aspectos históricos, constructivos y de su conservación.



FIGURA 8 Estudiantes dibujan el ábside de una iglesia en Maras, cerca de Cusco, en la asignatura "Proyecto Perú Sur." Fotografía: Luis Alberto Rengifo Zevallos. Cortesía: Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC).

b) "Proyecto Perú Norte." Viaje de estudio de diez días por la costa norte en el que se estudian sitios como Caral, el Centro Histórico de Trujillo, Chan Chan, las huacas del Sol y la Luna, y Túcume.
c) "Proyecto Perú Sur." Viaje de estudio de dieciséis días que permite entrar en contacto con algunos de los principales monumentos y sitios históricos de Arequipa, Puno y Cusco (fig. 8).

Conclusiones

La tierra fue el material con que se construyó la mayor parte de los monumentos en la costa peruana en el periodo prehispánico, fue la base en la edificación de viviendas en Lima durante el virreinato y es una tradición viva en Perú, especialmente en áreas rurales. Esto sugiere que se trata de temas que deberían ser considerados en los planes de estudio de las facultades de arquitectura en Lima.

En las últimas décadas, en el Perú se han desarrollado investigaciones sobre cómo mejorar los sistemas de construcción con tierra, tanto para viviendas rurales como para edificaciones históricas. Esta información debería ser asimilada y difundida para la formación profesional.

La Facultad de Arquitectura de la UPC ofrece en su plan de estudios tres asignaturas obligatorias que permiten al estudiante conocer la construcción con tierra desde el punto de vista teórico y práctico en "Obras Preliminares" del cuarto semestre, su importancia en el desarrollo nacional en "Arquitectura Peruana" del sexto semestre y, finalmente, interesarse por la conservación de edificaciones históricas en "Conservación del Patrimonio Cultural Inmueble" del séptimo semestre, siendo ésta una propuesta que articula tres importantes aspectos vinculados con la tradición arquitectónica local.

La metodología activa en la que los estudiantes aprenden de forma teórica y práctica permite el desarrollo de habilidades, conocimientos y aptitudes. La implementación de los talleres de construcción constituye un aporte significativo en la formación del futuro arquitecto. Contar con viajes de estudio específicos sobre estos temas complementan la oferta académica.

Actualmente no se dispone de datos estadísticos acerca de la repercusión de estos cursos en los arquitectos formados bajo esta metodología, pero es notoria su participación en instituciones públicas y privadas comprometidas con la conservación del patrimonio cultural edificado.

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PART 9

Historic Buildings and Structures / Edificios y estructuras históricas

Individual Engineering Solutions for Structural Problems in Earthen Buildings in the Al Ain World Heritage Site

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Abstract: *Since the launch of the Emergency Conservation Program in Abu Dhabi under the Department of Culture and Tourism (DCT) in 2008, conservation efforts have dealt with a wide range of sites across the emirate, and particularly for those within the Al Ain World Heritage Site. A major part of these efforts has concentrated on finding solutions that rely on the engineering aspects of the behaviors of the structures. These solutions should begin with an understanding of how to predict future conditions by analyzing the structures, which were built in traditional ways that do not adhere to present standards. It has repeatedly turned out that although the typical damage mechanisms can be treated with standard conservation solutions, a consideration of each building's condition remains essential under the precept of minimal intervention. It is necessary to first define the conservation aim from the point of view of site values and then, as a basis for a careful analysis of options, to determine the solution that comes closest to achieving these conservation aims without compromising values.*

Resumen: *A partir del lanzamiento del programa de Conservación de Emergencia en Abu Dabi con la aprobación del Departamento de Cultura y Turismo (DCT) en 2008, las acciones de conservación se centraron en una amplia variedad de sitios en todo el territorio de los Emiratos y, en particular, en los lugares que se encuentran dentro del sitio de Al Ain, declarado Patrimonio de la Humanidad. Una parte importante de estas acciones se enfocaron en la búsqueda de soluciones que se basan en los aspectos de ingeniería de comportamiento de estructuras. Las soluciones estructurales deben comenzar con la comprensión de cómo predecir el estado futuro de las estructuras y analizarlas; por ejemplo, cuáles se construyeron de forma tradicional y no se ajustan a las normas estructurales actuales. En muchos casos, se comprobó que, aunque los mecanismos de daño comunes pueden resolverse con soluciones de conservación típicas, sigue siendo necesario analizar el estado de cada edificio bajo el precepto de la mínima intervención. En primer lugar, es necesario definir la meta de conservación desde la perspectiva de los valores del sitio y luego, como base para un análisis cuidadoso de las opciones, determinar la solución que más se acerque a esas metas de conservación sin comprometer esos valores.*

Keywords: conservation engineering, individual solutions, structural safety, options, stitching, needling, cracks, strengthening, structural repair, monitoring, maintenance

Introduction

This paper presents the engineering solutions to structural problems in historic earthen buildings, which must always be individually adapted, for three conservation sites in Al Ain, UAE. The projects are:

- Bin Biduwa Al Darmaki House: a building that should be able to stand as a ruin safely and without supports;
- Al Qattara Souq: stabilization and presentation of part of the building of high cultural significance, at risk of collapse;
- Murabbʾa Fort Tower: needling of an overloaded masonry pillar at risk of collapse.

All of these sites are included in the Emergency Conservation Program for the cultural heritage of Abu Dhabi Emirate, implemented by the Department of Culture and Tourism–Abu Dhabi (DCT). The individual properties are components of the serial World Heritage property, Cultural Sites of Al Ain, which was inscribed in 2011 (Aqeel et al. 2012). DCT employs a specialized staff of archaeologists, architects, engineers, and craftspeople for the conservation of this large collection of earthen heritage sites that date from the Iron Age to the mid-twentieth century. DCT also collaborates with external experts, such as ZRS Ingenieure (ZRSI) from Berlin, in the field of conservation engineering.

While patterns in the pathologies affecting these earthen sites are similar and have been resolved with consistent conservation strategies, the specifics of each building's context must be considered to ensure minimal intervention by first defining the conservation aims from the point of view of the site's significant values and then by means of variant analysis. These steps help to determine the solutions that come closest to achieving the conservation aims without compromising the sites' values.

Bin Biduwa Al Darmaki House

The conservation aim for the Bin Biduwa Al Darmaki House, which was close to collapse in several sections, was to ensure that the building would be able to stand safely and without support as a ruin. The building should be safe for visitors to explore. This is a very typical objective that could apply to many abandoned, ruinous buildings that require intervention, but not full rehabilitation, at a reasonable expense (fig. 1).

The following damage patterns and mechanisms were identified in the building:



FIGURE 1 Bin Biduwa Al Darmaki House before conservation work. Parts of the building had already collapsed and others were about to do so. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

- Reduction of the cross section at the base of the wall due to rising damp and salts, resulting in settlement that was associated with the formation of cracks, inclination, and areas of partial collapse. The influence of moisture, and thus the reduction of the building's base strength, was intensified by the irrigation of an adjacent palm garden;
- Complete loss of strength of all wooden components due to termite infestation. The ceiling joists and lintels were already gone, resulting in the collapse of all ceilings and several walls;
- Superficial weathering had slowly reduced the wall cross section but had not yet reached a critical level.

First remediation steps included supporting the areas of the building that were in danger of collapsing with structurally effective scaffolding. Additionally, irrigation for the surrounding date palm garden was stopped (fig. 2). Next, the base masonry cross section was redone with earth blocks. While it would have been more durable to insert a horizontal barrier with materials such as natural stone in the foundation and plinth area, it was jointly decided to work with authentic materials and traditional construction techniques.

For the parts of the building that were unstable and temporarily secured by scaffolding, individual decisions were made as to how a stable condition could be reachieved. In some areas, remaining original components were supported by the reconstruction of lost elements. This measure had to meet the condition that the historical geometry—based on historical



FIGURE 2 Former entrance zone of the Bin Biduwa Al Darmaki House, secured by structural scaffolding. The scaffolding that was used to straighten the wall behind it is visible on the right side of the photograph. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.



FIGURE 3 Bin Biduwa Al Darmaki House after completion of the conservation work, straightening, and reconstruction of parts that were necessary for a self-standing building without scaffolding. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

photographs and archaeological evidence of the foundations—could be achieved again without conjecture. The supplemental components were finished with a smoother earthen plaster that differentiated them from the original surfaces.

One notable example of the reconstructed components was on the main historical gate. The gate had partially collapsed, and the adjacent walls suffered from some structural instability. An approximately 20 m^2 section of wall, which had to be supported by scaffolding due to its extreme inclination, was gradually straightened over the course of one day. The special challenge here was that the wall needed to be pressed up evenly over the entire surface to prevent it from breaking into several pieces. This process was successful.

Cracks were stitched with earthen blocks and filled with earthen mortar. Additional measures to increase stability, such as needling the cracks with fiberglass bars, were not necessary in this case. Lintels were reinstated with palm wood, as had been done traditionally, but the lintels were soaked in termite insecticide beforehand. Because the geometry of the walls and rooms provided sufficient stability for the structure, it was not necessary to reconstruct the ceilings and the rooms were left exposed to the open air.

Today, the building is considered exemplary for the successful handling of ruinous earthen buildings and is regularly featured during guided tours and presentations for professionals and tourists (fig. 3).

Al Qattara Souq

Al Qattara Souq and Al Qattara Arts Centre are the cultural heart of the Al Qattara Oasis in the northern part of Al Ain and are frequented by the local community and visitors. A part of the earthen Bin ʿAti Fort was rehabilitated and adapted into Al Qattara Arts Centre in 2012, serving as an art community center. Some of the DCT staff have their offices in the authentic earthen section of the center. Al Qattara Arts Centre also hosted the first International Course on the Conservation of Earthen Architecture (EAC), organized by the Getty Conservation Institute (GCI) and DCT, which was attended by students from the Middle East, North Africa, and South Asia.

The Qattara Souq building is a small, traditional earthen construction composed of two parallel rows of boxlike rooms that served as shops. The central aisle is covered with a shaded palm frond roof. The building contains remains from earlier building phases or from previous buildings, a fact that is presented to the public as a means of sharing historical context. The Qattara Souq was rehabilitated in 2013 as a traditional souq, providing a glimpse of what a souq was in the past to residents and visitors (fig. 4). It is a popular destination during the annual Traditional Handicrafts Festival.

In 2018, settlement and cracks were noticed on a column between the shop windows, and a shell of earthen block masonry fell into the interior of one of the shops. As the shop



FIGURE 4 View of the central aisle of Al Qattara Souq. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

openings are wide, the columns are well loaded, but not so heavily that these damages should have occurred. An investigation determined that the wooden lintels were placed over a window opening in an earlier construction phase, and these beams had been completely undermined by termite infestation. As a result, compression had occurred at the height of the beams, which led to the settlement of the upper section of the column and the roof, as well as the formation of cracks in the adjacent transversal wall. The earthen block masonry of the different building phases was not interlocked and therefore did not have the stability of a solid homogeneous masonry (fig. 5).

Since the Qattara Souq is publicly accessible, DCT wanted to ensure its safety for visitors and shop operators while also ensuring the building's stability and authenticity. DCT conservators determined that the unstable wall and lintel remains of the early construction phase were highly valuable for preservation, but maintaining an unstable component in this condition was in contradiction to the necessary structural function of the column. In order to preserve and present the wall section of the earlier building phase, especially the wooden lintels, as comprehensively as possible, the following strategies were studied:

- Replace the wooden beam layer in combination with strengthening the masonry;
- Stabilize the remains of the wooden beam layer by injection, thereby strengthening the masonry;
- Implement a load-bearing wooden frame and minimally stabilize the masonry;



FIGURE 5 Al Qattara Souq project after loose sections were carefully removed and the wall was secured with scaffolding. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

- Implement a load-bearing metal frame and minimally stabilize the masonry.

The advantages and disadvantages of the different options and materials were thoroughly evaluated. Students from the concurrent EAC course (GCI and DCT) were also involved in the discussion. Together, it was decided to go for the last option, the implementation of a metal frame. More precisely, the solution consisted of four individual steel frames placed one behind the other inside the thick wall. The advantages were that the weight of the individual components was low and that they could be manually inserted piece by piece.



FIGURE 6 Installed frame and minimally stabilized masonry at Al Qattara Souq. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

The color and geometric patterns of the steel frame are similar to those of the surrounding wooden frames of the shop openings, and it is not perceived as a disturbing element (fig. 6). The restored wall sections were minimally stabilized and are now visibly distinct to visitors. Future settlement within the frame is possible but, as it is no longer a load-bearing masonry, this would be harmless.

Murabb'a Fort Tower

The main structure of the Murabb'a Fort in Al Ain's city center is its tower. Built of earthen blocks, the tower is one of the few three-story earthen block buildings in the UAE. The tower has historic value as the region's first police station, and the building is to be made accessible to the public again. For this, issues of stability and safety needed to be addressed.

Due to differential settlement along the northern outer wall of the tower, loads were transferred to the central column of the staircase. This caused an overload that manifested in extensive longitudinal and diagonal cracking across and through the column. Despite the narrow crack width, the load capacity of the pillar was significantly reduced. It became clear that, in addition to the stabilization of the north wall, it was urgently necessary to strengthen this column in order to prevent a collapse. The following options were considered:

- Dismantling and rebuilding the pillar;
- Strengthening by means of wrapping;
- Strengthening by means of needling.

The first option was excluded because of the key values of the original structure and, per the second option, it would have been extremely difficult to wrap the free ends of the stairs along the landings and steps. The third option was preferred since it considered the minimum required intervention with the least impact on the original fabric. It was executed with 8 mm diameter fiberglass Schöck Combar needles. The needles have a ribbed surface similar to rebar and, compared to reinforcing steel or stainless steel, they have the advantage of being more flexible and therefore better adapted to the earthen block masonry. The needles were arranged according to ZRS Ingenieure's engineering expertise, in vertical distances of 50 cm and with an alternating length of 50 and 100 cm behind the line of the crack if possible.

The mortar used to coat the needles had to bridge the high strength of the needle and the low strength of the earth block masonry. A low-hydraulic lime mortar is normally used for this purpose, but because such a hydraulic lime could not be procured locally, a mortar was prepared that can be described as a lime mortar with very low cement content. The material's chemical composition and strength are similar.

Slots were mortised for the needles, which were placed parallel to the surface and embedded in the fresh mortar (fig. 7). Access channels were drilled out for needles to be laid transversely and diagonally, and the prepared liquid mortar was flowed into these channels prior to the insertion of the



FIGURE 7 Test placement of the needle before the mortar is placed at Murabb'a Fort Tower. Photo: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

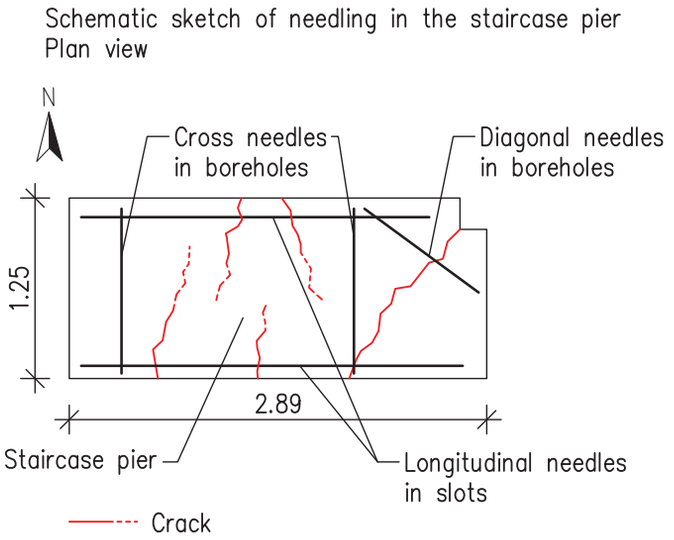


FIGURE 8 Schematic for needle placement at Murabb'a Fort Tower. The stripes show the needles inserted superficially on both sides of the pier. The dots mark the places where the needles were installed transversely. Illustration: Christof Ziegert, © ZRSI / DCT Abu Dhabi.

needles. The mortar was moistened during the following two weeks to allow for a humid cure.

The intervention was successful. Regular monitoring has shown that up to now, 2.5 years after the intervention, the cracks have remained closed and no new cracks have appeared. A schematic sketch of the placement of the needles is shown in figure 8. A detailed description of needling as a method of structural strengthening of cracked earthen building structures can be found in the book *Earthen Building Practice* (Röhlen and Ziegert 2020). There is no worldwide code of practice for the positioning and calculation of such measures. In other exemplary rehabilitation measures for earthen buildings in earthquake zones, the strengthening measures were also determined individually by experts (Yuste Miguel et al. 2017). There is always a need for experts who are competent and willing to take responsibility for an individually adapted concept.

Conclusion

The three examples from this paper show that historic earthen buildings can be prevented from collapsing and adequately strengthened with appropriate measures. Several options for each case have been put forward based on analysis and evaluation in order to choose the best one. The main criteria were to preserve the authenticity of the buildings while making sure that the targeted elements were structurally sound with minimal intervention. The methods and materials used must be carefully adapted to the existing structures. In the case of the Qattara Souq, the method that was implemented was an opportunity to present part of the fabric to the public. For the Bin Biduwa House, on the other hand, the need for permanent structural support of the freestanding walls led to the reconstruction of several components, such as the historical main gate. These cases demonstrate that durable and efficient solutions can be implemented while avoiding incompatible materials such as reinforced concrete.

The knowledge carried by a few experts must be made widely available through suitable courses, seminars, and publications. Nevertheless, the methods must be adapted to the respective building and situation. This is a general challenge for building conservation that is related not only to historic earthen buildings.

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The Conservation Journey of the Bin Biduwa Al Darmaki House, 2010–2019

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Abstract: *This paper offers a brief account of a holistic and incremental journey of conservation and restoration, still ongoing, that has been made in a number of distinct stages since 2009 at the historic earthen House of Bin Biduwa Al Darmaki, in the oasis city and World Heritage Property of Al Ain in the United Arab Emirates (UAE). Al Qattara Oasis is one of the seventeen components of the Cultural Sites of Al Ain, a UNESCO World Heritage Property since 2011. The oasis contains a number of historic earthen buildings dating from the seventeenth century CE onward, including mosques, forts, and houses. Bin Biduwa is one of the earliest structures in Qattara Oasis, with the core of the building dating from the mid-seventeenth century and therefore broadly contemporary with the creation of the adjacent oasis in its present form. The Department of Culture and Tourism–Abu Dhabi (DCT) has carried out a number of separate conservation campaigns at Bin Biduwa between 2010 and 2019. The goal is to open the site to visitors as part of a local activation initiative centered on the nearby Al Qattara Souq. This paper emphasizes the research and archaeological investigations that have informed the progress of the conservation and restoration. It explains how monitoring, structural solutions, testing methods, and documentation have all contributed to conservation decisions and the current presentation of the site.*

Resumen: *En este artículo se relata brevemente un proceso holístico y gradual de conservación y restauración que aún se encuentra en curso; se realizó en varias etapas diferentes desde 2009 en la histórica casa de tierra de Bin Biduwa Al-Darmaki, en la ciudad oasis declarada Patrimonio de la Humanidad de Al Ain, en los Emiratos Árabes Unidos (EAU). El oasis de Al Qattara es uno de los diecisiete componentes de los sitios culturales de Al Ain, declarados Patrimonio de la Humanidad por la UNESCO desde 2011. El oasis tiene un conjunto de edificios históricos de tierra que datan del siglo xvii en adelante e incluyen mezquitas, fortalezas y casas. Bin Biduwa es una de las primeras estructuras del oasis de Qattara, ya que el centro del edificio data de mediados del siglo xvii, prácticamente es contemporáneo a la creación del oasis adyacente en su forma actual. El Departamento de Cultura y Turismo (DCT) de Abu Dabi llevó adelante diferentes campañas de conservación en Bin Biduwa entre 2010 y 2019. El objetivo es abrir el sitio a los visitantes como parte de una iniciativa de activación local centrada en el cercano Souq al-Qattara. En este artículo, profundizamos en el estudio y las investigaciones arqueológicas que sirvieron de base para el progreso de la conservación y la restauración. Se explica la manera en la que la supervisión, las soluciones estructurales, los métodos de prueba y la documentación contribuyeron a las decisiones de conservación y a la presentación actual del sitio.*

Keywords: conservation cycle, buildings archaeology, World Heritage Site, oasis, earthen structure

Understanding and Conserving Historic Earthen Buildings in the Oasis Landscape of Al Ain, UAE

Qattara Oasis (Al Ain, UAE) is one of the seventeen components of the Cultural Sites of Al Ain, a serial property that testifies to continuous human occupation of an arid region since the Neolithic period and a UNESCO World Heritage Property since 2011. The oasis contains a number of historic earthen buildings dating from the seventeenth century CE onward, including mosques, forts, and houses (fig. 1). One of these, the Bin ʿAti Al-Darmaki House, was rehabilitated in 2011 as the Qattara Arts Centre and has since become a vibrant focal point for art, culture, and crafts in Al Ain.

Another significant historic earthen building is Al Qattara Souq, a 35 m long structure composed of one-room shops arranged on either side of a central covered passage. Immediately to the north of the souk, the fortified house of Mohammed Saleh bin Biduwa Al Darmaki lies partially concealed within a palm grove on the western edge of the oasis. The imposing three-story tower at the northwest corner of the house survives largely intact. To the east of the tower is a range of well-preserved rooms. The evidence from historic photographs and a number of wall fragments to the east and south of the main building show that the complex originally extended over a larger area (fig. 2).

Like many journeys, the progress of this one can be measured on a map, and ours began with the initial base mapping and survey of the structure carried out in 2009 as a

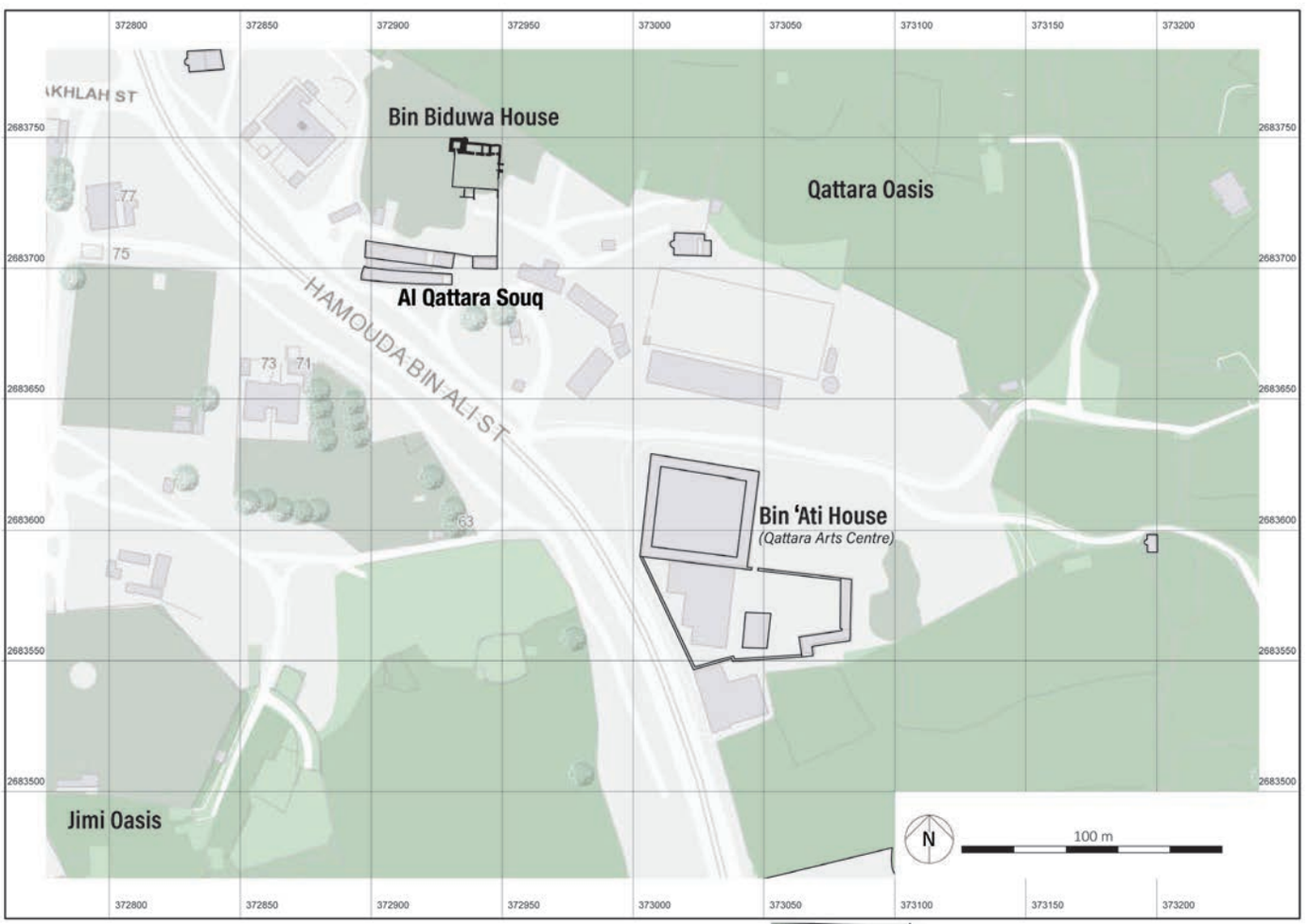


FIGURE 1 Plan of Qattara Oasis and village showing the other historic earthen buildings that survive near the Bin Biduwa House. Illustration: Malak Al Ajou/DCT Abu Dhabi.

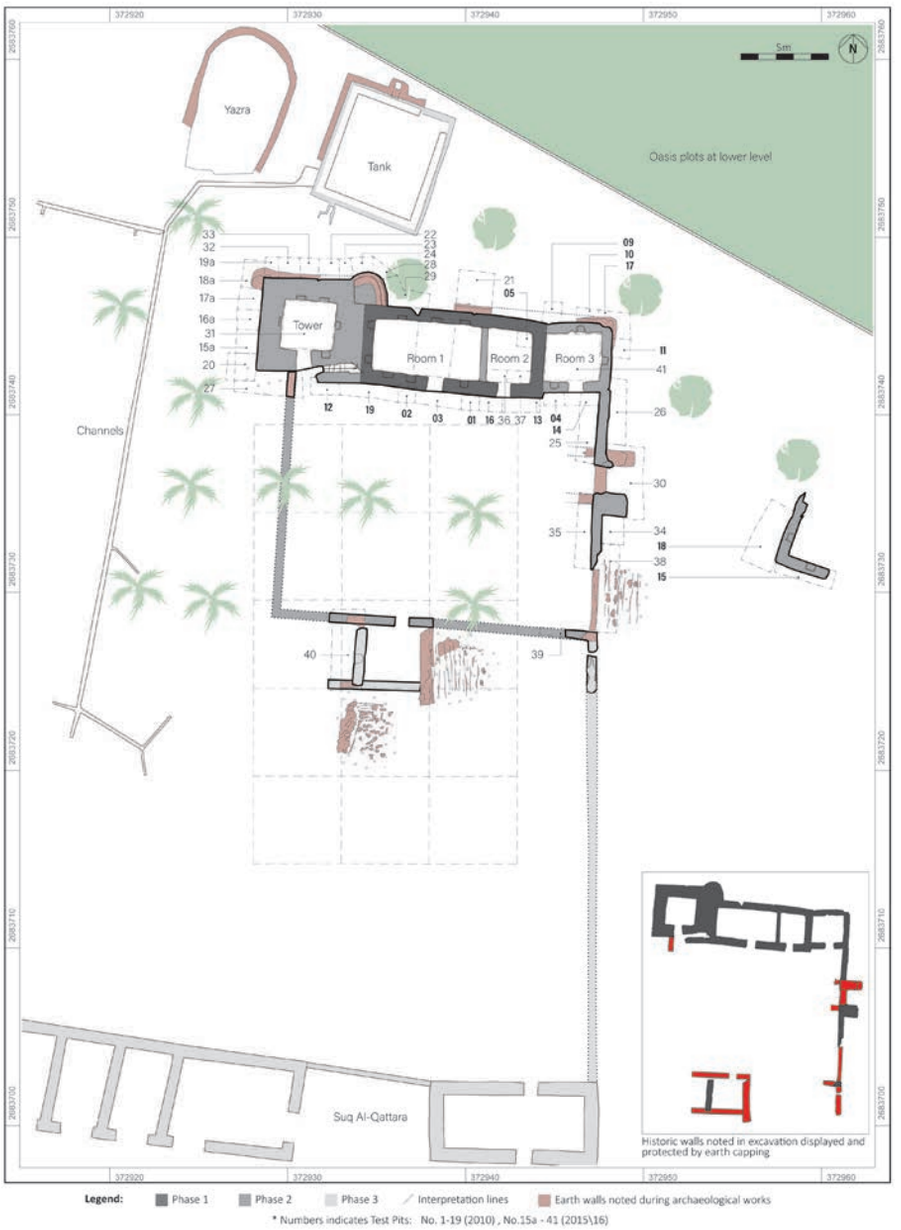


FIGURE 2 Plan showing the development of the Bin Biduwa House over time and the various archaeological investigations carried out ahead of conservation interventions. Illustration: Malak Al Ajou/DCT Abu Dhabi.

prelude to propping of the building and the initial emergency repairs to the coving damage visible at the base of the walls. The mapping has subsequently been updated over time to show the interrelated progress of archaeological investigations and conservation works. These two activities constitute the conservation cycle in action at Bin Biduwa, where the current state of understanding of the building has informed its conservation, resulting in further understanding and thus further conservation. This base mapping of the various archaeological and conservation interventions has been supplemented along the way, both by traditional manual techniques in the CIAV VERNADOC 2012 camp that focused on Bin Biduwa, Al Qattara Souq, and two nearby historic earthen mosques (Mattila 2015), and more recently by the latest developments in digital photogrammetric recording (Muhammad 2013).

In the absence of written historical sources, much of our understanding of historic earthen buildings in Al Ain derives from archaeological investigations. Archaeological research is driven by the desire to understand buildings and their setting in the landscape in the fullest manner possible.



FIGURE 3 View from the northwest showing the progress of staggered test pits around the eroded base of the house's three-story tower. Photo: Peter Sheehan/DCT Abu Dhabi.

The identification of archaeological "horizons" around the building and key stratigraphic relationships between its different phases are two of the main resources for understanding the development of the Bin Biduwa House. Therefore, a carefully planned incremental program of test pits and "opening-up works," intended both to clarify existing conditions and to facilitate repairs, has formed the key interface between archaeology and conservation interventions (fig. 3). Archaeological recording at each of a staggered series of test pits excavated to allow conservation works around the eroded base of the building has provided a cross section through the journey of its construction, occupation, and subsequent abandonment. The opportunity to demonstrate, investigate, and record the processes of construction and occupation and the cycles of reuse and disuse inherent in the building provided an ideal location for an archaeological field school held in 2012, the inaugural season of the Al Ain Oases Mapping Project carried out jointly from 2012 to 2017 by DCT Abu Dhabi and Zayed University, Abu Dhabi (Power et al. 2016).

Bin Biduwa Chronology: Construction and Occupation, Additions, and Abandonment

There are seventeen surviving historic earthen buildings in and around the oasis of Qattara, and together they provide a great deal of information on the dating of the oasis, its development over time, and, in particular, the steps taken from the seventeenth century onward to defend it (Power and Sheehan 2012). Archaeological investigations over the past ten years have shown that the historic earthen buildings of Al Ain developed over several main chronological episodes, dating from the mid-seventeenth through the early twentieth century CE. The main phases of construction and abandonment noted during archaeological works at the House of Bin Biduwa fit within the same broad overall framework (fig. 4).

Bin Biduwa is one of the earliest structures in Qattara Oasis, with the core of the building dating from the mid-seventeenth century and therefore broadly contemporary with the creation of the adjacent oasis in its present form. It is one of a group of single-story fortified earthen houses, positioned to be intervisible, that are evenly spaced along a broad line defending key strategic points in the western approaches to the twin oases of Qattara and Jimi. This westward focus remained a feature of subsequent periods and is significant as an indicator of where the principal danger was expected to come from. This type of structure was the forerunner of the later three-story *murabbʾa* buildings that continued to be built into the 1950s with much the same purpose and in similar locations. As with other vernacular buildings in Al Ain and the region, the house was constructed of sun-dried earth blocks with earth mortar and plaster (Sheehan 2015). Other surviving examples of this early form show a striking similarity in type, with thick walls, a single door at ground level, and a parapet at roof level pierced with sloping gun loops on all four sides from which the defenders could bring musket fire to bear on attackers at the base of the wall (fig. 5).

There is archaeological and cartographic evidence from around the beginning of the nineteenth century for a further development of building typology in the region with the appearance of a number of small square forts. The Khandaq fort in nearby Buraimi may have served as a local model for this form, which was also probably influenced by the Portuguese forts built on the coasts of Oman and the Persian Gulf from the sixteenth century onward. The stratigraphic relationships of different components of the Bin Biduwa House clearly show that the original house was enclosed in this second phase to form part of a gated square courtyard, with the addition of an impressive three-story square tower abutting the earlier house to form the northwest corner of the new square enclosure. The location obviously remained a significant one in terms of its views of the approaches to Al Ain from the west. Buttresses, artfully built to conceal the joint between the blockhouse and the tower, underline the twin functions of these buildings as both watchtowers and powerful political markers in the landscape intended to be seen from afar.

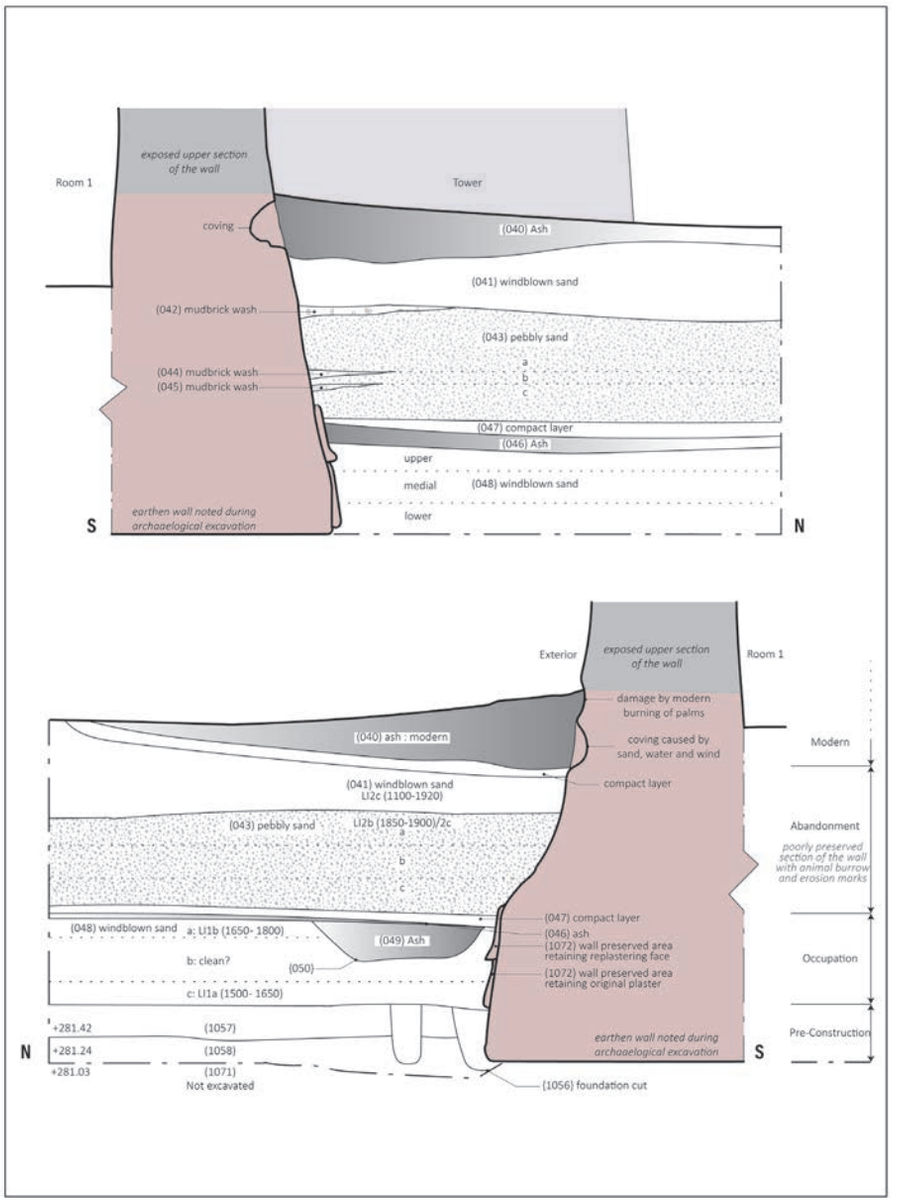


FIGURE 4 Sketch sections of one of the test pits (TR. 21), illustrating how archaeological investigations have demonstrated the construction history of the building. Illustration: Tim Power/Malak Al-Ajou/DCT Abu Dhabi.

A number of ancillary rooms at Bin Biduwa, added against the south wall of the square courtyard, formed part of a third building phase that was subsequently further modified, first in the 1930s, to form Al Qattara Souq, and then again in the 1970s during the remodeling of the souq. The square fort was abandoned by the early twentieth century and became a dumping ground that was gradually subsumed into a new palm grove planted along the upper edge of the original oasis basin. The large earthen brick-lined, animal-powered *yazra* (well) and its associated water tank (originally also an earthen tank lined with waterproof *sarooj* plaster) immediately to the north of the tower appear to date from this ultimate phase. The rebuilt tank is still used to irrigate the palm grove adjacent to the Bin Biduwa House.

Our understanding of these later developments and modifications to Bin Biduwa was further enhanced during conservation and rehabilitation of the adjacent Al Qattara Souq in 2012. Historic walls identified during the refurbishment of the souq were given a plaster finish that follows the more irregular contours of the historic fabric, differentiating it from the smooth finish used for the parts rebuilt in the 1970s. These different finishes were carried over into the



FIGURE 5 View of the main south-facing facade, showing the key stratigraphic relationship between the original seventeenth-century blockhouse and the later nineteenth-century tower. Photo: Peter Sheehan/DCT Abu Dhabi.

works at Bin Biduwa to differentiate original fabric from those areas repaired or restored during ongoing conservation works.

The Conservation Journey: Repairs, Reconstruction, and Render

Conservation adopted a values-based approach to the Bin Biduwa House as a ruined vernacular building, and the work was carried out in line with contemporary best practice (Chabbi et al. 2012). The main values driving this approach are the historic fabric and the desire to maintain authenticity by basing conservation on a thorough investigation and understanding of the building, as was laid out by the Burra Charter—understand significance, develop policy, and manage the site in accordance with policy. Table 1 shows a few examples of how the guidelines of the Burra Charter were applied (Australia ICOMOS 2013).

Conservation works have thus been guided throughout by the archaeological information underpinning this understanding. The initial staggered test pits on the main south-facing elevation of the building allowed us to assess the overall conditions and carry out emergency repairs and interim support for those parts of the building in danger of collapse. These works formed part of a larger Emergency Conservation Program carried out across Abu Dhabi Emirate between 2008 and 2012 (Aqeel et al. 2012). The main purpose of this program was to stabilize the existing situations found in buildings and to minimize or eliminate the further decay of historic buildings across the emirate. At Bin Biduwa these interim measures included both scaffolding and temporary support with dry bricks, as well as careful pruning of the huge and ancient *ghaf* (*Prosopis cineraria*) tree growing immediately next to the house. The program of mid-term or holistic conservation initiated in 2015 aimed to find solutions that would allow us to gradually remove the scaffolding support, eliminate or control existing threats, and open the building to visitors.

Table 1 Application of Burra Charter Guidelines during the Conservation of the Bin Biduwa Al Darmaki House

Burra Charter articles	Application in the project
Article 3. Cautious Approach 3.1 Conservation is based on a respect for the existing fabric, use, associations, and meanings. It requires a cautious approach of changing as much as necessary but as little as possible.	Emergency and mid-term conservation works focused on repairs that are critical to the structural stability of the building. Coving repairs to foundations and the base of walls and realignment of a leaning wall of the house were completed in an effort to stabilize the building.
3.2 Changes to a place should not distort the physical or other evidence it provides, nor be based on conjecture.	The reconstruction of the partially collapsed gate of the house was based on the documentary evidence (a photograph from 2004) and the construction methods of similar gates preserved in other historic buildings in Al Ain (see below).
Article 4. Knowledge, Skills, and Techniques 4.2 Traditional techniques and materials are preferred for the conservation of significant fabric. In some circumstances modern techniques and materials which offer substantial conservation benefits may be appropriate.	Local materials and traditional construction techniques were used in the reconstruction of the missing sections of the gate. Craftsmen with relevant knowledge and training in the application of traditional materials and building techniques were employed on the project. Sun-dried earthen bricks produced in our building and crafts workshop were used.
Article 20. Reconstruction 20.2 Reconstruction should be identifiable on close inspection or through additional interpretation.	Newly reconstructed sections of wall bases and the northern part of the gate are easily distinguished from the heavily weathered existing building materials.



FIGURE 6 Jacking and hand-wrenching by workers to push the wall north of the gate back to a near-vertical position. Photo: Salman Muhammad/DCT Abu Dhabi.



FIGURE 7 View of the gate of Bin Biduwa in 2004. Photo: Aqeel Ahmed Aqeel/DCT Abu Dhabi.

Between these two campaigns, structural monitoring of the building was aimed at understanding the behavior of its various elements. Mid-term holistic conservation works initially consisted of extending the earlier coving repairs around the base of the tower and the north wall of the house. The same gradual and holistic approach of informed decision making continued in 2016 with the investigation of the collapsed gate of the house and repairs to the circuit wall adjoining it immediately to the north. Coving at the base of this wall had caused it to slump and lean outward, so repairs to the foundations were followed by a slow and ultimately successful process of gently modifying the scaffolding to push the wall back into place—a process designed and personally supervised by Dr. Christof Ziegert of ZRS Architekten Ingenieure, Berlin (fig. 6).

A photograph from 2004 showed that the arched and fortified gatehouse of the fort had survived intact until very recently and had partially collapsed sometime between 2004 and 2007 (fig. 7). Similar gates are found in the square enclosure of Bin Jabr in Jimi Oasis, incorporating (as at Bin Biduwa) the earlier house within its circuit, as well as the partially preserved House of Bin Suroor in Mutaredh Oasis. For both of these, an early nineteenth-century date similar to that of the square fort phase at Bin Biduwa seems likely given the available archaeological evidence. These extant examples complemented the photographic documentation in providing the information on which to base an accurate and authentic restoration of the gate. Archaeological investigations were then carried out to find the surviving base of the north side of the gate, which was subsequently strengthened and incorporated into the restored structure. The decision to proceed down the route of gate reconstruction was based on the availability of both photographic and archaeological evidence and the similar surviving examples, coupled with the realization that the remaining southern part of the gate would not survive many more of the heavy winter rainstorms regularly experienced in Al Ain. Furthermore, the reconstructed gate would act as a structural connection and support to the freestanding walls on either side of it (fig. 8).

Other conservation works have followed from the archaeological recording of collapsed walls from the third and most recent phase of the house. Several of these have been



FIGURE 8 View of the restored gate from the interior of the house courtyard, showing the capping of subsurface walls and how the new masonry is clearly distinguished from original elements. Photo: Peter Sheehan/DCT Abu Dhabi.

reinstated as clearly conservation interventions that act as buttresses to the remaining freestanding walls. New mud capping has been used to indicate the position of buried historic walls encountered at a level below modern ground surface. Conservation works inside the house and tower have also included the replacement of lintels and repairs to minor areas of coving.

Conclusion

Since 2017, works around Bin Biduwa have focused on landscaping and presentation of the building within its historic oasis setting. This has included construction of new stone and gypsum plastered channels that take water from the water tank to the palm grove west of the house. Works on the building have continued to use the language of different plaster finishes to indicate where conservation has taken place. Landscaping works to the north of the house and a stone retaining wall to the east have stabilized the edge of the site.

The conservation of the Bin Biduwa House is one of the first successful examples in Abu Dhabi of a completed multidisciplinary conservation project approaching a ruinous but authentic site with a policy of minimum reconstruction based on archaeological information. The building is now open to visitors, and one of the most important milestones on its conservation journey has been the acceptance by the local Al Ain community, confirming that an approach based of minimal interventions enhances cultural significance and offers a richer interpretation for visitors than the total reconstruction of vernacular sites practiced in the region in the relatively recent past.

Today the historic Qattara village forms the core of its annual Traditional Handicrafts Festival, which draws large numbers of Emirati and expatriate visitors. Although much of the village was abandoned and then demolished in the 1980s, the survival of the remaining historic buildings and their recent conservation and rehabilitation has contributed to the flowering of a lively cultural scene in an authentic historic location that provides the public with access to a range of cultural activities including the ongoing archaeological and conservation work, workshops showcasing traditional crafts and building techniques, and intangible heritage activities such as dance, music, and poetry.

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The Collective Granaries in the Moroccan Atlas Mountains: Richness and Diversity of Architectural Forms

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Abstract: *The Atlas Mountains in Morocco are strewn with centuries-old constructions and institutions of major importance for Moroccan culture. These are collective granaries, which are basically fortified storage buildings where whole tribes, small groups of people, or villagers kept their harvests and valuables to protect them from natural risks or plundering by neighbors or enemies. These institutions, called* agadir *or* ighrem *depending on their location, represent places of memory charged with technical, cultural, and anthropological significance. They were a kind of social contract between the members of society and the heart of the socioeconomic and political systems of the region. Their origins remain unknown. The lack of written documents makes it difficult to understand the historical evolution of these imposing buildings, which are surprising in their architecture and organization. However, they reflect the independent spirit of the Atlas Berbers before the French Protectorate in 1912. The collective granaries, which were designed to adapt to group organization, the rigorous climate, and the defensive needs of the tribes, have fallen into disuse over the past several decades. They have been abandoned and poorly maintained, sometimes prone to inappropriate additions. Restoring and rehabilitating them is an urgent need. For the past thirty years, the Centre for the Restoration and Rehabilitation of the Architectural Heritage of Atlas and Sub-Atlas Zones (CERKAS) has endeavored to integrate them into the valorization process, alongside all other earthen heritage structures. An extensive inventory was conducted at close to 560 sites. This work helped in the preparation of studies and in the realization of restoration and protection work, and it will be used within three years for the preparation of the nomination dossier for the granaries of Morocco on UNESCO's World Heritage List. In this paper, I focus on the richness and diversity of this exceptional heritage and its future.*

Resumen: *En la cordillera del Atlas de Marruecos, hay construcciones e instituciones centenarias de gran importancia para la cultura marroquí. Se conservan graneros colectivos que son, básicamente, lugares de almacenamiento fortificados donde tribus enteras o pequeños grupos de pobladores guardaban sus cosechas y objetos de valor para protegerlos de las condiciones naturales y del saqueo por parte de vecinos o enemigos. Estas instituciones, denominadas* agadir *o* ighrem*, según su ubicación, son lugares de memoria cargados de significado técnico, cultural y antropológico; constituían una especie de contrato social entre los integrantes de la sociedad y el centro del sistema socioeconómico y político de la región; su origen es desconocido. La falta de documentos escritos vuelve muy difícil la posibilidad de comprender la evolución histórica de estos edificios imponentes, que sorprenden por su arquitectura y organización; sin embargo, reflejan el espíritu independiente de los bereberes del Atlas hasta el protectorado francés de 1912. Los graneros colectivos, diseñados para adaptarse a la organización del grupo, a la rigurosidad del clima y a las necesidades de defensa de las tribus, cayeron en un completo desuso en las últimas décadas, fueron abandonados, mal mantenidos y, en algunos casos, propensos a adiciones inadecuadas; su restauración y rehabilitación es una necesidad urgente. Durante los últimos treinta años, el Centre de Restoration et de Réhabilitation du Patrimoine Architectural des Zones Atlasiques et Subatlasiques (CERKAS) se ha esforzado por incorporarlos al proceso de valorización junto con todas las demás estructuras del patrimonio de tierra. Se ha elaborado un inventario amplio de alrededor de 560 sitios, que ayudó en la preparación de los estudios y los trabajos de restauración y protección, y que se utilizará durante tres años para la elaboración del expediente de la candidatura de los graneros de Marruecos a la Lista del Patrimonio de la Humanidad de la UNESCO. En este artículo, me enfoco en la riqueza y la diversidad de este increíble patrimonio y en su futuro.*

Keywords: collective granaries, earthen architectural heritage, conservation, cultural development opportunities

Introduction

Collective granaries are socioeconomic institutions linked to the sociocultural history of the populations of the regions where they were erected. They are monument-warehouses fortified and built by tribes, factions, lineages, and families to meet economic, political, social, and, above all, climatic needs.

Granaries are found over a large geographical area ranging from Tripoli to the Atlantic under different names: *qsar* or *temldelt* in Jbel Nafusa, *ghurfa* in southern Tunisia, *gela* or *kalaa* in Aurès, Algeria, *agadir* in Souss and the western High Atlas, and *ighrem* in the southern High Atlas. They have also been reported in other western parts of the Mediterranean basin, especially in Spain and Italy.

In Morocco, the collective granaries of the central and western Anti-Atlas, the western High Atlas, and part of the Sirwa massif, the domain of the Tachilhiyt dialect, are known by the word *agadir* (pl. *igidar*), an Amazigh term with Semitic roots that was introduced to North Africa by the Phoenicians (del Perugia 1978–79) and designates the wall, the fortified village, and the fortress. The term *ighrem* is used to refer to the same institutions in the regions of Sirwa, the valleys of Imini, Ounila, in the central and eastern High Atlas, extending to the Middle Atlas. This heritage is also known as the fortified community villages of the pre-Saharan valleys of Dra, Mgoun, Toudgha, Farkala, and Ghris. We also encounter these institutions in the Rif region under the name *ajdir*.

A Still-Mysterious History

The peculiarity of these granaries, of unknown origin and incomplete history, has aroused the interest of several travelers, historians, and researchers since the nineteenth century such as Ch. De Foucault, R. Montagne, Dj. Jacques-Meunié, P. Dupas, H. Terrasse, A. Adam, and E. Laoust. Other ethnoarchaeological and scientific research has followed within the framework of cooperation programs led by the Centre for the Restoration and Rehabilitation of the Architectural Heritage of Atlas and Sub-Atlas Zones (CERKAS) and by the studies of many Moroccan authors such as M. Soussi, M. El Outhmani, S. Naji, Kh. Elaayoud, M. Aït Hamza, and myself.

Moreover, the appearance of collective granaries that were objects of study for many researchers remain a question to be clarified. The lack of sources and historical documents mainly from the *llouh* (customary rules for granaries) do not allow us to precisely know the origins of these buildings.

Regarding the history of these institutions, most researchers unanimously agree that the oldest document found is the customary law of the *agadir* Ajarif of Idouska Oufla (Confederation of Ilaln), which dates back to 1498 CE. This is the oldest *azerf* (pl. *izerfan*) (customary law), relating to collective storage from which all other charters were copied.

The granaries functioned according to an *azerf* or *llouh* that was transcribed in Arabic letters on paper or wooden boards by a literate and respected person. This law is witness to an elaborate legal, political, social, and architectural system, as well as a storage and conservation technique. The interior vestibules gave access to numerous stores intended for the deposit of family archives (marriage and inheritance certificates, property titles), jewelry, various tools, and all foodstuffs.

Despite the lack of knowledge of the origin and history of these granaries, a striking fact is that these warehouses reflect the genius and know-how of the inhabitants who erected them. Their architectural form and construction materials differ from region to region depending on social organization and lifestyle, as well as climatic, economic, and topographical conditions. These structures can be further categorized as cave-granaries, cliff-granaries, hilltop-granaries, plain-granaries, village-granaries, and so forth. They also feature unique design patterns depending on the materials used and construction techniques employed. They exist in circular forms, like that of Sidi Moussa among the Aït Bougmez, rectangular with corridors in the western Anti-Atlas, or square in the central Anti-Atlas. They can also be distinguished according to their function. If most of the granaries have a storage role, those of Sidi Moussa are warehouses and sanctuaries at the same time.

A Rational and Perfect Organization

The structural organization of the *igidar* space differs according to region, topography, climate, construction techniques, and materials (wood, stone, and rammed earth). They come in different types: laid out in caves and in *tihouna* huts in the cliffs, built on hilltops or on the plains, or built in villages. These strategically located citadel buildings can be circular, rectangular, or square. The surrounding walls and the rational plans of these places and their components (cisterns, mosques, workshops, beehives, lodges), including the concern for organization, reflect the strength and prosperity of their former occupants, who shared similar cultural traditions and ways of life. Functioning as checkpoints between the Atlas Mountains and the desert, they are places of passage where history and legend have mingled and have remained anchored in the popular memory.

These institutions with political and socioeconomic roles were endowed with a management council, made up of *Inflass n'Ugadir*, which appointed a *lamine n'Ugadir* (trusted man) who was responsible for the upkeep and control of the premises in exchange for an annual remuneration. Additionally, the *igidar* are sacred institutions endowed with symbolic protection around a saint and near a mosque, where the modes of management and conservation were associated with prophylactic practices and formulas begging for a good omen.

Diverse Typologies

Collective granaries in Morocco are architectural components with their own organization that reflect ancestral know-how and a particular way of life. Of different types, the *igidar* have undergone a specific evolution according to the political and socioeconomic context of each region and human group.

Architecturally, granaries differ in terms of spatial organization according to region, topography, climate, and construction materials used. They can be circular, rectangular, or square and are naturally fortified and erected in strategic places. They are protected by insurmountable artificial obstacles built of stone or surrounded by fences of thorns or cactus rackets.

Cave Granaries

Cave granaries represent the oldest and most widespread form in the valleys of Awnil and Imini (province of Ouarzazate), in *ighrem* Assaka on the northern slope of the High Atlas, and in the region of Tata. These granaries fall into the category of troglodyte heritage.

They are hollowed out horizontally and accessible only by ladders or ropes. The main access to the individual storage units is by a rectilinear corridor that connects cells of ovoid plan and of variable size, some of which are separated by mud bricks. A vertical chimney serves to simultaneously illuminate the galleries and communicate with the upper levels. The passage from one cave to another was traversed by means of interlaced branch balconies or woven reeds. These granaries, fabricated with great finesse, were once an important element in the life of transhumant social groups as places of safety (a primordial fact) and storage (for provisions) (fig. 1).

Cliff Granaries

Cliff granaries are built on steep cliffs that are almost inaccessible. Their construction, which includes huts under shelters, huts under rocks, and suspended huts, reflects the genius of the builders. These granaries are concentrated in the central High Atlas region. Among the most impressive are the two



FIGURE 1 The granary caves of Assaka, province of Ouarzazate. All photos courtesy of the author.



FIGURE 2 The cliff granary of Awjgal, province of Beni Mellal.

ledges of *tihouna* n'Uwjgal, the huts superimposed on several levels of *ighrem* n'Ushtin and *ighrem* n'Zerkan (Aït Abdi, Aït Chokhmane, provinces of Beni Mellal, Azilal, and Midelt). Others are dispersed in the region between Taliouine and Sirwa, such as *agadir* Tizgui n'Ayt Ubial and Ifri n'Imadiden, and toward the south (fig. 2).

Tihounan 'Uwjgal (110 km from Beni Mellal) represents the best example of this category. The granaries are built on a 400 m high axis of the Attache wadi. They are accessed by a staircase in a hole inside the cliff that provides access to a 700 m long stone ledge. The huts, well ventilated by openings that guarantee the longevity of the foodstuffs, are distributed over narrow natural cornices that separate the cliff into floors. Along the axis are tangles of planks embedded in posts with small stone bridges and wooden walkways. Rough stone walls enclose the doors in the cliff.



FIGURE 3 Tadakoust granary in the province of Tata (example of a hilltop granary).

Hilltop Granaries

Frequently encountered in the Anti-Atlas and the western and central High Atlas, hilltop granaries are buildings that hug the tops of hills or barred spurs, thus overlooking a ravine or a valley (fig. 3). They are difficult to access due to the steep topography. These constructions, in addition to their initial use as depositories for foodstuffs, valuables, documents, and weapons, also serve as places of surveillance, refuge, and withdrawal during times of siege and crisis. According to the interpretation of certain researchers in archaeology and history, the hilltop granaries correspond to an evolutionary phase of collective granaries linked to improvements that resulted from the shift from transhumant to sedentary lifestyles. This type of granary invariably has an enclosure, water cistern, beehives, cells, and watchtowers.

Agadir n'Uguellouy and that of Id Aïssa in the Amtoudi valley (province of Guelmim in the Aït Herbil) are two representative examples of the hilltop-granary type (fig. 4). They are



FIGURE 4 Id Aïssa granary in the Amtoudi valley.

characterized by an impressive architecture testifying to the ability of the inhabitants of the oasis in the exploitation of stone, which constitutes the ground and foundations of these structures, as well as their walls whose blocks are bound by a clay mortar. The upper frame is made of palm tree stems or laurel branches covered with a layer of earth mixed with gravel. These technical choices make the buildings less visible from a distance, as they blend into the landscape. Surrounded by an enclosure, the two granaries have a complex network of alleys serving the huts and a space reserved for prayer in addition to other common outbuildings. The cisterns, for their part, are supplied by rainwater that is drained by well-structured pipes. The granary of Sidi Moussa of Aït Bouguemez, located on a promontory of more than 2000 m in altitude, is built of adobe and bounded by a circular enclosure divided into two and reinforced by four towers. It houses the tomb of the eponymous saint, where women come to seek fertility through votive practices.

Plain Granaries

Located in the Anti-Atlas, plain granaries are, for the most part, corridor buildings that are quadrilateral in shape and consolidated by four towers. They contain storage cells and various components similar to those of the hilltop granaries. The locations of the plain granaries allow residents to make significant extensions. Representative examples of this type include *agadir* Imchguiguiln and *agadir* Ikounka (Chtouka-Aït Baha). They are, in most cases, surrounded by a lower stone enclosure, which in turn is surrounded by *azgur* (prickly pears or thorns). All the granaries follow the same spatial organization and are designed in such a way that each element fulfills a specific function. Built of earth or stone, they generally appear as tall buildings of three or four levels with towers at the corners. Two wide doors allow access to the granary—the one on the outside is wider than the one on the inside, probably to facilitate the passage of cattle. The large portal, often of austere appearance, gives access to the vestibule, which is an alley bordered by two stone benches and is used as a place for rest and waiting. Wooden sticks are fixed in the walls to hang weapons before entering the heart of the *agadir*. This is a *horm*, a sacred space that must not be defiled.

Near the main gate, a round-shaped mortar carved out of hard stone and nicknamed *barud* is placed inside the citadel. It is intended to accommodate gunpowder and symbolizes the strength and power of the community. The space also includes outbuildings, including one for the caretaker and the other for the granary.

The second door provides access to an open-air corridor where huts for each family are distributed over several levels. Their spatial arrangements express the social rank and importance of each family within the tribe. While the exterior doors are modest in appearance, those in the huts are all personalized. They are decorated with finesse and reflect the beliefs of the owners in a very assertive way.

To access the huts on the upper levels, the owners climb using the large overhanging slabs that are embedded in the walls and serve as steps. Another system consists of tree trunk ladders. The huts are ventilated by small openings integrated into the stone walls. The walls are coated with an impermeable plaster obtained by mixing earth and argan bark, and the roofs are executed in a traditional way (fig. 5).



FIGURE 5 Inside the granary of *agadir ighir ifran*, province of Chtouka-Aït Baha.



FIGURE 6 Village granary of the wawnzout, province of Taroudante.

Village Granaries

These *igidar* or *igherman* belong to the most recent category of collective granaries. Small in size, they are built in the middle of villages, surrounded by dwellings and public spaces, and provide daily grain needs such as at *ighrem* Aït Aballah and *ighrem* nʾTazleft. We note the existence of family granaries—collective stores used by a small number of families living in an isolated place who have erected these buildings to meet security needs. They were used for the storage of food, commodities, and valuable goods. Each family had one or more huts depending on their numbers and needs. The latter type was developed in the central High Atlas among the Aït Bouguemez, the Aït Mhammed, and in the valley of Anergui (fig. 6).

Effective but Limited Interventions

Components of Moroccan cultural heritage, collective granaries are of significant importance in the development of humans and the technical, sociocultural, economic, and natural aspects of their communities. These institutions, neglected for a long time despite their exceptional values, have been the subject of restoration and enhancement interventions with a view to classification, rehabilitation, and enhancement. Overall, we can say that the policy of revalorizing the architectural heritage of the south has created awareness of its multiple structural values.

The restoration and rehabilitation of a large number of collective granaries in different regions of Morocco (*ighrem* nʾFakhor, *ighrem* nʾSidi Moussa, *ighrem* nʾTazleft, *ighrem* nʾOugdal, *ighrem* Ibaqlioun, *tihouna* nʾOuwjgal, *agadir* nʾTkatert nʾIzli, *agadir* Ikounka, *agadir* Ouidouran, *agadir* nʾTkida, *agadir* Doudad, *ighrem* Aït Tigga, *ighrem* Aït Nabdas, etc.) have sparked renewed interest from local associations as well as regional and national institutions.

Indeed, CERKAS has been striving to integrate them into a process of enhancing the vernacular architectures of Morocco for thirty years. These architectural styles present an exceptional heritage. Synonymous with a distant culture and tradition, these monuments continue to feed on their own life and remain the most representative symbol of Amazigh architecture. Interventions up to now have not been reduced to purely technical consecrations and provisional actions, but they are part of a vision and a global concept of integration aimed first and foremost at the enhancement of this architectural heritage. This integration, the principles of which are inspired by human and ecological data, essentially aims to safeguard the cultural and artistic wealth and diversity of the region, the main objectives of which are the strengthening and continuity of the cultural identity of the inhabitants and improvement of their living conditions by creating activities around the vernacular architectural heritage.

In general, we are currently witnessing an awareness of the importance of the conservation of these buildings assumed by the inhabitants of these regions. This is undoubtedly one of the great achievements of undertaking a safeguarding and rehabilitation policy within an integrated vision of economic and cultural development.

In addition to restoration and rehabilitation work, systematic inventories have made it possible to make a large number of sites available for research. In this regard, we note the work of inventories of collective granaries in the provinces of Chtouka-Aït Baha, Sidi Ifni, Guelmim, Tata, Azilal, and Ouarzazate. Between 2000 and 2005, CERKAS carried out a large-scale ethnoarchaeological project on the granaries of the Ounila valley in collaboration with Wallonia-Brussels. All these actions will help to strengthen the preparation of the file for registration of Morocco's granaries on UNESCO's World Heritage List. A steering committee has already been set up by the Ministry of Culture.

Another method for presenting this exceptional heritage to humanity represents one of the oldest and best examples of scarcity construction and management institutions, as well as the most accomplished example of traditional rural architecture: Amazigh. These granaries perfectly illustrate the architectural forms, the organizational structures, the use of space, and the modes of social, legal, and economic management.

Conclusion

These beautiful sites, gradually destroyed or abandoned, are threatened with disappearance because of economic and cultural changes. Indeed, considering the threats that weaken this heritage, we have to prepare an effective and successful preservation intervention and rehabilitation plan. This plan should adapt to the needs of rural societies through the various current uses.

To tackle these challenges, a strong partnership between the state, NGOs, and associations is essential to investing in the rehabilitation of these *igidar*, but also for remedying the lack of awareness of the richness of this cultural heritage.

If collective granaries were previously social institutions of great importance in times of famine and conflict, they now represent a long-standing human heritage that deserves full attention for cultural, social, civilizational, and economic reasons. According to CERKAS, so many of these 560 inventoried monuments are neglected because they lost their role due to various factors. Nevertheless, there is a great awareness on the part of associations and residents of the importance of these constructions in creating a certain economic dynamism. Moreover, restoration interventions, even if they are still limited, have created an air of confidence in the future of Morocco's granaries. A major project is being set up to nominate these granaries for the UNESCO World Heritage List. These historic establishments have spanned centuries and their World Heritage inscription would be a deserved international recognition. All actions and measures aimed at safeguarding heritage are doomed to failure if they are not part of a local and regional development vision. These granaries should be accessible to current and future generations by respecting their cultural significance (figs. 7, 8).



FIGURE 7 *Agadir* n'Tkida in 2015, after restoration.



FIGURE 8 *Agadir* n'Tkida in 2010, before restoration.

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Las campañas de mantenimiento del patrimonio vernáculo en tierra: El caso del barrio San Francisco de Oña, Ecuador

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Resumen: *El barrio San Francisco de Oña es uno de los asentamientos coloniales más antiguos de la provincia del Azuay, en el sur de Ecuador; allí se emplazan cincuenta y cinco edificaciones con valor patrimonial, la mayoría de ellas construidas con adobe. Además de las construcciones, su paisaje constituye un importante potencial cultural y de desarrollo. Mediante una investigación llevada a cabo por el noveno curso de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca (Arce et al. 2019), se determinó que el 19 % de las edificaciones patrimoniales se encuentra en avanzado estado de deterioro. Este artículo expone una iniciativa para su conservación a través del modelo de las Campañas de Mantenimiento, que son procesos innovadores desarrollados por la Universidad de Cuenca, a partir del reconocimiento de valores y de la participación de diferentes actores involucrados mediante el trabajo colaborativo, denominado "minga" en el mundo andino. Las campañas se apoyan en la aplicación de la metodología del ICOMOS 2003 y en procesos participativos que hacen posible activar diversos espacios de interacción y aprendizaje mutuo para detonar la conservación a largo plazo. Todo ello permite asumir este especial escenario de la arquitectura rural andina ecuatoriana como un nuevo laboratorio de trabajo de múltiples beneficios: habitabilidad y calidad de vida para los propietarios, conocimiento y escenarios didácticos reales para la academia, experiencia de servicio profesional para los técnicos, y el inicio de un nuevo ciclo vital para la comunidad de un barrio ecuatoriano, que recupera parte de su legado histórico.*

Abstract: *The San Francisco de Oña neighborhood is one of the oldest colonial settlements in the province of Azuay, in southern Ecuador. Fifty-five buildings with heritage value are located there, most of which were built with adobe. In addition to these constructions, the neighborhood's landscape has important cultural and development potential. Through research carried out by the ninth course of the School of Architecture and Urban Planning at the Universidad de Cuenca, it was determined that 19% of the heritage buildings are in an advanced state of deterioration. This article sets forth an initiative for their conservation through the model of maintenance campaigns, which are innovative processes developed by the Universidad de Cuenca based on the recognition of values and the participation of different actors involved through collaborative work, called* minga, *in the Andean world. The campaigns are based on the application of the ICOMOS 2003 methodology and on participatory processes that enable different spaces for interaction and mutual learning to be activated to promote long-term conservation. All of this makes it possible to embrace this special scenario of Ecuadorian Andean rural architecture as a new work laboratory with multiple benefits: habitability and quality of life for the owners, knowledge and real educational scenarios for academia, professional experience for technicians, and the beginning of a new life cycle for the community of an Ecuadorian neighborhood recovering part of its historical legacy.*

Palabras clave: campañas de mantenimiento, arquitectura patrimonial vernácula rural, Oña

Introducción

San Francisco, ubicado en el cantón San Felipe de Oña, es el barrio original del asentamiento, configurado por un conjunto de edificaciones de arquitectura vernácula de adobe, dispuestas a lo largo de una acequia y un antiguo *chaquiñán* (camino de herradura) (fig. 1). El paisaje natural, los canales de riego, sembríos, caminos prehispánicos y un fuerte sentimiento de apropiación de los vecinos que lo habitan, aportan al valor del sitio. En el año 2013, el centro del cantón San Felipe de Oña y el barrio San Francisco fueron declarados Patrimonio Cultural del Estado por el Instituto Nacional de Patrimonio Cultural (INPC), realizando entonces el inventario de 16 edificaciones de las 55 que conforman el barrio. Sin embargo, pese a no haber sufrido grandes procesos de transformación arquitectónica, este antiguo asentamiento humano está eclipsado por el deterioro y abandono. De ahí que, con el objetivo de conservar la arquitectura patrimonial del barrio fomentando su valoración y la participación de diferentes actores, el Grupo Ciudad Patrimonio Mundial (CPM) de la Universidad de Cuenca (UC) se ha planteado un proceso de investigación que sustente futuras intervenciones a través de las denominadas "Campañas de Mantenimiento." Estas campañas aplican modelos organizativos ancestrales y socialmente utilizados en la actualidad como la *minga*, una forma de trabajo comunitario propio de las culturas precoloniales, especialmente en la región andina, que se fundamenta en la suma de esfuerzos individuales concertados para realizar una actividad de beneficio común o familiar.

La primera Campaña de Mantenimiento basada en este modelo se realizó en Susudel en 2011: se ejecutó el mantenimiento de 49 pequeñas edificaciones campesinas en una semana. Para ratificar su eficacia en otros objetos arquitectónicos, en 2013, se realizó una segunda campaña en el cementerio de Susudel, la cual duró cinco días con apoyo de las comunas aledañas. A partir de estas primeras experiencias rurales, las Campañas de Mantenimiento se trasladaron a un entorno urbano: el centro histórico de Cuenca. De esta manera, en 2014, se realizó una tercera campaña en el barrio San Roque, actuando sobre veintidós edificaciones, más complejas y con nuevos desafíos propios del contexto urbano. Por último, en 2018 se realizó la campaña en la calle Las Herrerías del barrio El Vergel (fig. 2), con veintiuna edificaciones intervenidas. Al igual que en las campañas anteriores, en esta iniciativa se contó con el apoyo de la UC, las Fuerzas Armadas, el INPC y el Municipio de Cuenca. En los casos de las iniciativas urbanas, los habitantes de los barrios aportaron con pagos consensuados previamente para cofinanciar la mano de obra responsable del trabajo (Cardoso *et al.* 2019).

En el barrio San Francisco de Oña, en 2007 se comenzaron los estudios para la restauración de una de sus edificaciones, denominada la "Bella de París," para utilizarse como centro intercultural comunitario. Para tal efecto, se activó la cooperación institucional del Municipio de Bierbeek, Bélgica.



FIGURA 1 Fotografía aérea del barrio San Francisco. Fotografía: Fabián Miguel Benítez Crespo, 2021. Oña, Ecuador.



FIGURA 2 Proyecto Ciudad Patrimonio Mundial. Miembros de las Fuerzas Armadas y estudiantes de la Universidad de Cuenca en la Campaña de Mantenimiento en el barrio El Vergel. Fotografía: Fausto Adrián Cardoso Martínez, 2018.

Posteriormente, en 2008, la UC y el INPC comenzaron investigaciones que derivaron en el desarrollo del expediente técnico para la declaratoria de Oña como Patrimonio Cultural del Estado.

La arquitectura vernácula es una respuesta directa a los requerimientos del habitar. La íntima relación que existe entre la arquitectura vernácula, aplicando un modo de construir emanado de la propia comunidad en un estrecho entendimiento del contexto inmediato, y las características de un sitio en diferentes momentos de la historia, es lo que la convierte en una parte esencial de la identidad de una comunidad (ICOMOS 1999). Ésta es una razón fundamental para que las edificaciones patrimoniales deban ser protegidas por sus sociedades, con el fin de que puedan ser apreciadas, estudiadas y disfrutadas por las generaciones futuras.

Por tanto, este artículo muestra el proceso que se desarrolló aplicando los principios de la conservación preventiva y activando un proceso participativo que aspira concluir con un proyecto de intervención en la arquitectura patrimonial de Oña. Los objetivos planteados son:

- Desarrollar una investigación documental y de campo con enfoque participativo para conocer y poner en evidencia –principalmente ante la comunidad de Oña– la historia, el contexto actual y los valores culturales del barrio San Francisco y las edificaciones a intervenir.
- Elaborar propuestas de intervención para las edificaciones patrimoniales en el barrio San Francisco, considerando la opinión de los propietarios, en un proceso de diseño participativo que incentive su implicación más adelante en una Campaña de Mantenimiento.



FIGURA 3 Proyecto Ciudad Patrimonio Mundial. Calle Sucre del barrio San Francisco en 1988. Fotografía: Fausto Adrián Cardoso Martínez, 1988. Oña, Ecuador

El barrio San Francisco de Oña

El barrio San Francisco es el asentamiento colonial de más remoto origen del sur del Ecuador (Ministerio de Cultura y Patrimonio 2013). Aquí se concentraban las actividades administrativas, comerciales y sociales (Alvarado y Vallejo 2007). Desde la colonia, se sabe que era un sitio de paso y descanso obligado, pues a lo largo de la calle Sucre, antiguo camino de herradura, transitaban quienes se desplazaban entre las ciudades de Cuenca y Loja (fig. 3). Esto explica la existencia del portal, de uso común en la mayoría de sus construcciones; es un espacio de transición entre lo privado y lo social, abierto hacia la calle. En la década de 1970, fuera de los límites del barrio, se construyó la nueva carretera panamericana y se inició la consolidación de la nueva plaza central con fondos donados por un vecino del poblado. Ambos procesos provocaron el progresivo desplazamiento y abandono del barrio. A este fenómeno interno se sumó la constante migración de los habitantes de Oña hacia la provincia de El Oro (Ullauri 2011), por lo que sus edificaciones se fueron descuidando y abandonando, lo que derivó en su degradación.

Metodología

Con base en experiencias previas ejecutadas en la región por el Grupo CPM, la metodología utilizada se basa en la articulación de los principios de la conservación preventiva (análisis,

diagnóstico, terapia y control) propuestos por el Consejo Internacional de Monumentos y Sitios (ICOMOS 2003) y las metodologías de investigación participativa propuestas por la Red CIMAS (2015).

Las metodologías participativas buscan facilitar y promover procesos de transformación social mediante iniciativas que fomenten la implicación de diversos actores: habitantes del barrio, miembros de la academia, técnicos, funcionarios de las instituciones públicas, entre otros. De esta manera, se fomentan procesos de creatividad vinculados con el interés social, a fin de considerar e incluir la opinión de todos los participantes para adoptar decisiones consensuadas en el grado más alto posible. Cada fase se complementa con un proceso de investigación documental que resulta esencial para validar y retroalimentar esta información con la comunidad y demás actores, mediante actividades participativas, obteniendo un resultado final compartido entre los actores.

Resultados y discusión

Fase I. Análisis

En esta etapa se recoge información utilizada para la determinación de los valores patrimoniales. Estudiantes y docentes del noveno curso de la Facultad de Arquitectura de la UC, Opción Conservación del Patrimonio, antes y durante el confinamiento debido al covid-19, combinaron trabajo documental y de campo para luego, en conjunto con la comunidad y demás actores, validar e interpretar la información recabada. Entre los diversos análisis, fue importante la selección de las edificaciones a intervenir, sobre la base de cuatro criterios: valoración patrimonial, estado de conservación, disponibilidad y capacidad económica del propietario.

Para recabar esta información, el proyecto CPM ha desarrollado categorías de análisis secuenciales mediante fichas de campo. Primero se realizó el análisis de preregistro, mediante un recorrido entre actores, para un primer reconocimiento visual de todas las edificaciones del barrio, a fin de entender al conjunto como un bien cultural; luego se aplicó el análisis de registro, en cuyas fichas se recogen los valores, patologías, predisposición del dueño, entre otros datos; por último, se aplicó la ficha socioeconómica a los propietarios. En la figura 4, se puede observar el puntaje obtenido por las edificaciones según los criterios mencionados. Adicionalmente, mediante el análisis de las fichas aplicadas, se pudo determinar que el 19 % de las edificaciones del barrio se encuentran en mal estado de conservación y que el 51 % tiene un valor patrimonial alto. Con esta información, se realizó la selección de las viviendas y se llevó a cabo su levantamiento arquitectónico y fotográfico.



FIGURA 4 Prioridad de intervención según criterios de selección de edificaciones para la Campaña de Mantenimiento del barrio San Francisco de Oña. Dibujo: John Guachichulca, 2021. Cuenca, Ecuador.

Fase II. Diagnóstico

En un ejercicio de integración de los distintos análisis realizados, se determinó el estado actual, la historia y los valores tanto del barrio como de las edificaciones. Se empleó una matriz FODA (cuadro 1) para el entendimiento de los valores paisajísticos del asentamiento y de las relaciones sociales identificadas. Además, se aplicó la Matriz de Nara para realizar una síntesis de los valores del barrio (fig. 5).

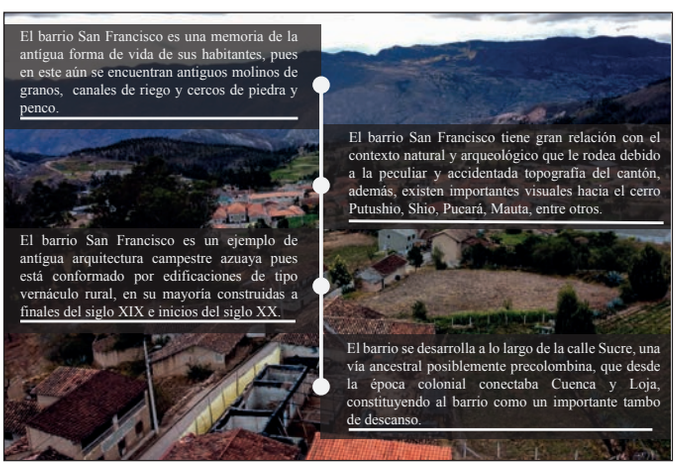


FIGURA 5 Síntesis de valoración del barrio San Francisco de Oña. Dibujo: John Guachichulca, 2021. Cuenca, Ecuador.

Cuadro 1 FODA del barrio San Francisco.

Fortalezas	**Debilidades**
Ubicación privilegiada.	Alto grado de abandono de las viviendas del barrio.
Visuales de todo el Valle de Oña.	Escasas oportunidades de trabajo y educación.
Tiene gran cantidad de bienes catalogados como Patrimonio Nacional.	Gran porcentaje de migración por parte de los habitantes del barrio.
Alta cohesión social del barrio.	La intervención de adoquinado del barrio impide la accesibilidad y conexiones con las edificaciones.
Gran cantidad de terrenos baldíos sin uso específico.	Ausencia de población joven en el barrio.
Se continúa celebrando la fiesta de carnaval en la calle con afluencia de personas locales y foráneas.	Escaso espacio público.
Estado bueno de conservación en la mayoría de las edificaciones.	En gran parte del barrio, el agua vertiente de la zona superior fue canalizada.
	Falta de ordenanza y control municipal en la protección del patrimonio.
Oportunidades	**Amenazas**
Prevalencia de la memoria histórica del barrio en varios habitantes.	Mudanza de personas cerca del centro de Oña debido a la concentración de comercio y equipamientos.
Potencial turístico arquitectónico (edificaciones patrimoniales).	La atención prestada a la importancia del barrio San Francisco por parte de las autoridades gubernamentales es reciente.
Potencial turístico natural (cascadas, lagunas, bosques) en zonas cercanas.	La población que migra no regresa al barrio o lo hace de manera periódica.
La parte alta del barrio no ha sido fuertemente intervenida, permitiendo un adecuado plan de intervención.	
Se pueden utilizar los terrenos baldíos para usos complementarios.	
Varias viviendas poseen relación con la calle a través de espacios semipúblicos (portales).	
Disponibilidad de materiales en la zona para la intervención.	

Fuente: Adaptado de Arce *et al.* 2019.

Fase III. Terapia

Para esta fase, se consideró la ejecución de la Campaña de Mantenimiento en dieciséis edificaciones con las propuestas de intervención desarrolladas en la primera etapa y con la participación activa de todos los actores involucrados. Es un trabajo conjunto en el que se han interesado instituciones como el GAD Municipal del Cantón San Felipe de Oña (GAD Oña), el Instituto Nacional de Patrimonio Cultural (INPC) y la Prefectura del Azuay, entre otros (fig. 6).

A pesar de gestiones con el Municipio de Oña, el INPC y otros actores, las restricciones provocadas por la pandemia del covid-19 obligaron a reconsiderar la iniciativa, pues incluso el desplazamiento al sitio implicaba un enorme esfuerzo y riesgo. Además, el colapso económico provocó la necesidad de priorizar las inversiones de los gobiernos locales para hacer frente a los problemas de salud pública. Sumando esfuerzos y adaptándose a las nuevas circunstancias, a través de una *minga* multiactores se intervino en la casa "Lara-Espinoza." Esta centenaria edificación se encontraba en mal estado y, gracias a la disposición del propietario, el Municipio, el INPC y la UC, se pudo recuperar. De esta manera, se cumplió con las expectativas al contar con un laboratorio vivo de experimentación en beneficio de la educación y la comunidad con mutuos aprendizajes (fig. 7).

Conclusiones

Las nuevas condiciones generadas por la pandemia afectaron directamente las gestiones realizadas, dificultando la ejecución de los proyectos de mantenimiento planteados. Sin embargo, al término de este artículo, se logró impulsar una pequeña red de cooperación (*minga* multiactores) con el impulso de su propietario y el grupo de estudiantes de la UC, lo que generó las condiciones para realizar la Campaña de Mantenimiento, que se nutrió del proceso desarrollado en los dos años anteriores.

Al inicio de la campaña, varios vecinos se interesaron en el proceso desarrollado y pidieron colaboración para efectuar acciones similares en sus viviendas, lo que permitió evidenciar que basta emprender un impulso inicial para que se detonen procesos similares. Esto ayudó a fomentar la

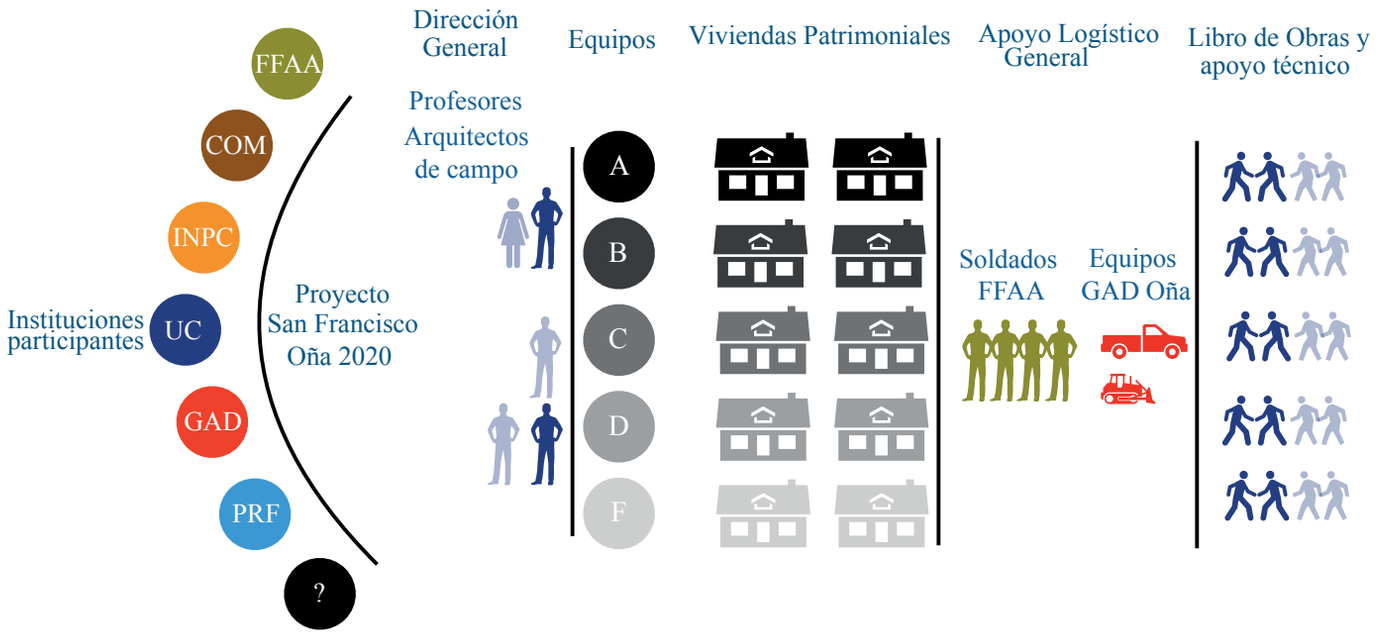


FIGURA 6 Proyecto Ciudad Patrimonio Mundial. Diagrama de actores implicados en la Campaña de Mantenimiento. Dibujo: Fausto Adrián Cardoso Martínez, 2020.



FIGURA 7 Proyecto Ciudad Patrimonio Mundial. Miembros del GAD Oña y estudiantes de la UC en la Campaña de Mantenimiento de la vivienda "Lara-Espinoza," Oña, Ecuador. Fotografía: Fausto Adrián Cardoso Martínez, 2021.

valoración del barrio y su reactivación con algunas iniciativas autónomas en marcha. Por lo menos cinco casas fueron sucesivamente intervenidas, y los emprendimientos de servicios de salud y alimentación poco a poco han dinamizado las relaciones humanas e inyectado vitalidad al barrio de San Francisco de Oña.

Consecuentemente, a partir de esta primera intervención, el reto es incidir no solo en la mejora física de los edificios patrimoniales, sino también en la activación de redes de cooperación multiactores en torno al patrimonio. Por último, es necesaria la incorporación de metodologías que favorezcan la formación de grupos de iniciativas en los territorios, que trasciendan el ámbito académico, así como activar estructuras territoriales horizontales, proactivas y participativas para la protección y mantenimiento del patrimonio cultural, tendientes a articular de manera sostenible estrategias de bienestar local.

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Construyendo el cuidado a largo plazo: Plan de monitoreo multidisciplinario para el templo de Kuñotambo, Perú

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Resumen: *La obra de conservación y estabilización sismorresistente del templo en adobe de Santiago Apóstol de Kuñotambo, en la región de Cusco, fue llevada a cabo por la Dirección Desconcentrada de Cultura de Cusco (DDC–C) como proyecto de colaboración con el Getty Conservation Institute (GCI) de 2016 a 2019. Actualmente, el GCI está colaborando con socios peruanos y partes interesadas en el desarrollo de un plan de monitoreo multidisciplinario para el templo. El plan es la herramienta necesaria para la preservación a largo plazo del edificio y la gestión de sus riesgos; la verificación de los resultados de las intervenciones con atención a la estabilización sismorresistente y la conservación de las pinturas murales; así como el monitoreo del comportamiento del edificio y los cambios después de eventos naturales importantes. Además, el plan servirá como modelo de cuidado participativo para intervenciones similares de la DDC–C. El plan incluye tres protocolos adaptados a diferentes grupos, considerando su experiencia, equipo y disponibilidad de tiempo: (1) instrucciones básicas para la comunidad local; (2) protocolo rápido de baja tecnología para el equipo técnico del Arzobispado; y (3) protocolo completo para ingenieros, arquitectos y profesionales de la conservación, con apoyo del GCI y la DDC–C. Esta ponencia explicará cómo las partes interesadas están colaborando para definir la estrategia del plan, diseñar e implementar los protocolos. El plan define medidas apropiadas para la preservación y gestión de riesgos para una arquitectura de tierra patrimonial en zona sísmica, a través de diferentes niveles de monitoreo. La atribución clara de roles y responsabilidades para las partes interesadas asegura la sostenibilidad del plan a largo plazo.*

Abstract: *Retrofitting and conservation works at the adobe church of Santiago Apóstol of Kuñotambo, in Peru's Cusco region, were carried out by the Ministry of Culture of Peru in Cusco (DDC-C) as a collaborative project with the Getty Conservation Institute (GCI) from 2016 to 2019. The GCI is currently working with Peruvian partners and site stakeholders to develop a multidisciplinary monitoring plan for the church. The plan is a much-needed tool to extend the life of the building and manage its risks, to verify the results of the interventions with attention to the seismic retrofitting and conservation of its mural paintings, and to monitor the behavior of the building and changes after major natural events. Moreover, it will serve as a model for the DDC-C to ensure participative care of similar buildings they preserve. The monitoring plan includes three inspection protocols tailored to different groups that consider their expertise, equipment, and time availability: (1) basic monitoring instructions for the local community, (2) low-tech expedited monitoring protocol for the archbishopric technical team, and (3) a comprehensive protocol to be carried out by engineers, architects, and conservation professionals with the support of the GCI and DDC-C. This paper explains how the stakeholders are collaborating to define the plan, the strategy, and design and implement the monitoring protocols. The plan defines appropriate preservation measures and risk management for a heritage earthen building in an*

earthquake-prone zone, through different monitoring levels. The clear attribution of roles and responsibilities for all stakeholders ensures the plan's long-term sustainability.

Palabras clave: monitoreo, arquitectura de tierra, conservación programada, protocolo de inspección, monitoreo de salud estructural, pinturas murales, mantenimiento, Perú

Introducción

Esta ponencia presenta el plan de monitoreo multidisciplinario para el templo de adobe de Santiago Apóstol de Kuñotambo, en la región de Cusco, diseñado de forma colaborativa a partir de las características del sitio y los requerimientos de las partes interesadas. El plan tiene múltiples objetivos, como garantizar la conservación del monumento a largo plazo, verificar los resultados de las intervenciones y establecer un modelo participativo de mantenimiento para obras similares en la región. No solo define buenas prácticas difundidas a través de actividades de capacitación, sino también plantea un sistema de diferentes protocolos de inspección y recolección de datos que, aunque diseñados para funcionar de manera integrada para el caso de Kuñotambo, pueden ser aplicados de forma independiente a otros sitios patrimoniales, según sus peculiaridades y los recursos disponibles.

La importancia del cuidado regular de los sitios históricos es reconocida en la mayoría de las cartas internacionales (ICOMOS 1931; ICOMOS 1964; Australia ICOMOS 2013), aunque el enfoque de la conservación preventiva sobre todo en relación con el patrimonio arquitectónico, es un tema que ha tomado importancia en las últimas decadas (KU Leuven s. f.; CORDIS Europa s. f.; Čebron Lipovec y Van Balen 2008a; Cardoso y Rodas 2013; Van Balen y Vandesande 2013; Della Torre y Borgarino 2014; Van Balen y Vandesande 2018; Vandesande et al. 2020). Esto corresponde a un cambio de perspectiva de la restauración como "evento" dirigido por expertos a la conservación como "proceso" cíclico por parte de los usuarios (Della Torre 2020).

La conservación preventiva y programada, que incluye sistemas de monitoreo y acciones de mantenimiento, ha demostrado ser extremadamente eficaz en gestionar estructuras y entornos históricos, con destacables ventajas desde el punto de vista económico, ambiental y con relación a políticas de empleo local (Vandesande et al. 2018).

El monitoreo implica la recopilación de datos cualitativos y cuantitativos, y la verificación periódica de cualquier signo de cambio que pueda afectar el sitio, su entorno y su significado cultural, con atención a los varios elementos que lo componen (ICOMOS 2003a; ICOMOS 2003b). Para ser sustentables, los procedimientos deben ser simples, pero contar con actividades de capacitación. Para ser eficaces, requieren un método estándar de recolección de datos, además de un formato estándar para su presentación, para que las informaciones recaudadas puedan facilitar la planificación de intervenciones (Walton 2003). El monitoreo representa entonces una herramienta de diagnóstico, imprescindible del proceso cíclico de conservación, que debe verse en relación con prácticas de educación y sensibilización (Van Balen 2015). De hecho, la protección de bienes culturales requiere la participación activa y responsable de todos los integrantes de la sociedad a la cual beneficia (ICOMOS 2014) y el concepto de conservación preventiva y programada está conectado al de participación comunitaria, en el que las tareas para gestionar los sitios patrimoniales están repartidas entre todas las partes interesadas, incluidas instituciones, propietarios y usuarios (Van Balen y Vandesande 2015; García et al. 2021). El compromiso activo de los diferentes miembros de la "comunidad patrimonial" (Council of Europe 2005) ayuda a la salvaguardia del espíritu del lugar (Čebron Lipovec y Van Balen 2008b) y, al mismo tiempo, asegura la sostenibilidad de las acciones de conservación a futuro.

El templo de Santiago Apóstol de Kuñotambo

El Getty Conservation Institute (GCI) está colaborando con socios peruanos y partes interesadas en el desarrollo e implementación de un plan de monitoreo multidisciplinario para el templo de Santiago Apóstol de Kuñotambo, construcción de adobe del siglo XVII ubicada en una pequeña comunidad de la provincia de Acomayo, en el departamento de Cusco y en la jurisdicción del Arzobispado del Cusco.

El templo de Kuñotambo es uno de los cuatro casos de estudio del Proyecto de Estabilización Sismorresistente (SRP, por sus siglas en inglés) del GCI que tiene como objetivo diseñar, probar e implementar técnicas de estabilización sismorresistente y programas de mantenimiento para edificios patrimoniales de tierra, utilizando capacidad local y materiales asequibles de tecnología simple (GCI s. f.). El templo fue seleccionado por ser representativo de las construcciones religiosas de los Andes erigidas durante el período del virreinato (Cancino y Lardinois 2012), exhibiendo gruesos muros de adobe, un techo con armaduras de madera de par y nudillo, y pinturas murales en su interior (figs. 1, 2).



FIGURA 1 Vista del templo de Kuñotambo y de la torre del campanario en el pueblo de Kuñotambo, después de la conclusión de las obras de conservación y estabilización sismorresistente. Fotografía: Elena Macchioni, ©2019 J. Paul Getty Trust.



FIGURA 2 Vista del interior del templo de Kuñotambo mirando hacia la fachada principal, donde se pueden ver las pinturas murales de la nave. Fotografía: Anna Flavin, ©2019 J. Paul Getty Trust.

La vulnerabilidad sísmica del templo y las recomendaciones para su estabilización fueron determinadas por los estudios de materiales y sistemas estructurales realizados por la Pontificia Universidad Católica del Perú (Torrealva *et al.* 2018), junto con pruebas *in situ* y modelos numéricos llevados a cabo por la Universidad del Minho (Lourenço y Pereira 2018; Lourenço *et al.* 2019), asesores del SRP.

La Oficina de Gestión de Proyectos de la Dirección Desconcentrada de Cultura de Cusco (DDC–C), oficina regional del Ministerio de Cultura del Perú, desarrolló las especificaciones técnicas, la propuesta arquitectónica y de conservación, mientras que el GCI y sus asesores diseñaron la propuesta estructural, así como la metodología para la estabilización de las pinturas murales *in situ*, evitando su desprendimiento durante la obra (Vernaza *et al.* 2018). La obra a cargo de la Oficina de Obras de la DDC–C empezó en septiembre de 2016. Informaciones detalladas sobre la implementación de técnicas de estabilización sismorresistente se pueden encontrar en Cancino *et al.* (2020).

La conclusión de la obra en junio de 2019 marcó el inicio de una nueva etapa, bajo la responsabilidad del Arzobispado de Cusco, propietario del edificio.

El plan de monitoreo para el templo de Kuñotambo

El plan de monitoreo diseñado para el templo es una herramienta esencial para la preservación del sitio, la mitigación de daños por riesgos como eventos naturales (terremotos, lluvias, vientos fuertes, etc.) y la detección de falta de mantenimiento. De igual manera, permite comprobar los resultados de las intervenciones, en este caso, de las técnicas implementadas para la estabilización sismorresistente y la consolidación de las pinturas murales. De hecho, los datos del monitoreo estructural pueden aportar información valiosa para evaluar las técnicas de estabilización diseñadas por el SRP y así perfeccionar las directrices finales del proyecto, concebidas para ser aplicadas en edificios patrimoniales de tierra de Latinoamérica. Finalmente, el plan garantiza la adquisición de datos sobre el comportamiento del edificio y cambios que puedan ocasionarse después de eventos naturales importantes, proporcionando informaciones para el equipo de investigación y permitiendo la detección temprana de daños.

Las partes interesadas identificadas para el desarrollo del plan son: la DDC–C, que necesita establecer un protocolo participativo para el cuidado a largo plazo de los edificios religiosos que conserva, y el pequeño equipo técnico del Arzobispado, encargado de gestionar un patrimonio numeroso y diseminado en un territorio bastante amplio. Además, es esencial la participación de la comunidad local; de hecho, en el caso de la conservación del patrimonio arquitectónico

de tierra, que a menudo puede contar con la permanencia de conocimientos y técnicas constructivas tradicionales, un sistema de cuidado continuo garantiza la transferencia de habilidades artesanales, a lado de sistemas de trabajo comunitario, como aquellos que existen en la región andina (Heras *et al*. 2019; Vázquez *et al*. 2018).

En diciembre de 2019, el SRP organizó reuniones entre las partes interesadas, el equipo del GCI y sus asesores. El templo fue analizado según los componentes principales que se abordaron durante su intervención: estructuras, arquitectura y pinturas murales. Posteriormente, fueron diseñados y discutidos entre las partes interesadas tres protocolos de análisis e inspección a corto, mediano y largo plazo, adaptados a los componentes establecidos. Estos protocolos fueron desarrollados considerando la capacidad local, disponibilidad de tiempo y equipo con el que se cuenta (cuadro 1). Igualmente, dado que el SRP tiene como uno de sus objetivos el verificar la validez de las técnicas de estabilización sismorresistente implementadas, el plan incluye la instalación de un sistema permanente de Monitoreo de Salud Estructural (MSE; Structural Health Monitoring, en inglés).

Documentación del sitio

Una actividad fundamental para el desarrollo del plan de monitoreo fue el llevar a cabo y proporcionar a las partes involucradas un levantamiento del sitio una vez terminada la obra. A finales de 2019, un equipo del Carleton Immersive Media Studio (CIMS), asesor del GCI, realizó una campaña de levantamiento del contexto, del templo y su campanario, así como de las pinturas murales.

El CIMS definió una red geodésica de puntos de control para combinar los diferentes conjuntos de datos generados a través del escaneo láser 3D y de la fotogrametría aérea y terrestre, y así poder referenciar toda documentación generada en el futuro. La red se compone de puntos de control fijos en piso no-histórico del exterior e interior del templo, junto con puntos de control naturales en las pinturas murales, por ejemplo, esquinas de marcos pintados (fig. 3).

Cuadro 1 Esquema del plan de monitoreo que describe las estrategias y los protocolos para los diversos actores involucrados. En la primera fase, las acciones serán llevadas a cabo con apoyo del GCI, incluidos talleres de capacitación.

Protocolo	¿Quién?	¿Cómo?	¿Cuándo?
Instrucciones básicas para la comunidad local.	Representantes de la comunidad capacitados.	Análisis visual.	Cada mes.
		Análisis visual con ficha de inspección simple y registro fotográfico.	Cada seis meses o después de eventos naturales.
Protocolo rápido de tecnología simple.	Equipo técnico del Arzobispado, con apoyo de la DDC–C (al menos dos arquitectos con experiencia en construcciones históricas y dos conservadores de pinturas murales).	Análisis visual con ficha de inspección detallada y registro fotográfico (incluida inspección de elementos estructurales y arquitectónicos, así como pinturas murales; áreas representativas de pinturas murales; sistema eléctrico, de alarma y de protección contra incendios).	Cada año o después de eventos naturales importantes.
Protocolo completo para especialistas.	Especialistas de la conservación del Arzobispado, con apoyo de la DDC-C y asesores externos (equipo multidisciplinario con arquitectos e ingenieros con experiencia en construcciones históricas, y conservadores de pinturas murales).	Sistema permanente de MSE.	Continuo, adquisición por al menos 2 años.
		Levantamiento de condiciones detallado de todos los elementos estructurales, arquitectónicos y pinturas murales, con mapeo de condiciones; inspección de sistema eléctrico, de alarma y de protección contra incendios; levantamiento digital, con fotogrametría; ensayos y análisis dinámicos.	Cada 5 años o después de eventos naturales importantes.
		Levantamiento de condiciones detallado de todos los elementos estructurales, arquitectónicos y pinturas murales, con mapeo de condiciones; inspección de sistema eléctrico, de alarma y de protección contra incendios; levantamiento digital completo, con fotogrametría y estación total/escaneo laser 3D; ensayos y análisis dinámicos.	Cada 10 años o después de eventos naturales extremos.

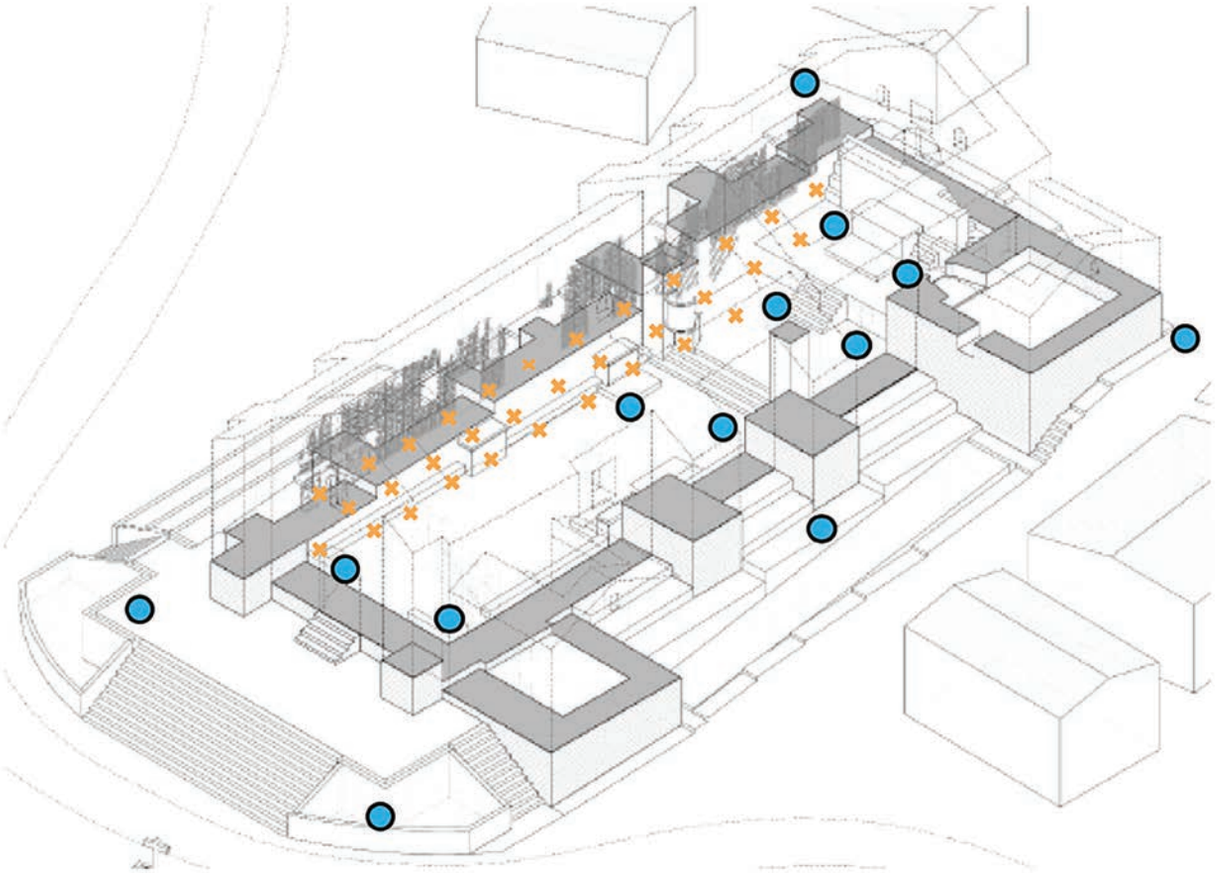


FIGURA 3 La red geodésica de puntos definida por CIMS: representación gráfica de la red en el templo, incluyendo puntos de control fijos en piso no-histórico de los alrededores del edificio y del interior de la nave (marcados con círculos en azul), además de puntos naturales en las pinturas murales (cruces en amarillo). Imagen: CIMS, ©2020 J. Paul Getty Trust.

Los planos producidos sirvieron para el primer levantamiento de condiciones en 2022, constituyendo la base para las actividades de monitoreo a futuro, y la nube de puntos podrá ser comparada con adquisiciones subsiguientes, para evaluar hasta las más pequeñas modificaciones en la geometría del sitio (fig. 4).

Adicionalmente, el CIMS colaboró con las partes interesadas para definir pautas para la adquisición y procesamiento de datos de levantamientos futuros para el monitoreo de las pinturas murales (Reina Ortiz *et al.* 2021).

Instrucciones de monitoreo básico para la comunidad local

Los miembros de la comunidad de Kuñotambo son responsables del uso adecuado y cuidado regular del templo, y fueron designados para llevar a cabo un monitoreo básico. Es importante mencionar que fueron capacitados para saber reconocer situaciones que requieren atención urgente por parte de especialistas.

El monitoreo básico se desarrolla a través de un control diario del templo y de inspecciones mensuales más detalladas. Dos veces al año, la inspección se realiza utilizando una ficha de inspección simple. Esta ficha es un documento impreso de pocas páginas e incluye una serie de preguntas relacionadas con los daños que se pueden presentar con mayor frecuencia; puede ser complementada con algunas fotografías generales y de detalle, sin requerir alta calidad, de forma que puedan ser tomadas con la cámara de un teléfono celular. Una vez completa, se adjunta al libro de actas de la parroquia con copia a la DDC–C y al Arzobispado.

Si el control del edificio muestra situaciones de deterioro, la comunidad debe contactar a la Oficina de Proyectos Patrimoniales de Conservación del Arzobispado, que puede solicitar la asesoría de profesionales especializados de la

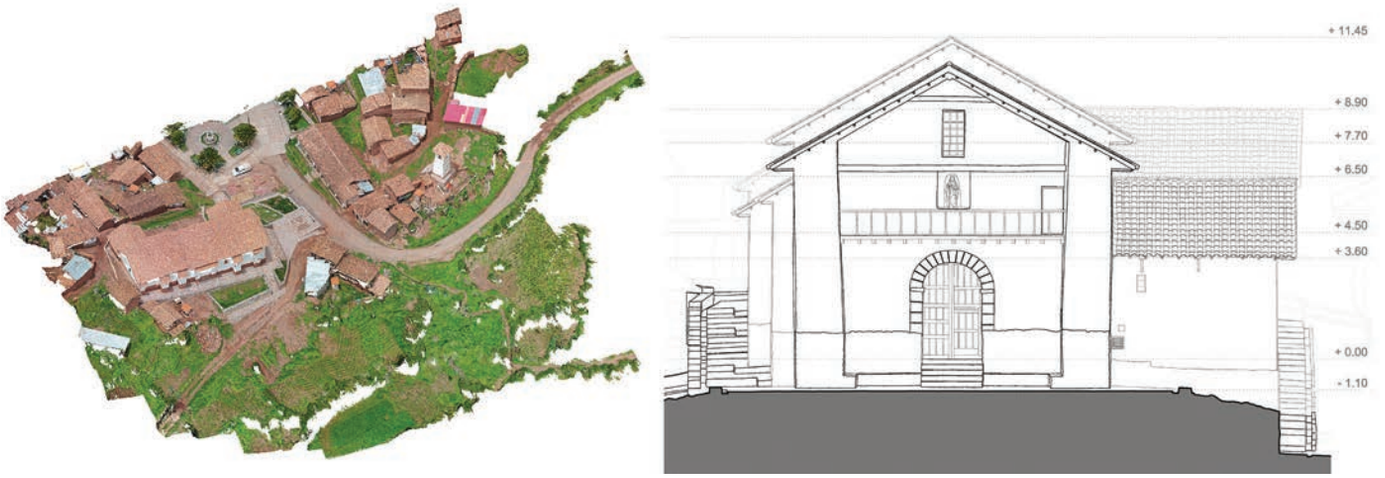


FIGURA 4 Ejemplos de archivos producidos por CIMS tras el levantamiento del sitio, que constituyen la línea base para los protocolos de monitoreo y para comparar con levantamientos futuros: nube de puntos obtenida de la fotogrametría (izquierda) y planos en formato AutoCAD y PDF (derecha). Imágenes: CIMS, ©2020 J. Paul Getty Trust.

Oficina de Patrimonio Histórico de la DDC–C. Con este fin, se ha reforzado la integración entre la comunidad y las organizaciones civiles y religiosas, proporcionando una lista de contactos y un protocolo claro en caso de detección de deterioros.

Contando con el apoyo de asesores peruanos del GCI, se realizó un taller sobre el uso de la ficha de inspección simple y se han recolectado datos desde junio de 2020, evidenciando la necesidad de obras parciales de retejado, así como limpieza de los canales de desagüe y del interior del templo.

Protocolo de monitoreo rápido y de tecnología simple

Anualmente, después de la temporada de lluvias, representantes de la Oficina de Proyectos Patrimoniales de Conservación del Arzobispado y de la Oficina de Patrimonio Histórico de la DDC–C llevan a cabo inspecciones rápidas del sitio. Esto permite planificar actividades de mantenimiento en la temporada seca. El mismo protocolo de inspección será implementado después de una alerta por parte de la comunidad o de eventos naturales importantes.

El protocolo rápido, desarrollado en conjunto por el equipo del GCI, de la DDC–C y del Arzobispado, incluye una inspección visual, el llenado de una ficha de inspección detallada y mapeo simplificado de condiciones en planos del sitio, además de un registro fotográfico (fig. 5). Se sugiere que el equipo de inspección esté compuesto de al menos dos arquitectos y dos conservadores de pinturas murales. De preferencia, debería ser el mismo personal que participó en las inspecciones anteriores.

Además de datos generales sobre uso, intervenciones previas o eventos naturales, la ficha incluye el análisis de todos los elementos arquitectónicos, estructurales, de las pinturas murales y de algunas áreas representativas de las mismas. Los inspectores deben describir las condiciones encontradas y las posibles causas del deterioro, llegando a determinar el plazo para una posible intervención. En las conclusiones se deben detallar las acciones a tomar: investigaciones adicionales, intervenciones con diferentes prioridades (con plazo máximo de 3 meses, para el siguiente ciclo de inspección o deseables a futuro) y/o pequeñas obras de refacción a ser llevadas a cabo por parte de la comunidad sin necesitar documentos de aprobación de las autoridades. El Arzobispado está a cargo de las demás intervenciones, contando con el apoyo técnico de la DDC–C. Después de la inspección, los datos deben ser transferidos a formato digital y guardados junto a la documentación anterior.

En mayo de 2021 se realizó la primera inspección anual, con participación de profesionales de la DDC–C y del Arzobispado, con consultores peruanos del GCI. Esto permitió comprobar y perfeccionar el protocolo de inspección y la ficha. Además, se planificaron las acciones de mantenimiento urgentes a realizarse antes de la temporada de lluvias (como consolidación de pequeños desprendimientos en pinturas murales, sellado de grietas no estructurales en interfaces, cierre de aberturas para evitar ingreso de aves, instalación de testigos de grietas y fisuras) y para el siguiente ciclo de mantenimiento (obras de retejado, enlucido y pintado).

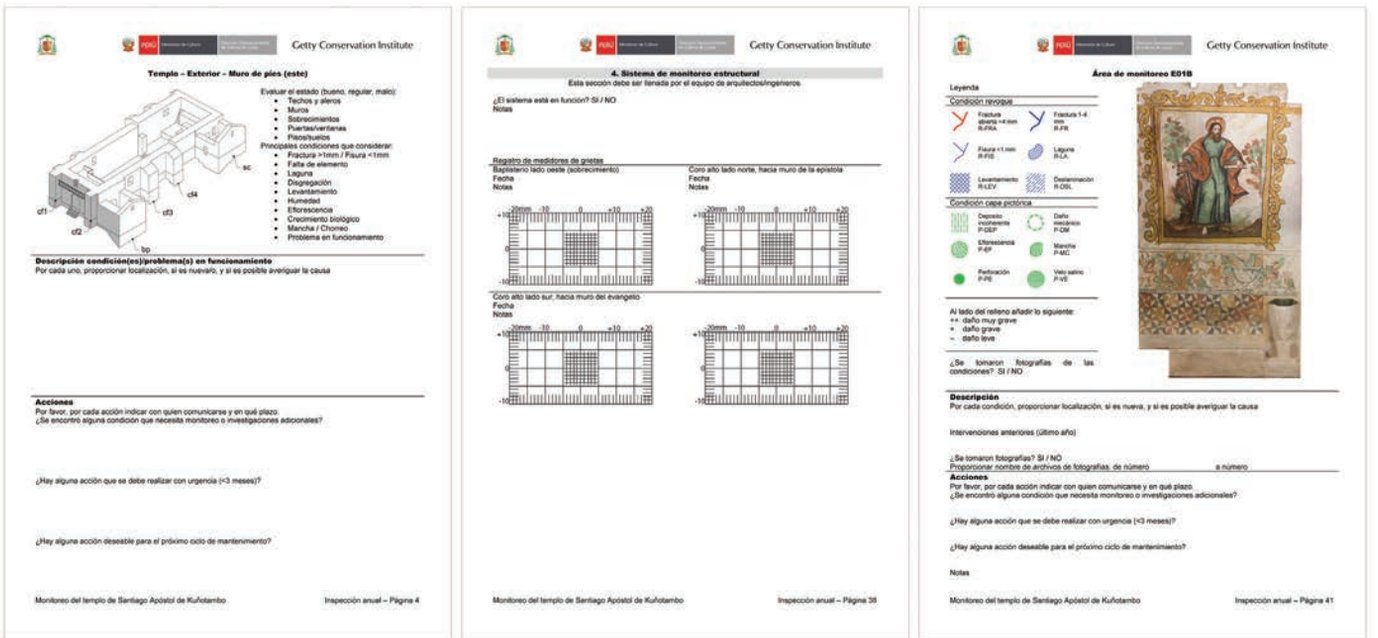


FIGURA 5 Páginas de la ficha de inspección anual que incluye informaciones generales, análisis de condiciones y de áreas de monitoreo de las pinturas murales. La ficha también se complementa con informaciones de mapeo rápido en planos del sitio y registro fotográfico. Imagen: GCI, ©2021 J. Paul Getty Trust.

Protocolo de monitoreo para especialistas

El tercer protocolo de monitoreo está diseñado para ser llevado a cabo cada 5 años por profesionales especializados. Incluye un levantamiento detallado de condiciones, utilizando la documentación producida después de la conclusión de la obra y el monitoreo de los años anteriores, complementado por un registro fotográfico y documentación del sitio. Participan miembros del equipo técnico del Arzobispado, de la subdirección de Patrimonio Histórico de la DDC–C y asesores externos. Profesionales del GCI colaborarán en el primer monitoreo de especialistas a realizarse en 2022.

En abril de 2022, el equipo de trabajo instaló un sistema permanente de MSE, para adquirir datos sobre el desempeño de la estructura tras su reforzamiento. Actualmente el sistema es gestionado por la Universidad del Minho en Portugal; luego, la gestión de datos pasará a la Pontificia Universidad Católica del Perú, en Lima. De igual manera, el SRP pretende capacitar a ingenieros cusqueños para finalmente darles a ellos el encargo a futuro.

Para diseñar e implementar de manera eficiente un sistema permanente de MSE, son fundamentales los procesos de documentación previos y de evaluación estructural a lo largo de la vida del edificio. La norma ISO 13822:2010 proporciona un marco estandarizado para la evaluación y el monitoreo de las estructuras existentes. Aquí, el MSE puede definirse como el registro, recolección de datos y correlación estadística de las condiciones estructurales, acciones y otros parámetros ambientales, estableciendo una relación clara entre causas y efectos.

Una parte crucial del proceso es la correlación entre los datos cualitativos obtenidos durante el monitoreo básico y rápido (inspecciones, análisis visual, mapeo de condiciones, etc.) y los datos cuantitativos obtenidos por el MSE, orientando inspecciones visuales más detalladas en las áreas que presenten daños y verificando condiciones adversas, como filtraciones de agua o fallas de anclajes de madera después de un terremoto, que potencialmente pueden alterar el comportamiento estructural. Los datos de las inspecciones y de las pruebas no destructivas *in situ* antes y después de la estabilización sismorresistente, el estudio desarrollado para el diseño de las intervenciones, la forma en que se llevó a cabo la implementación en obra y la actualización del modelo de elementos finitos del edificio ya intervenido son también cruciales para el diseño del MSE (fig. 6).



FIGURA 6 Ensayos no destructivos *in situ* para la evaluación del comportamiento de la estructura, realizados por el equipo de TecMinho de la Universidad del Minho después de la implementación del reforzamiento: adquisiciones de ensayos de vibración ambiental (izquierda) y señales de vibración en tiempo real, durante la adquisición (derecha). Imágenes: TecMinho, ©2021 J. Paul Getty Trust.

El MSE para el templo de Kuñotambo tiene como objetivo registrar alteraciones de la forma y generación de grietas vinculadas a datos ambientales y datos sísmicos, con el fin de analizar la capacidad estructural y las deformaciones de la estructura para entender las posibles causas de los daños observados. Este tipo de monitoreo ha demostrado ser indicativo para la detección de daños, especialmente después de terremotos (Kita *et al.* 2019; Cardani y Massetti 2017; Cavalagli *et al.* 2017; Saisi *et al.* 2015; Gentile *et al.* 2016).

El plan de MSE instalado en 2022 (fig. 7) involucra los elementos que se describen a continuación. Primero, sensores para el monitoreo de temperatura y humedad, que tienen un efecto directo en alteraciones de la forma, la generación y transformación de grietas. Segundo, un sistema de acelerómetros para la detección de vibraciones ambientales y eventos sísmicos que tiene como objetivo principal monitorear los modos de flexión fuera del plano de los muros laterales, parámetros indicativos de la efectividad de los sistemas de arriostramiento y anclaje. Tercero, sensores en grietas, ubicados en puntos seleccionados; por ejemplo, interfaces entre materiales diferentes o grietas existentes. Cuarto, medidores de inclinación en los muros para detectar cualquier desplomo indicativo de una rotación fuera de plano, un tipo de daño común en las estructuras de mampostería portante no reforzada. Finalmente, un sistema integrado de adquisición, almacenamiento y diagnóstico de los datos del sistema de MSE. Las adquisiciones de datos son continuas, con frecuencias de muestreo adecuadas para cada cantidad medida; las grabaciones son programadas de forma intermitente y activadas en caso de terremotos. Los datos recolectados por los sensores mencionados son compilados en una computadora portátil instalada en el sitio y suben a una nube de almacenamiento vía teléfono celular para que puedan ser procesados desde la oficina en Portugal, usando procedimientos automáticos y con activadores de alerta.

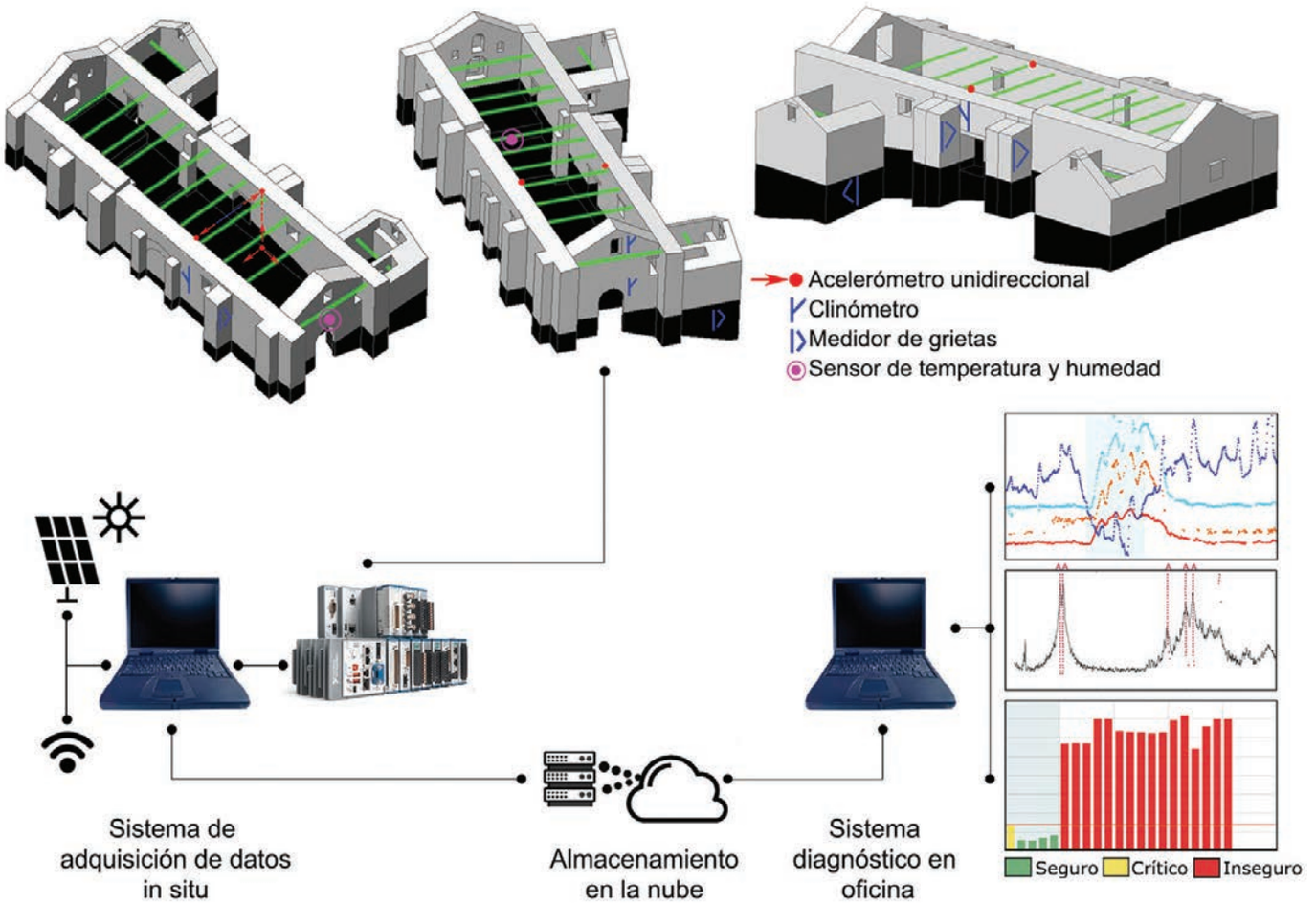


FIGURA 7 Representación gráfica del plan de MSE a largo plazo del templo de Kuñotambo diseñado por la Universidad del Minho después de las intervenciones de estabilización sismorresistente. Imagen: TecMinho, ©2021 J. Paul Getty Trust.

Conclusiones

Dada la importancia de verificar la validez de las intervenciones realizadas como parte del proyecto e implementación de las obras de reforzamiento y conservación en el templo de Kuñotambo, el GCI diseñó con socios peruanos y partes interesadas un plan de monitoreo, el cual está siendo implementado por un equipo local e internacional de carácter multidisciplinario. El involucrar expertos en levantamiento, arquitectos e ingenieros con experiencia en construcciones históricas y conservadores de pintura mural asegura que el plan permita mitigar daños por riesgos, así como comprobar los resultados de las intervenciones pasadas y, en este caso, de las técnicas implementadas para la estabilización sismorresistente y la consolidación de las pinturas murales. El haber considerado la capacidad local, la disponibilidad de tiempo y el equipo con el que se cuenta por parte de los actores involucrados al diseñar diferentes niveles de monitoreo con responsabilidades asignadas a diferentes grupos, permite monitorear el comportamiento del edificio y guiar las acciones de refacción y mantenimiento. Los protocolos descritos se diseñaron para estar integrados; sin embargo, pueden funcionar de forma independiente. De hecho, debido a la pandemia de covid-19, se implementaron solo algunas de las acciones previstas, como la primera inspección anual del protocolo rápido de tecnología simple, mientras otras se realizaron a partir de 2022, incluido el primer ciclo del protocolo para especialistas y talleres de capacitación adicionales para representantes de la comunidad campesina, profesionales de las instituciones involucradas y miembros de instituciones académicas nacionales.

Esperamos que el plan de monitoreo multidisciplinario, de enfoque holístico y adaptado a una realidad específica que

se ha presentado, sirva de guía y pueda ser utilizado en su totalidad o por partes, según los recursos disponibles, en otros sitios similares en Cusco y Latinoamérica.

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El patrimonio arquitectónico construido en tierra en la Península Ibérica y su vulnerabilidad frente a los riesgos naturales: Un primer estudio de identificación de los parámetros

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Resumen: *La Península Ibérica es un territorio con un importante patrimonio arquitectónico monumental y vernáculo construido con tierra. La extensión del territorio y su heterogeneidad geográfica y climática, la variedad de los materiales disponibles y la diversidad cultural constituyen los factores principales que han generado la gran riqueza de su arquitectura, de los conjuntos urbanos y rurales, y de las técnicas de construcción. Sin embargo, aunque represente una parte fundamental de la cultura de este territorio, este patrimonio ha sufrido, a lo largo del último siglo, un abandono significativo debido a los cambios de los hábitos de vida, la despoblación de las áreas rurales, la falta de reconocimiento social, etc. Esta arquitectura, expuesta desde siempre a una serie de peligros naturales (sismos, inundaciones, deslizamientos, etc.), ha sabido, en muchos casos, desarrollar mecanismos de resiliencia frente a ellos que hoy en día pueden brindar lecciones de las que se puede aprender. Además, la agudización de los fenómenos ambientales debidos al proceso del cambio climático expone este patrimonio arquitectónico a nuevos riesgos y retos. Este texto, que recoge un primer análisis de la vulnerabilidad del patrimonio arquitectónico construido en tierra frente a los diferentes peligros naturales (acciones de sismo, inundación, desertificación y variabilidad climática), se enmarca en el proyecto de investigación "RISK-Terra: La arquitectura de tierra en la Península Ibérica; estudio de los riesgos naturales, sociales y antrópicos y estrategias de gestión e incremento de la resiliencia (RTI2018-095302-B-I00)," financiado por el Ministerio de Ciencia, Innovación y Universidades del Gobierno de España. El estudio de 50 casos distribuidos en todo el territorio de la Península Ibérica permite analizar las características arquitectónicas y constructivas de las diversas tipologías y establecer el nivel de vulnerabilidad de cada una de ellas ante los diversos peligros naturales. Este análisis pretende crear una metodología de identificación de los parámetros de vulnerabilidad de la arquitectura vernácula construida con tierra aplicable a cualquier edificio del territorio de la Península Ibérica y, por extensión, a cualquier edificio de ámbito internacional, con el objetivo de evaluar los posibles riesgos y establecer pautas para la mejora de la resiliencia de este patrimonio cultural.*

Abstract: *The Iberian Peninsula is an area with considerable monumental and vernacular earthen architectural heritage. Its size, heterogeneous geography and climate, variety of available materials, and cultural diversity are the main factors that have led to the great wealth of its architecture, urban and rural complexes, and construction techniques. Although heritage forms a large part of the culture of the peninsula, it has been largely abandoned in the past century due to changes in lifestyle, the depopulation of rural areas, and the lack of social recognition. This architecture has always been exposed to a series of natural dangers (earthquakes, floods, landslides, etc.) and has often successfully developed mechanisms for resilience. Although these mechanisms now provide lessons from which we can benefit, environmental phenomena heightened by climate change have*

brought about new risks and challenges to this architectural heritage. This paper, which presents an initial analysis of the vulnerability of earthen architectural heritage when faced with various natural risks, is part of the research project "Risk-Terra: Earthen Architecture in the Iberian Peninsula; Study of Natural, Social, and Anthropic Risks and Strategies to Improve Resilience (RTI2018-095302-B-I00)," funded by the Spanish Ministry for Science, Innovation, and Universities. Based on fifty case studies throughout the Iberian Peninsula, an analysis of the architectural and construction characteristics of the different typologies identifies individual levels of vulnerability in the face of different natural risks. The aim of this analysis is the creation of a methodology for identifying vulnerability parameters affecting built earthen architectural heritage that are applicable to any building in the Iberian Peninsula, and, by extension, any international setting, to evaluate the possible risks and establish guidelines to improve their resilience.

Palabras clave: arquitectura de tierra, vulnerabilidad, riesgos naturales, Península Ibérica

Introducción: El proyecto RISK-Terra

La arquitectura de tierra representa una parte fundamental de la cultura constructiva de la Península Ibérica. La riqueza del territorio a nivel geográfico, geológico y climático se refleja en el amplio abanico de técnicas empleadas en esta arquitectura (tapia, adobe, entramado, pared de mano, terrones, etc.) y en las diferentes variantes surgidas en cada lugar a tenor de los materiales disponibles y de la implantación en su entorno medioambiental, social y cultural (Sanz 1996).

Además, los peligros naturales siempre han sido parte de la historia del hombre y del desarrollo de las civilizaciones. Actualmente, existe una amplia documentación general sobre el nivel de riesgos naturales en el territorio peninsular y también diversos estudios respecto a los riesgos en relación con el patrimonio construido, como el desarrollado por la UNESCO en 2008, en el que se estableció un listado de las amenazas más importantes para el Patrimonio Mundial natural y cultural (UNESCO 2008) sobre la base de años de experiencia en el seguimiento de los sitios declarados. Los riesgos naturales que afectan al patrimonio cultural constituyen, en la actualidad, un foco de atención importante en la investigación internacional. Incluso está siendo objeto de análisis la propia metodología de estudio de riesgos aplicado al patrimonio en general (Andretta et al. 2017; Fatorić y Seekamp 2018; Pavlova et al. 2017). A nivel de la Península Ibérica, existen diversos estudios sobre el riesgo sísmico para el patrimonio arquitectónico (Cantarino et al. 2014), pero menos estudios sobre otro tipo de riesgos naturales, y muchos menos estudios enfocados específicamente en el patrimonio construido en tierra. A nivel internacional, sí que existen estudios de referencia que han analizado concretamente el riesgo sísmico en el caso de la arquitectura de tierra, como el proyecto Seismic Retrofitting Project del Getty Conservation Institute, que ha supuesto una de las experiencias recientes más relevantes en el estudio del comportamiento estructural y sísmico de la arquitectura de tierra (Cancino et al. 2014; Lourenço et al. 2019; Karanikoloudis y Lourenço 2018).

En este marco, surge el proyecto RISK-Terra, que pretende abarcar de una forma científica el estudio de las amenazas naturales (inundaciones, terremotos, vientos, incremento de temperaturas, etc.), sociales (abandono, descrédito social, presión demográfica, desarrollo turístico, etc.) y antrópicas (descuidos y negligencias, falta de protección y mantenimiento, etc.), además de los mecanismos de deterioro (erosión, pérdida de materiales y partes, derrumbe, etc.) y las dinámicas de transformación (sustitución, empleo de técnicas y materiales incompatibles, etc.), a los que está sometida la arquitectura de tierra en este momento en la Península Ibérica (Mileto et al. 2020).

Con estos antecedentes, el estudio que aquí se expone se centra en el análisis de 50 casos de estudio de arquitectura vernácula de tierra (tapia, adobe y entramado) distribuidos por toda la geografía peninsular (fig. 1) a partir de los cuales desarrollar una metodología de análisis que permita evaluar la vulnerabilidad de esta arquitectura frente a diversas amenazas y riesgos naturales.

Objetivos

El trabajo de investigación presentado en este texto trata de conseguir los siguientes objetivos generales:

- Definir las amenazas y riesgos naturales que intervienen en el territorio de la Península Ibérica y que pueden ser más susceptibles de provocar daños sobre la arquitectura construida en tierra.
- Organizar y sistematizar la catalogación de la arquitectura construida en tierra de forma que se pueda recoger su gran riqueza y variabilidad en cuanto a características y sistemas constructivos en una sola herramienta de análisis.



FIGURA 1 Mapa de distribución de los 50 casos de estudio analizados en el territorio de la Península Ibérica.

- Puesta a punto y aplicación de una metodología de análisis y evaluación de la vulnerabilidad (susceptibilidad y resiliencia) de la arquitectura de tierra. Esta metodología multidisciplinar abarcará los diferentes aspectos que pueden influir en la susceptibilidad de la arquitectura de tierra y en su resiliencia frente a las amenazas naturales.

Identificación de las amenazas naturales

Para establecer una metodología de análisis de la arquitectura construida con tierra, en primer lugar, se ha tratado de determinar los riesgos concretos, cuya acción pueda menoscabar las características particulares y la función genérica de la arquitectura (ICOG 2008). Con esta premisa, se propone el estudio del riesgo frente a la acción del sismo, el riesgo frente a inundaciones por avenidas de agua, y el riesgo ante el cambio climático, que recientemente ha cobrado mayor presencia, importancia y notoriedad. Este último se analiza desde dos puntos de vista, el primero de ellos considerando el incremento en incidencia, frecuencia e intensidad de fenómenos meteorológicos adversos, los cuales provocan alteraciones de las condiciones ambientales en cortos plazos de tiempo, pero de gran agresividad; y el segundo de ellos considerado la variación de las condiciones ambientales históricas a nivel global que, como consecuencia, requiere la adaptación a esas nuevas condiciones. Con relación a esta última cuestión, cabe destacar el proceso de desertificación que afecta notablemente al territorio de la Península Ibérica (Mileto et al. 2019) (fig. 2).

Riesgo de inundación

Las inundaciones constituyen un riesgo indiscutible que genera daños tanto a nivel humano como físico y material en el territorio. Por consiguiente, las construcciones arquitectónicas ven menoscabadas sus características físicas y materiales tras la intervención de este fenómeno. Según la Dirección General de Protección Civil y Emergencias del Ministerio del Interior del Gobierno de España (2020), las inundaciones

suponen el fenómeno natural con mayor impacto económico y social en España. Su origen se puede atribuir a la gran desproporción entre los caudales ordinarios y extraordinarios de algunos ríos que se produce de forma repentina o en periodos de tiempo muy reducidos, así como a las crecidas repentinas del nivel del mar. Su carácter de poca predictibilidad ocasiona que los daños producidos revistan especial gravedad.

Riesgo sísmico

Uno de los riesgos naturales históricamente reconocidos es el riesgo frente a la acción del sismo. Este tiene su origen en los movimientos en forma de ondas que se propagan en todas direcciones, originados por la liberación repentina de la energía acumulada en la corteza terrestre.

Actualmente, según la Dirección General de Protección Civil y Emergencias del Ministerio del Interior del Gobierno de España (2020), no existe ningún método capaz de predecir el tiempo, lugar y magnitud de un terremoto. Esta dificultad radica en el comportamiento no lineal y bastante caótico que caracteriza a los movimientos. Su carácter de acción repentina e impredecible es el que principalmente lo hace suponer un grave riesgo para la seguridad de las personas, relacionada directamente con la de las construcciones.

Riesgo de desertificación

En el estudio de los riesgos de origen natural a los que se ve expuesta la arquitectura construida con tierra, cada vez toman mayor presencia los derivados del cambio climático (Olcina Cantos 2012). De entre los fenómenos climáticos que se encuentran en evolución, uno de los de mayor notoriedad es el fenómeno de la desertificación. Este fenómeno está relacionado con el cambio paulatino de las condiciones ambientales respecto de épocas pasadas. En la evaluación del riesgo de desertificación, se tienen en cuenta la transformación y las variaciones relacionadas con el índice de aridez del suelo, la evapotranspiración, los niveles de precipitación evaluados según máximas en veinticuatro horas y medias acumuladas anualmente, las temperaturas medias anuales, y el grado de erosividad de la lluvia y el viento.

Riesgo de fenómenos meteorológicos adversos

Los fenómenos atmosféricos se consideran uno de los principales factores de alteración a los que se encuentra expuesta la arquitectura vernácula. Habitualmente, son el origen de gran parte de los procesos patológicos que se desarrollan en este tipo de construcciones. Estos fenómenos están relacionados con los riesgos meteorológicos y, cuando intervienen con gran intensidad, espontaneidad y arbitrariedad, se pueden identificar como fenómenos meteorológicos adversos.

Según la Agencia Estatal de Meteorología (AEMET, http://www.aemet.es/), los mencionados eventos son los relacionados con la acción de fuertes rachas de vientos, precipitaciones torrenciales, tormentas de nieve o heladas, variaciones bruscas de temperatura, etc.

Metodología para el análisis y caracterización de la arquitectura construida con tierra

Dada la extensión y gran variabilidad tanto a nivel geográfico como ambiental del ámbito de estudio, existe una gran heterogeneidad del territorio en cuanto a factores geográficos y ambientales. Esto genera la aparición de una gran variedad de materiales disponibles para la construcción, así como una gran diversidad cultural. Estas condicionantes originan una gran variabilidad y riqueza en cuanto a elementos arquitectónicos y técnicas constructivas (Benito y Timón 2014).

La metodología de análisis propuesta para la caracterización de la arquitectura vernácula se basa en el estudio de forma pormenorizada de todas aquellas características propias que la componen. Para ello, se ha seleccionado una muestra basada en 50 construcciones distribuidas de forma homogénea por el territorio peninsular y teniendo en cuenta la característica principal a evaluar: el sistema constructivo de tierra empleado.

De los casos seleccionados se han extraído las características que los definen, con sus múltiples variaciones. Estas se han considerado teniendo en cuenta que, de algún modo, dependiendo de sus distintas combinaciones, pueden generar respuestas dispares frente a la exposición a un riesgo específico. Es decir, se han determinado los factores y condicionantes existentes en la arquitectura que pueden ser influyentes en cuanto al tipo y forma de respuesta frente a la acción de un factor de riesgo externo. De este modo, se definen características relacionadas con el entorno inmediato, la morfología y los sistemas constructivos (ver cuadro 1).

El análisis de las características que constituyen las construcciones, con su posible respuesta ante la acción de los distintos riesgos, nos permitirá conocer la vulnerabilidad del conjunto de cada una de las construcciones que se proponga evaluar. Así pues, el análisis de la vulnerabilidad se realiza a través de una metodología de comparación por combinación de características arquitectónicas.

De cada una de las características se estudia la respuesta de sus variables frente a la acción de cada uno

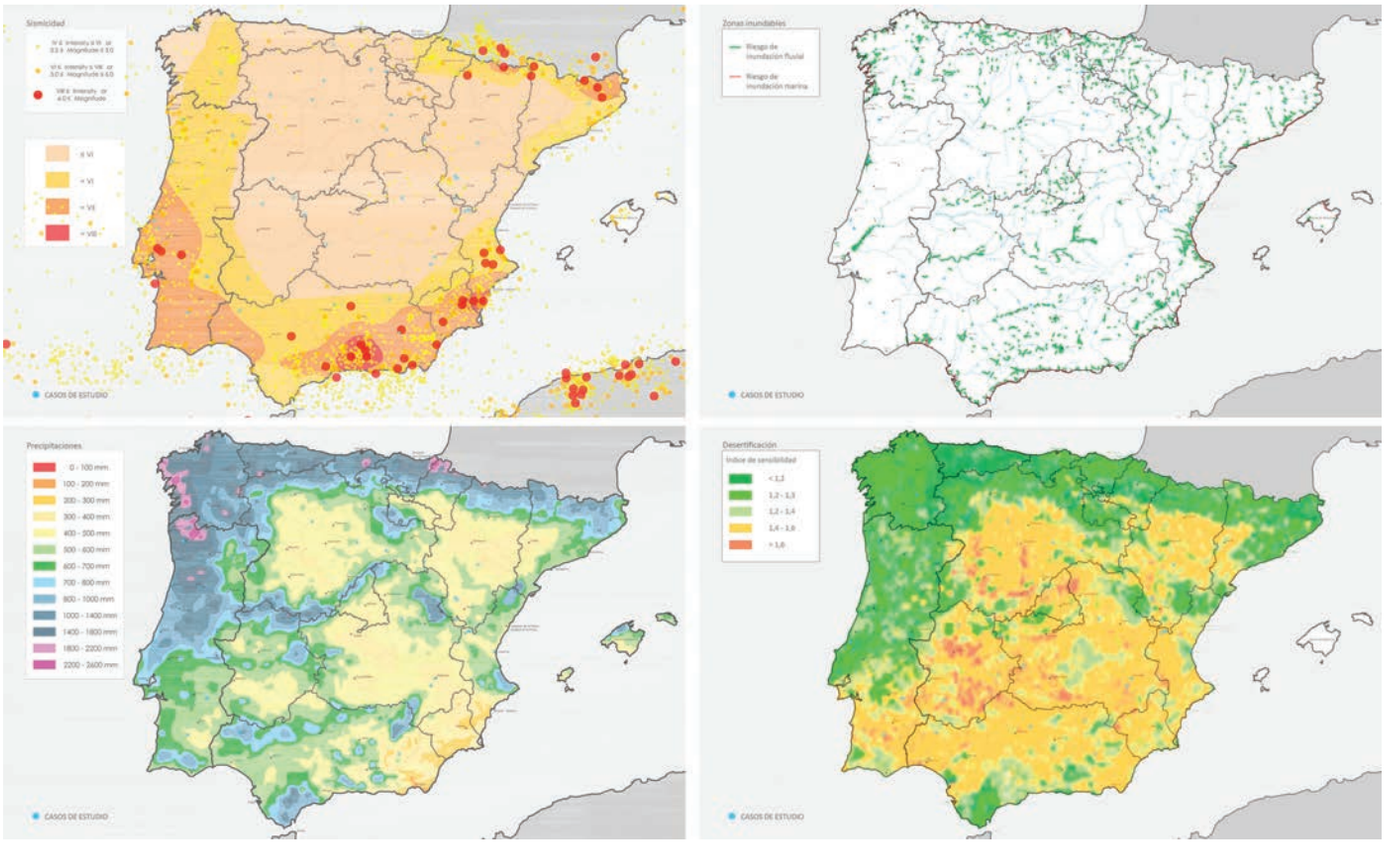


FIGURA 2 Localización de los casos de estudio en el análisis de los riesgos. (a) Sismo: análisis de intensidad y magnitud sísmica; (b) Inundación: áreas inundables de origen marino y fluvial; (c) Fenómenos meteorológicos adversos: precipitación media anual (1971–2000); (d) Desertificación: índice de sensibilidad a la desertificación en 2008–2017. *Fuentes:* (a) Atlas Nacional de España; Instituto Geográfico Nacional; Ministerio de Fomento; European Seismological Commission; (b) Instituto Geográfico Nacional; Atlas Nacional de España; MAPAMA 2015; Sistema Nacional de Información de Ambiente (SNIAmb); (c) Atlas Climático Ibérico; Atlas Nacional de España; Ministerio de Medio Ambiente y Medio Rural y Marino, Gobierno de España; (d) Tribunal de Cuentas Europeo, Informe especial n.º 33: *La lucha contra la desertificación en la UE: Una amenaza creciente contra la que se debe actuar más intensamente* (2018).

de los riesgos definidos de forma independiente, buscando establecer una gradación propia según el nivel de influencia; es decir, según se vea más o menos afectado o degradado el conjunto de la construcción por su nivel de resistencia o respuesta específico.

Características susceptibles frente a riesgo de inundación

Tradicionalmente, la arquitectura vernácula se ha constituido en base al conocimiento heredado tanto de técnicas como de las condiciones que debían tenerse en cuenta en cuanto al lugar y la forma de realizar las construcciones. Sin embargo, la evolución y las transformaciones, tanto urbanas como geográficas y territoriales de origen antrópico, han propiciado un cambio en las características primigenias sobre las cuales se basaba la tradición constructiva. Por ello, la arquitectura tradicional puede mostrar elevados niveles de vulnerabilidad frente al riesgo de inundación.

El nivel de vulnerabilidad que presenten las construcciones estará relacionado principalmente con las características materiales del sistema constructivo, pero también con las características geométricas y su relación con el entorno urbano (fig. 3).

Características susceptibles frente a riesgo de sismo

La arquitectura vernácula se ha formulado tradicionalmente desde el punto de vista de adaptación al medio (Correia, Lourenço y Varum 2015), y en gran medida debido a ello, existe

Cuadro 1 Resumen de las características

CARACTERÍSTICAS DE ENTORNO		
EDIFICIOS COLINDANTES	**CONDICIÓN URBANA**	**TIPOLOGÍA URBANA**
De mayor o igual altura	Con sótano	Aislado
Combinación de mayor con igual altura	Bajo rasante	Terminal de manzana
Combinación de menor con igual altura	A nivel	En esquina
De menor altura	Sobre rasante	Entre medianeras
No existen	A varios niveles	
CARACTERÍSTICAS MORFOLÓGICAS		
PROPORCIÓN GEOMÉTRICA	**TIPO DE CUBIERTA**	**SUPERFICIE OCUPADA**
a × a	Plana	Menor de 50 m^2
a × 2a	Con inclinación menor del 30 %	Entre 50 y 150 m^2
a × 3a o mayor	Con inclinación mayor del 30 %	Mayor de 150 m^2
PORCENTAJE DE HUECOS	**TIPO DE ALERO**	**PROTECCIÓN VERTICAL**
Menor del 30 %	Sin alero	No existe
Entre el 30 % y el 70 %	Alero de vuelo corto	Presenta protección adicional
Mayor del 70 %	Alero de vuelo significativo	
NÚMERO DE PLANTAS	**ARRIOSTRAMIENTO INTERIOR**	
1	Forjados con muros en dos direcciones	
2–3	Forjados con muros en una dirección	
4–5	Forjados	
Más de 5	Sin elementos de arriostramiento	
CARACTERÍSTICAS CONSTRUCTIVAS		
TÉCNICA CONSTRUCTIVA	**CARACTERÍSTICAS DEL SISTEMA**	
Tapia	Tapia uniforme	Fábrica de adobe mixta
Adobe	Tapia suplementada	Entramado sencillo
Entramado	Tapia mixta	Entramado complejo
	Fábrica de adobe uniforme	
	Fábrica de adobe suplementada	
Tipo de muro: TAPIA	Tipo de muro: ADOBE	Tipo de muro: ENTRAMADO
Simple	Con juntas de tierra	Rellenos de fábrica
Real	Con juntas de cal	Rellenos monolíticos
Real con mampuestos	Con cañizos en las juntas	Encestados o cañizo
Mampostería encofrada	Con ladrillos en las juntas	
Trabada con madera	Con piedra en las juntas	
Hormigón de cal	Con madera en las juntas	
De yeso		
Calicostrada		
Careada con ladrillo		
Careada con piedra		
Con juntas de yeso		
Con juntas de cal		
Con brencas de yeso		
ZÓCALO	**REVESTIMIENTO**	
Sin zócalo	Sin revestimiento	
De mampostería	Mortero de tierra	
De fábrica de sillares o sillarejo	Mortero de tierra y cal	
De fábrica de ladrillo cerámico	Mortero de tierra con fibras	
	Mortero de cal	
	Yeso	

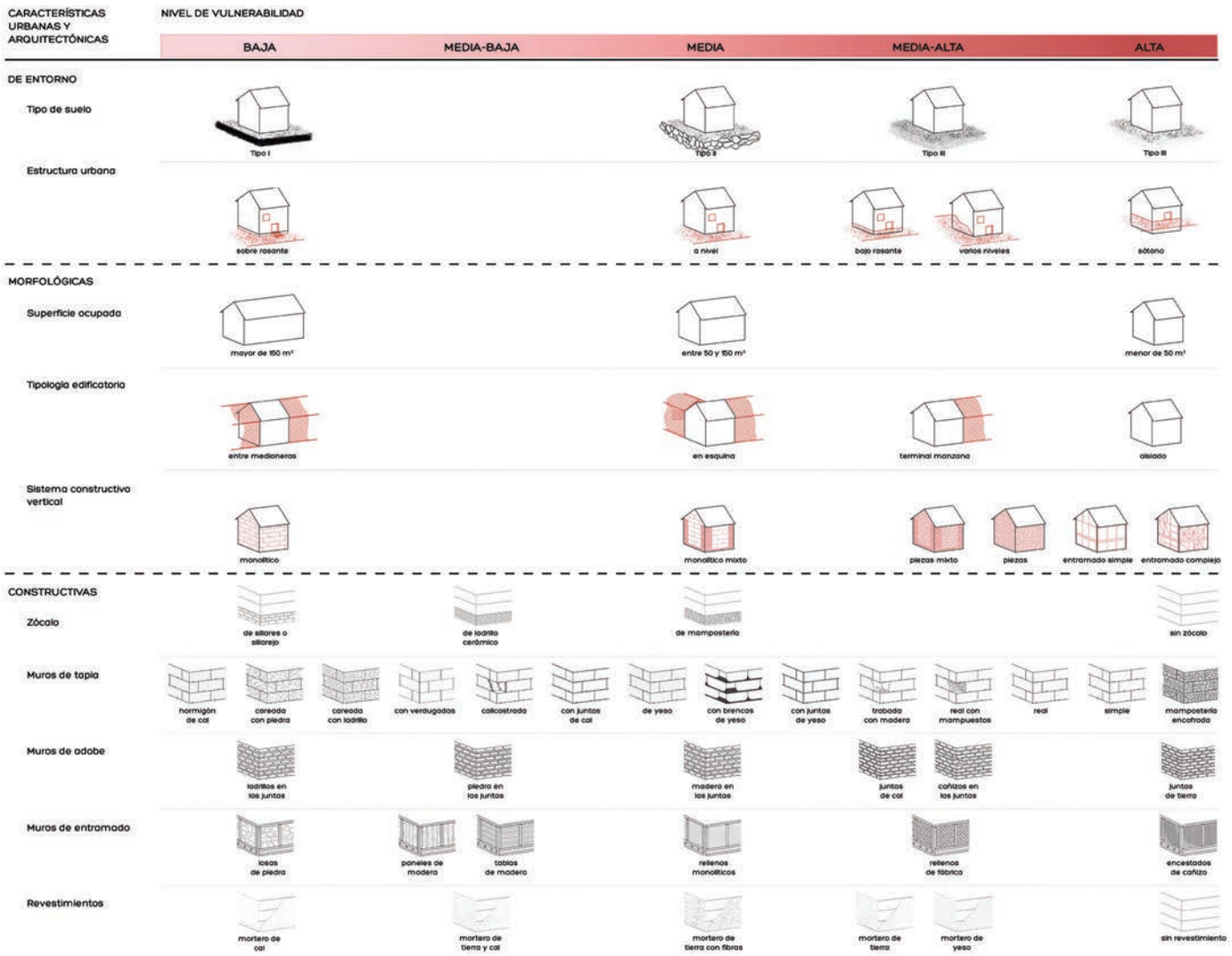


FIGURA 3 Características arquitectónicas y constructivas con sus distintas variantes (determinadas a partir de los 50 casos de estudio analizados) que influyen en la capacidad de respuesta del conjunto de una construcción frente a la presencia de riesgo de inundación. Las variantes se encuentran organizadas según el nivel de vulnerabilidad que suponen por sí solas al conjunto de la construcción, en función de su materialidad y/o forma. Figuras 3–6 cortesía des los autores.

la gran variabilidad de tipos y sistemas empleados en todo el territorio. De entre todas las características y tipos, la vulnerabilidad de las construcciones relacionada con la acción del sismo vendrá determinada principalmente por la capacidad de absorción de movimientos, la conexión entre los distintos elementos y las características dimensionales. Estos rasgos están relacionados mayormente con la morfología de las construcciones, pero indiscutiblemente también con el tipo de sistema constructivo y sus particularidades materiales (fig. 4).

Características susceptibles frente a desertificación

El riesgo de desertificación viene básicamente asociado a la calidad del ambiente y a la productividad del suelo, donde los principales factores a tener en cuenta son el incremento de la erosión y la alta capacidad de disgregación. La arquitectura de tierra por sus propias características materiales se ve directamente afectada en su durabilidad y estabilidad por estos mismos factores, que son los principales causantes de su desaparición.

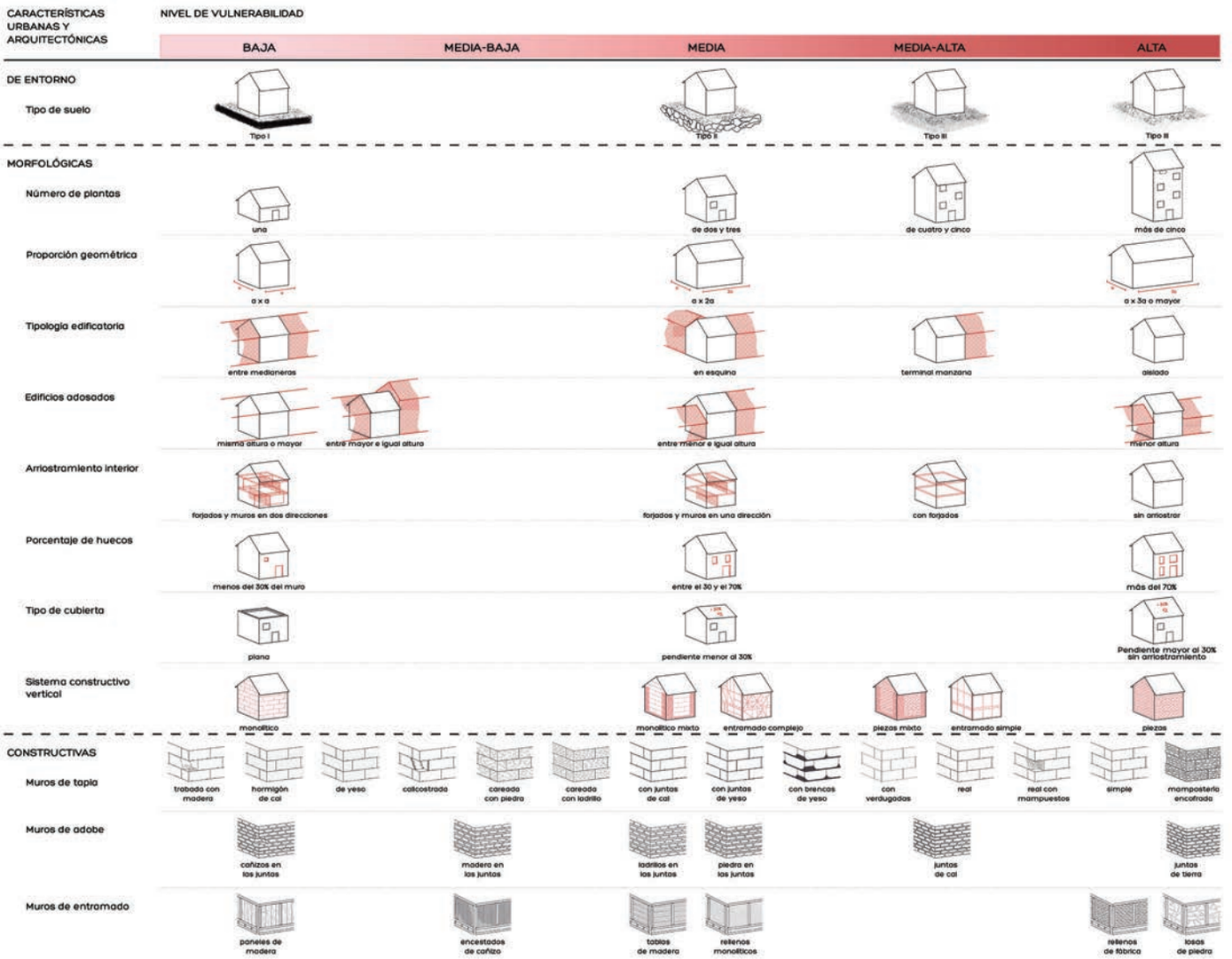


FIGURA 4 Características arquitectónicas y constructivas con sus distintas variantes (determinadas a partir de los 50 casos de estudio analizados) que influyen en la capacidad de respuesta del conjunto de una construcción frente al riesgo de la acción del sismo. Las variantes se encuentran organizadas según el nivel de vulnerabilidad que suponen por sí solas al conjunto de la construcción, en función de su materialidad y/o forma.

Por ello, el nivel de vulnerabilidad relacionada con las características arquitectónicas ante este riesgo se encuentra asociado directamente a su grado de exposición, a los elementos de protección de que disponga y a la resistencia frente a la erosión característica del material y dosificación específica de cada tipo constructivo (fig. 5).

Características susceptibles frente a fenómenos meteorológicos adversos

La arquitectura vernácula demuestra características que aportan mayores niveles de protección frente a la acción de los fenómenos meteorológicos en aquellas áreas que tradicionalmente se han encontrado expuestas. Sin embargo, es fácilmente observable la expansión del área de incidencia del riesgo, puesto que encontramos construcciones actualmente con altos grados de exposición que no presentan elementos similares de protección.

Las características arquitectónicas concretas de cada construcción son, por tanto, determinantes de cara a establecer un nivel de vulnerabilidad frente a este riesgo. Se analizan para ello las variantes de cada característica constructiva relacionada con el nivel de exposición de las superficies exteriores,

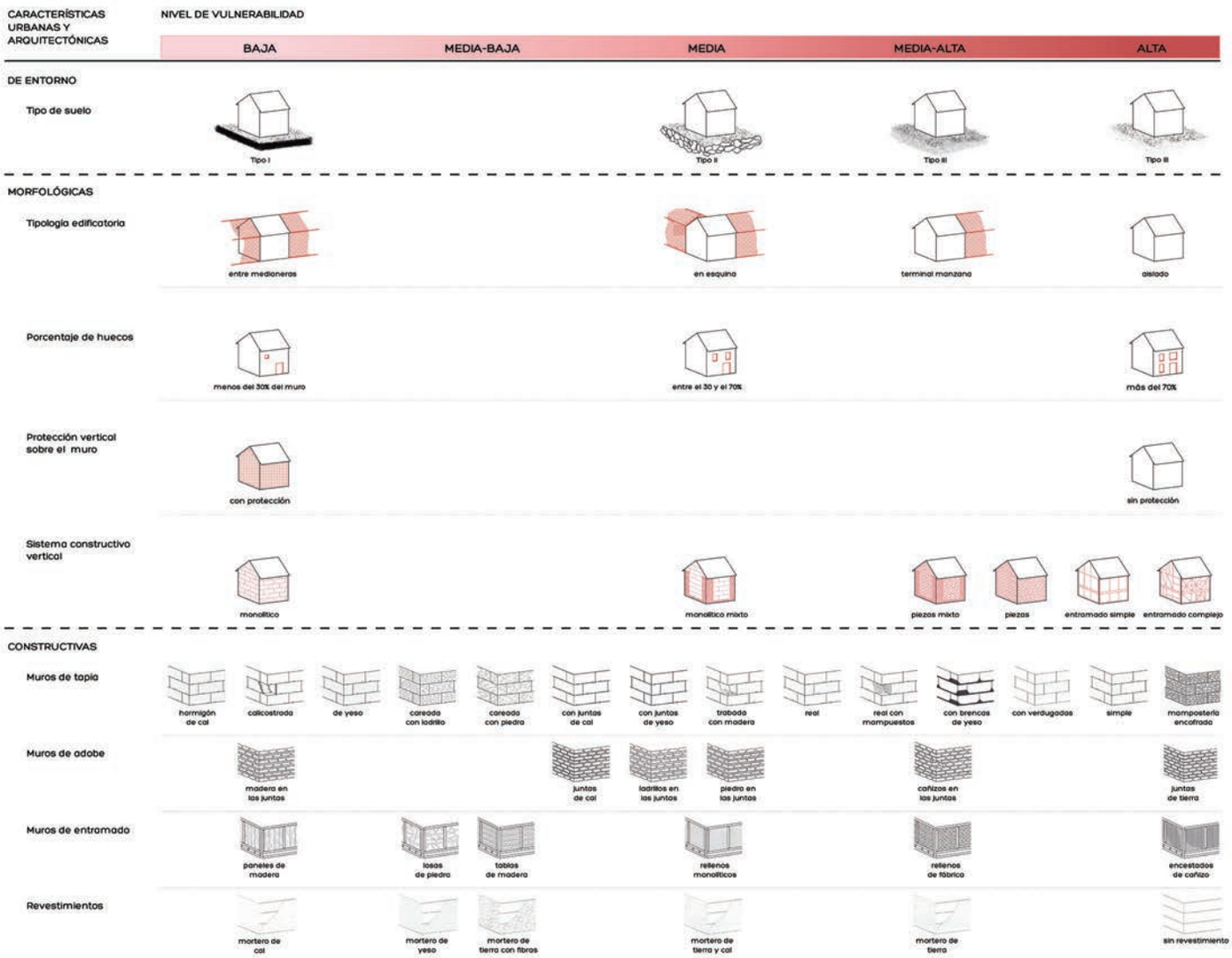


FIGURA 5 Características arquitectónicas y constructivas con sus distintas variantes (determinadas a partir de los 50 casos de estudio analizados) que influyen en la capacidad de respuesta del conjunto de una construcción frente al riesgo de desertificación. Las variantes se encuentran organizadas según el nivel de vulnerabilidad que suponen por sí solas al conjunto de la construcción, en función de su materialidad y/o forma.

el grado de protección que le atribuyan elementos como los aleros o las protecciones verticales, así como la resistencia y permeabilidad con la que cuenten los materiales que forman los distintos elementos constructivos (fig. 6).

Resultados obtenidos

A partir de la metodología expuesta, se ha generado una herramienta para la evaluación en términos cuantitativos del nivel de susceptibilidad de la arquitectura a ser vulnerable, según sus características constructivas, frente a la acción de cada uno de los riesgos definidos. Para ello, se ha establecido una escala numérica (del 1 al 5, donde 1 es el nivel mínimo y 5 un nivel elevado de susceptibilidad aportado al conjunto) de análisis de la vulnerabilidad asociada a cada variable de cada una de las características. Esta escala se ha determinado a partir de la consulta a diversos expertos en la materia.

Con este primer análisis, se ha detectado, a nivel general, un mayor grado de susceptibilidad a los fenómenos de inundación y desertificación. De igual modo, se puede observar que la presencia de casos con el máximo grado de susceptibilidad asociado a cada uno de los riesgos se encuentra por debajo del 3,5 %.

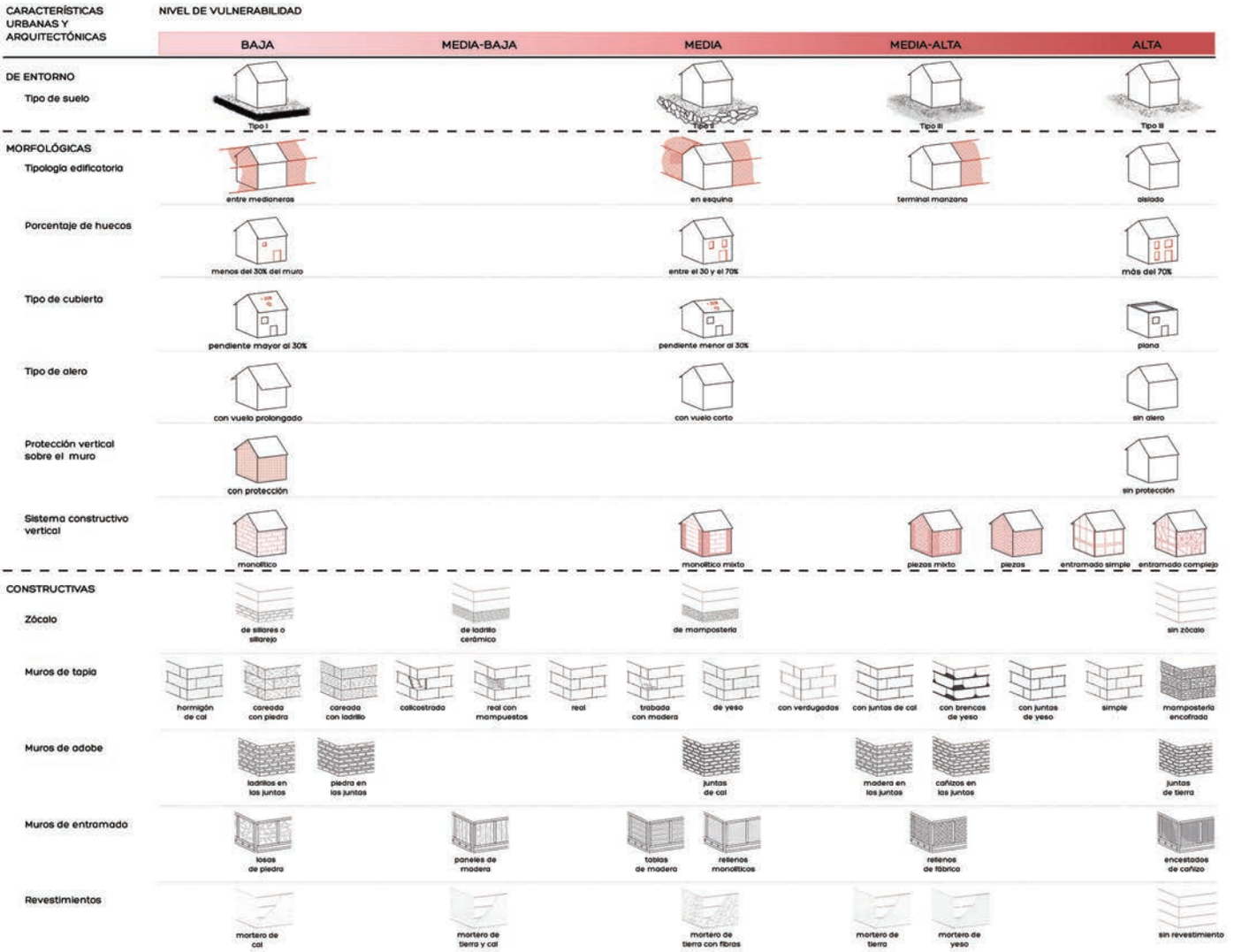


FIGURA 6 Características arquitectónicas y constructivas con sus distintas variantes (determinadas a partir de los 50 casos de estudio analizados) que influyen en la capacidad de respuesta del conjunto de una construcción frente al riesgo de intervención de fenómenos meteorológicos adversos. Las variantes se encuentran organizadas según el nivel de vulnerabilidad que suponen por sí solas al conjunto de la construcción, en función de su materialidad y/o forma.

Para comprender mejor la metodología empleada se va a mostrar el ejemplo de uno de los 50 casos evaluados. Se trata de una construcción aislada situada en la provincia de Albacete (España), concretamente en la localidad de Peñas de San Pedro, sin sobreelevación en su base ni sótano (a nivel), con una sola altura sobre rasante, de proporción cuadrada (a × a) y una superficie ocupada mayor de 150 m², que cuenta con una superficie de huecos en fachada inferior al 30 % del total y una cubierta inclinada de pendiente suave (<30 %) con alero corto. La técnica constructiva empleada en este caso se trata de tapia calicostrada sin revestimiento ulterior, con machones de mampostería a modo de refuerzo en jambas y esquinas, y con zócalo también de mampostería (fig. 7). Esta construcción evaluada frente al riesgo sísmico devuelve un valor de susceptibilidad de 2,48 sobre 5, el cual supone un grado medio-bajo. Esto es debido, principalmente, a sus proporciones geométricas y de huecos, así como al carácter monolítico de sus muros. Sin embargo, evaluada frente al riesgo de intervención de fenómenos meteorológicos adversos devuelve un valor de 3,28 sobre 5, suponiendo, por tanto, un nivel medio-alto de



FIGURA 7 Construcción aislada situada en la localidad de Peñas de San Pedro, provincia de Albacete (España). Fotografía: Camilla Mileto.

susceptibilidad. Esto se asocia principalmente a la falta de protección de sus paramentos verticales y a su condición de construcción aislada.

Futuras líneas de investigación

La herramienta descrita se encuentra en proceso de evaluación con una muestra de mayor dimensión, contando con 258 casos de arquitectura construida en tierra también distribuidos en todo el ámbito territorial de la Península Ibérica.

Como evaluación final de la vulnerabilidad de la arquitectura construida en tierra, mediante el solape de los casos con los mapas de riesgo, se podrá comprobar y evaluar la necesidad de intervención para la adaptación y prevención frente a la acción de los riesgos, o bien, comprobar la capacidad de adaptación que se le atribuye a este tipo de construcciones.

El objetivo final por perseguir es el de contribuir a la prevención, planificación y priorización frente a los riesgos naturales para la arquitectura de tierra y la sociedad actual en la Península Ibérica. Para alcanzar este objetivo a partir de la clara identificación de las amenazas, la peligrosidad y la vulnerabilidad (susceptibilidad y resiliencia) de esta arquitectura, se establecerán de forma objetiva unos niveles homogéneos de riesgo que permitan, según diferentes niveles de urgencia y emergencia, planificar y priorizar las actuaciones en el patrimonio construido en tierra a la hora de proteger, intervenir e invertir.

Nota

1 El trabajo de investigación presentado forma parte del proyecto "RISK-Terra: La arquitectura de tierra en la Península Ibérica; Estudio de los riesgos naturales, sociales y antrópicos y estrategias de intervención e incremento de la resiliencia" financiado por el Ministerio de Ciencia, Innovación y Universidades (MCIU), la Agencia Estatal de Investigación (AEI) y el Fondo Europeo de Desarrollo Regional (FEDER) (ref. RTI2018-095302-B-I00; IP: Camilla Mileto y Fernando Vegas).

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An Inventory for *Massone*: Abruzzo's Rural Earthen Anti-Seismic House

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Abstract: Massone, *a vernacular building technique also known as cob or bauge, has a long history in central Italy, particularly in the Abruzzo and Marche regions, areas deeply affected by severe earthquakes in the past that have irrevocably damaged their historical heritage.* Massone *houses (pl.* massoni*) are intimately connected to common know-how passed down through generations, and, because of historically destructive seismic activity, the region has deep generational memory related to the development of anti-seismic buildings. Abruzzo's earthen houses suffer from a lack of maintenance and, whether from initial damages or long-term neglect, earthquakes have only increased the percentage of losses. Therefore, it is essential to understand both the art of traditional techniques and the current state of conservation for the fragile* massone *heritage through the execution of a well-planned survey. This paper proposes a scientific and up-to-date inventory of the remaining* massoni *in order to advance a maintenance plan shared among citizens and associations that would serve as a framework in defining future regeneration and restoration initiatives for this significant rural heritage. A survey, including 3D mapping, would be a useful tool in developing an atlas of the state of conservation of surviving* massone *houses in order to propose strategies for their protection and rehabilitation applicable to municipalities and professionals. Indeed, some of the houses have recently been identified as eligible for public funds for their restoration—a promise to pursue this approach of good practice in order to best address this valorization of local earthen heritage.*

Resumen: *Italia central y en particular las regiones de los Abruzos y las Marcas aún conservan una importante tipología arquitectónica de tierra denominada* 'massone'*, edificada con la técnica de construcción vernácula también conocida como cob o bauge. Esta zona se ha visto profundamente afectada por terremotos severos en los últimos años, y su patrimonio histórico ha sido dañado irremediablemente. Las casas* massone *están íntimamente conectadas con el saber hacer común transmitido de generación en generación. La memoria histórica relacionada con los terremotos llevó a la gente a construir edificios antisísmicos. Sin embargo, las casas de tierra en los Abruzos sufren de falta de mantenimiento: los terremotos, junto con su abandono inicial, han aumentado el porcentaje de pérdida de* massoni*. Por lo tanto, es esencial conocer la regla del arte de las técnicas tradicionales, pero también comprender el estado de conservación de las casas* massone *a través de una encuesta bien planificada. En este trabajo se propone un inventario científico y actualizado de las* massoni *restantes con el fin de hacer avanzar un plan de mantenimiento compartido entre ciudadanos y asociaciones, que pueda servir de marco para definir futuras iniciativas de regeneración y restauración de este importante patrimonio rural. El mapeo y el estudio son herramientas extremadamente útiles para implementar el inventario y proponer un atlas del estado de conservación de las casas* massone *existentes. Posteriormente, se podrán proponer estrategias para su protección y rehabilitación aplicables a municipios y profesionales. Recientemente se ha identificado que una gran cantidad de casas* massone *puede optar a fondos públicos para su restauración; ya existe una declaración de intención para seguir este enfoque de buenas prácticas, con el fin de abordar mejor la valorización del patrimonio de tierra local.*

Keywords: Abruzzo region, *massone* house, inventory, local know-how, historical memory, rehabilitation, seismic response

The Vernacular Earthen Abruzzo Houses

Earthen Abruzzo houses, part of a fabrication tradition that dates to the second half of the nineteenth century, are located along the hilly zone (approx. 300 m above sea level) of the Adriatic coast, near the provinces of Chieti, Pescara, and Teramo. Their location in this particular geographical context is intimately connected to the presence of readily available earthen material, which demonstrates the close relationship between construction technique and territorial morphology. Contrary to the norm in other regions, where the earth is used to build entire urban centers (such as Sardinia), the situation in the Abruzzo region is quite different, as the use of earth is connected to isolated rural houses with backyards used for cultivation, or alternatively, in small *contrada*, or districts, near the urban center.

The Technique and Traditional Process

Massone, a vernacular construction technique typical of the Abruzzo region, includes the use of raw earth and fibers in its mixture. The *massoni*, different from adobe, are irregular pieces of earth worked by hand that ideally recall the shape of a loaf. This technique is similar to cob, typical of England and Scotland, and bauge, widely used in France. Houses made of *massone* are referred to by this technique's name (fig. 1).

Traditionally, construction materials would be excavated in situ and mixed by workers or animals who crush the components in a pit. In fact, *massone* houses do not have foundations, as their walls rise directly from the ground in overlapping layers of material that form a monolithic structure. The walls have a tapered shape, with thick (80–90 cm) masonry at the base that gradually decreases in thickness as it rises, reaching a height of up to 50 cm.

Massone construction technique is deeply connected to the soil composition, particularly to a high percentage of clay and low quantities of sand. The same technique can be found in the Marche region, which has a similar geological configuration to that of Abruzzo, known there as *atterrato*. An *atterrato* building has similar characteristics to *massone* but is different in that the material is sometimes mixed with fired bricks and lime, lending it waterproofing characteristics.

Both techniques have good seismic responses due to the fact that they are each configured from modular elements, have small wall openings, and are of limited height (maximum two floors). *Massoni* and *atterrati* are therefore conceived according to the "rule of art," which prescribes some constructive expediencies, such as the use of reinforcing wooden elements in the earthen masonry that work as *diatons*, or the use of seismic joints between the original house and any frequent later additions. Moreover, these earthen houses are assembled with only natural materials: the roof has a peculiar configuration composed of traditional tiles placed on top of a light layer of earth that is laid on woven reeds; the structural elements are characterized by wooden beams and wooden rafters (fig. 2).

The mixing procedure often required the engagement of the *contrada* (communities) to build these rural natural homes.

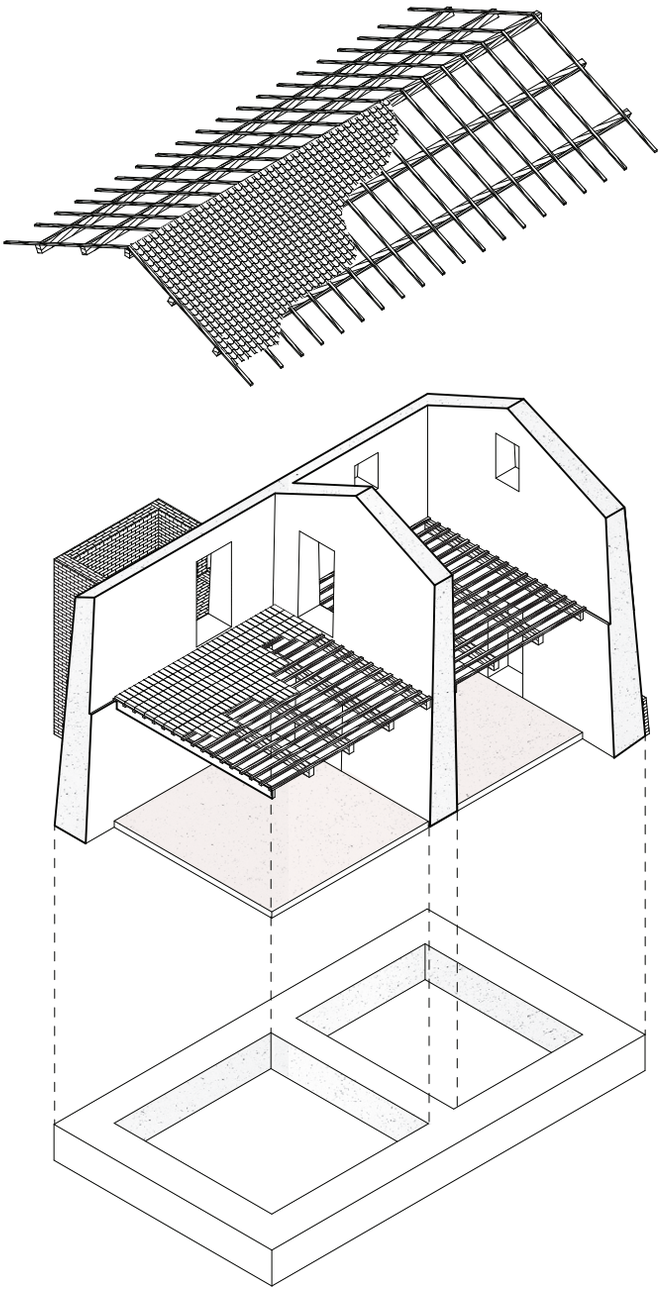


FIGURE 1 Schematic axonometry of a typical *massone* house. Diagram: Ambrantonella Lattanzio.



FIGURE 2 Roof structure of a *massone* house in Manoppello (province of Chieti). Photo: Ambrantonella Lattanzio.

All the participants in the construction had a task, and guidance was given by the "master," an expert mason. Construction generally took place during the spring, and it often took an entire season to finish a structure. Part of this was due to the fact that the individual earthen layers were approximately 80 cm thick, and each layer needed to be completely dried before the subsequent application. The earthen material had to be in a workable, plastic state so that it could be hand-mixed with straw and other aggregates. Once the *massone* was assembled, it was then wrapped in straw to impart a tensional resistance. It is interesting to highlight that the majority of earthen heritage in central Italy was built in the nineteenth century and is still standing even though it has received little maintenance.

Typology

Both *massone* and *atterrato* houses typically have two floors, and the upper floor is accessible from an external fired-brick staircase with a small loggia that works both as a shelter from the sun and as a functional space. As mentioned, earthen houses in Abruzzo are isolated or are often aggregated in small *contrada* such as the Rione Giancola, Malandra Vecchia (province of Chieti), or Cugnoli (province of Pescara), but the cellular configurations of the houses usually do not exceed two attached units. This is different in Borgo Ficana (Marche region), where *atterrati* have terraced configurations wherein structures belong to enclosed rural settlements. The "good boots and good hat" concept applies to all the earthen house typologies, meaning that they need to have a solid structural footing and a consistent, well-insulated roof overhang to provide shelter from the rain and to prevent water from washing out the lime finish.

Table 1 Chronology of Earthquakes between 1706 and 2017 (period related to the construction of earthen houses)

Date (dd/mm/yyyy)	Magnitude	Observed Effects Post-Earthquake
03/11/1706	6.6	Manoppello (PE) was completely destroyed; 212 deaths.
10/06/1841	4.96	Data not found
24/02/1874	5.12	Data not found
10/09/1881	5.41	Data not found
24/02/1904	5.68	Data not found
13/01/1915	7.0	The earthquake caused the collapse of most of the country.
23/11/1933	5.9	The earthquake caused significant damage: many public and private buildings were damaged.
05/09/1950	5.69	
07/05/1984	5.9	The church of S. Lorenzo (Manoppello - PE) collapses. The dome of the church of San Donato collapses (Guardiagrele - CH).
06/04/2009	6.2	L'Aquila was destroyed; 309 deaths and over 1600 wounded.
18/01/2017	5.2	The earthquake of "Central Italy" affected several regions: Abruzzo, Lazio, Umbria, Marche.

Regional Earthen Houses: Seismic Hazards and Field Analyses

The study of regional construction typologies, as well as the technical components that characterize earthen heritage, highlights a know-how that aimed to improve the structures' behavior during seismic activity. Indeed, earthquakes are rooted in Abruzzo's historical memory. By overlaying data from the regional inventory (drafted in 1999) and data related to seismic hazards of the region (table 1 and fig. 3, respectively), it is clear that these vernacular earthen houses were built as a response to seismic episodes (1706–2017) and are located mainly in areas with the highest seismic activity. Nevertheless, field analyses that assessed the damage to earthen houses affected by the earthquakes of L'Aquila in 2009 and central Italy in 2017 (Abruzzo, Marche, Umbria, and Lazio) found that earthen houses did not exhibit severe cracks and, in fact, demonstrated greater resistance when

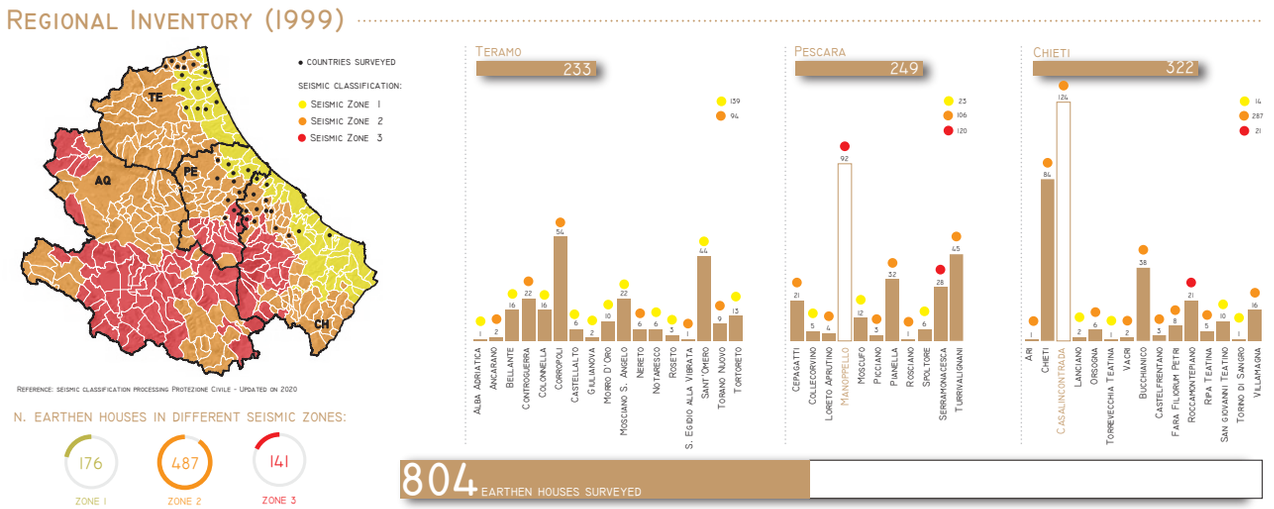


FIGURE 3 Earthen houses in different seismic zones of Abruzzo. Illustrations: Ambrantonella Lattanzio.

compared to certain contemporary constructions. Therefore, it should be acknowledged that the critical conservation state of Abruzzo's heritage is related to the lack of rehabilitation and preservation interventions and, in some cases, to their complete abandonment.

An Updated Regional Inventory of Massone Houses

As mentioned above, many earthen houses in the Abruzzo region have been lost due to a lack of perceived value and of preventive measures. It is clear that a digital inventory of the remaining *massone* built heritage must be undertaken. The public sector plays a powerful role in drafting strategies for the protection and valorization of *massoni* and *atterrati*, but without the efforts of local NGOs such delicate heritage cannot be fully maintained or properly promoted.

Public administration, in cooperation with local associations who are actively engaged in the process of regenerating earthen houses, could supervise and manage conservation projects for this fragile heritage through bespoke software that would increase accessibility with geo-localized mapping. The use of these technologies to investigate the present state of *massoni* by analyzing their applied materials, vernacular constructive technologies, and decay conditions would guide the development of suitable methodologies for their restoration and readaptation to functional and contemporary uses. The result would be an atlas of effective strategies for the restoration and reuse of this heritage.

Certain programs such as Revit, and other Building Information Modeling (BIM) software, enable the possibility of "interrogating" a building by accessing data within the 3D model. The model could contain record cards that include information on the current state of a house, providing a location for data that can be consistently updated by technical experts and used for monitoring in the field. This type of digital inventory of earthen heritage is a valid tool for monitoring the buildings and providing a framework for appropriate and timely interventions.

A digital archive also could be shared with local associations working to enhance the perceived value of earthen heritage. For example, entities such as the International Association of Earthen Cities Network (CRAterre) might lend their support and expertise in keeping the inventory updated. It is therefore important to guarantee frequent inspections and surveys of these vernacular earthen houses in order to provide all the technical information on their current situation and intervene promptly in case of advanced decay. Accessibility and management of the digital archive are essential in the effort to revitalize, regenerate, safeguard, and preserve this heritage.

Ongoing Good Earthen Heritage Valorization Practices

It is important to have an accessible database to map and record the earthen heritage in the Abruzzo region that can be updated by local practitioners in coordination with the municipalities. An updated digital survey should therefore

be at the core of valorization strategies for every village with extant *massoni*.

Another interesting aspect is the possibility to geo-localize such heritage to integrate it with the cultural itineraries promoted by local associations and by CRAterre, including it in the "Terraccogliente" project. Terrae Onlus, a local NGO located in the town of Casalincontrada (province of Chieti), is actively engaged in promoting activities based on the valorization and dissemination of earthen heritage. Significantly, the annual event "Festa della Terra," held in Casalincontrada and celebrating its twenty-fifth edition in 2022, is dedicated to the exchange of knowledge on international earthen heritage in which educational training activities are performed on-site to teach practitioners about the traditional vernacular technique of *massone*.

University students and professionals are often involved in research activities and projects, using the Centre of Permanent Documentation on Earth Houses (CEDTerra) in Casalincontrada as a reference point for their studies. It is essential to establish a thorough understanding of traditional techniques, thus ensuring a continuity between ancient and contemporary building cultures and the transfer of information to future generations.

In addition, it is worthwhile to note that the Abruzzo region recently funded restoration projects (in 2021) for three earthen houses in the provinces of Pescara and Chieti, initiatives that will also be included in the framework of good practices for the valorization and safeguarding of earthen houses. The master plan can be seen from the perspective of becoming a facilitator for a wider regeneration policy of earthen houses and the subsequent implementation of their inventory.



FIGURE 4 House in Roccamontepiano, Cugnoli *contrada*. Photo: Elena De Santis.



FIGURE 5 House in Turrivalignani, Cugnoli *contrada*. Photo: Elena De Santis.

The houses of Rione Giancola (Roccamontepiano) (fig. 4) and Turrivalignani (Cugnoli *contrada*) (fig. 5) were selected to be restored and readapted as part of the master plan. Additionally, the *contrada* of Malandra Vecchia was chosen to be eligible for a landscape design and urban development plan as part of the same regional master plan.

In conclusion, with all of the possibilities for carrying on this virtuous process of strengthening the collaboration between public and private sectors, as well as for finding innovative ways to promote and preserve earthen houses, the digital inventory is one of the leading and essential tools for success.

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PART 10

History of Conservation / Historia de la conservación

Reinstating a Historic Earthen Gate: The North Gate of Al Jahili Fort

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Abstract: *Located in the city of Al Ain, Jahili Fort is considered one of the most important historical earthen buildings in the United Arab Emirates (UAE). Built by Sheikh Zayed I in 1898, the fort underwent different phases of modifications until reaching its present form. One significant change was the disappearance of the original main arched gate on the north side of the fort, which was incorporated into the original boundary wall during the 1980s restorations. This paper presents and discusses the technicalities of reinstating a historic architectural element without undermining the authenticity and integrity of the historic building. Reinstating historic buildings is not the usual conservation practice by the Department of Culture and Tourism–Abu Dhabi (DCT). However, the high symbolic and social values of the north gate of Jahili Fort and the availability of sufficient information led to the decision to reinstate the gate. There was a lack of historical visual materials, for example, with only one picture taken in 1948 by the well-known traveler Wilfred Thesiger. The photo was carefully analyzed to determine the shape of the old gate. In parallel, other research on documentary materials, archaeological evidence, and comparative analysis of different historic gates in Al Ain was done to inform the design and construction. The paper begins with an explanation of the research conducted to arrive at the rationale of designing the Jahili north gate. The second part focuses on the conservation approach, with respect to conservation best practice. The final part describes the implementation phase.*

Resumen: *El fuerte Jahili, ubicado en la ciudad de Al Ain, se considera uno de los más importantes edificios históricos de tierra de los Emiratos Árabes Unidos (EAU). Fue construido por Sheikh Zayed I en 1898 y pasó por varias etapas de modificaciones hasta llegar a su forma actual. Uno de los cambios más importantes fue la desaparición del arco de entrada principal, ubicado en el lado norte del fuerte que se incorporó al muro limítrofe original durante las restauraciones realizadas en la década de 1980. En este artículo, se presentan y analizan los aspectos técnicos del restablecimiento de un elemento arquitectónico histórico sin perjudicar la autenticidad e integridad del edificio histórico. El restablecimiento de edificios históricos no es una práctica de conservación habitual del DCT de Abu Dabi. Sin embargo, el alto valor simbólico y social de la entrada norte del fuerte Jahili y la disponibilidad de la información necesaria condujo a la decisión de restablecer la entrada. Por ejemplo, aunque los materiales visuales históricos eran escasos, había una fotografía que el reconocido viajero Wilfred Thesiger tomó en 1948, la cual se analizó cuidadosamente para determinar la forma de la antigua entrada. Simultáneamente, para respaldar el proceso de diseño y construcción, se realizó una investigación documental y se estudió la evidencia arqueológica y los análisis comparativos de las distintas entradas históricas en la región de Al Ain. El artículo comienza con una explicación de la investigación realizada para llegar al diseño de la puerta norte de Jahili. En la segunda parte, se trata el enfoque de conservación que contempla las prácticas recomendadas para la actividad. En la última parte, se detalla la etapa de implementación.*

Keywords: conservation, reinstating, research, traditional earthen building techniques

Introduction

Al Jahili Fort is an earthen building complex that has come to symbolize Al Ain and its historic past. Due to its prominent and central location in Al Ain, the fort is a visual landmark and distinguishes itself from other forts with its round, terraced tower, large number of rooms, and vast number of enclosed spaces. A source of pride for the community, the fort was built in the 1890s by Sheikh Zayed I, one of the longest-reigning and most illustrious rulers of the Al Nahyan family. It was built as a symbol of power and political stability and was also used as a summer residence (Sheehan 2012).

From the 1950s to the 1970s, the building was used as an army base by the Trucial Oman Scouts, and modifications to its layout and appearance were made during that time. The north gate was subject to major change when it was widened to allow army vehicles to pass through. It is thought that the outer edges of the original gate columns were maintained and made slimmer. While some major restoration activities occurred in the 1980s, the fort remained closed and visits were restricted. One of the modifications of the 1980s was infilling the main gate that was integrated into the boundary wall (fig. 1).

In 2008, Al Jahili Fort was the subject of the first comprehensive rehabilitation project by the Department of Culture and Tourism–Abu Dhabi (DCT) when its outer boundary walls were conserved and rehabilitated into a permanent exhibition gallery, visitor center, and temporary exhibition hall using both traditional and modern techniques (El-Masri 2009).

Reinstating the North Gate

Al Jahili Fort has significant symbolic and political value for the history of Al Ain and its traditional architecture. Moreover, the north gate was a key feature illustrating an important phase of the fort's history (Chabbi 2012). Key stakeholders wished to reinstate this element to provide evidence of this important era.

The main objective of this project was to restore the original gate as an active access point into the fort. Gates in historic forts are usually important architectural and historical features as they reflect the building's style and are often the first thing one sees when approaching. In the case of Al Jahili, the fort's north gate is evidence of the original entry point that was removed in the 1980s restoration. Reinstating

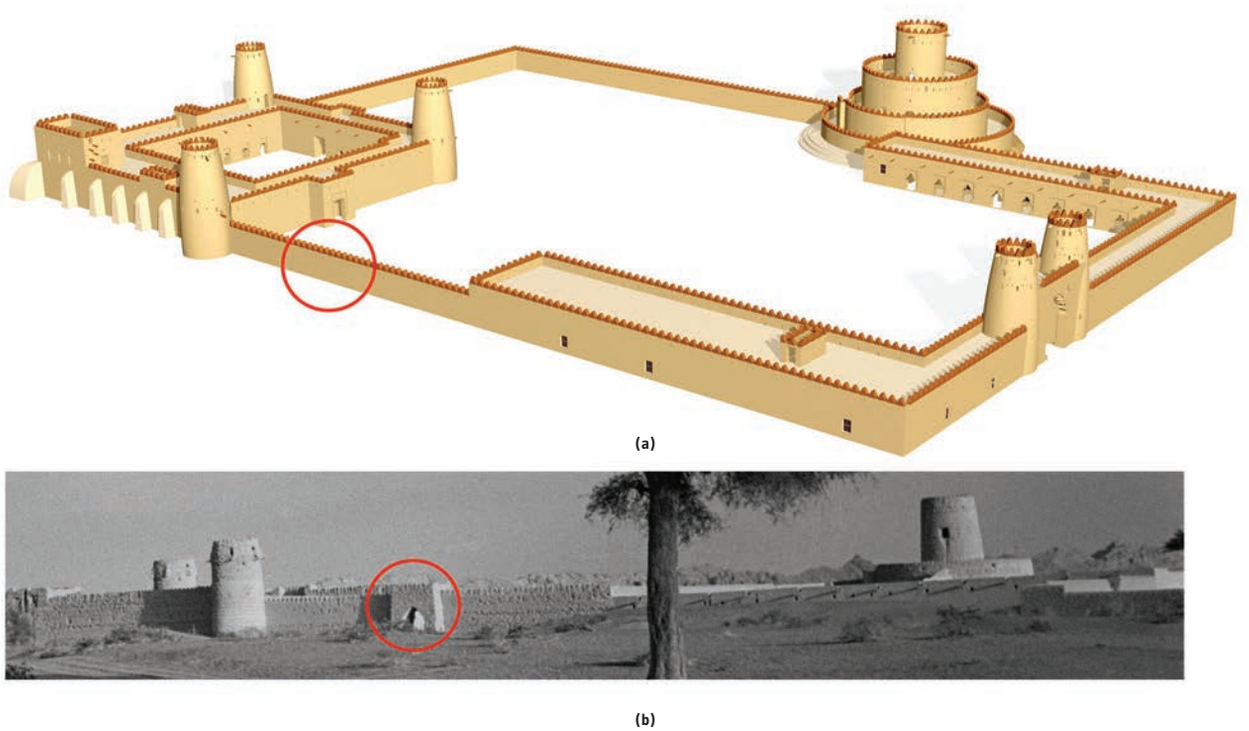


FIGURE 1 (a) Jahili Fort general view, showing the location of the former north gate, and (b) photo by Wilfred Thesiger of Jahili Fort in 1948. Illustration: © DCT Abu Dhabi; photo: Wilfred Thesiger archive, Pitt Rivers Museum.

it would be a significant step in restoring the original context as well as an opportunity to explain the process to the public. From a historical point of view, the gate was a main witness to the changes that occurred at the fort, beginning with the gate's original construction in the 1890s, when the fort was built as a residence for Sheikh Zayed I; its enlargement in the 1950s, when the fort was used as a base for the Trucial Oman Scouts; its concealment during the 1980s refurbishment when a new and different access gate was introduced on the western facade; and, finally, its reinstatement in the 2010s.

The three-pointed, arched gate has a unique architectural shape that is not a common typology in Al Ain. It is mainly seen in Al Jahili area, such as in the south gate of Al Jahili Inner Fort and the adjacent Al Jahili Mosque. From a construction point of view, which will be elaborated on later in this paper, the arch was, in fact, a corbel arch. This explains why these arches in Al Jahili area were supported by thick columns to provide enough strength to bear the weight and resist the sheer forces. This also explains the level of craftsmanship at that time, where it was preferred to build using this easier method instead of true arches. Based on the above historical, architectural, and politically significant values, it was very important to reinstate the gate, celebrate its architectural design, and make it functional again.

The project was based on available information that was used to design and implement a gate similar in shape and location to the original, following best practice in international conservation.[1] This was done to ensure minimal impact on the existing fabric, reversibility of the new construction, and distinguishability between the old and new fabric while using traditional techniques, fully documenting the process, and basing the design on thorough studies.

Research

The only visual resource of the original gate was a photo taken by Wilfred Thesiger in 1948 (see fig. 1). Thesiger was a well-known English traveler who crossed the Empty Quarter twice in the late 1940s. He published his accounts and observations in his famous book *Arabian Sands* in 1959, where he recounted stories from when he stayed with the late Sheikh Zayed bin Sultan Al Nahyan in Al Ain. From the picture, it was clear that the shape of the arch was similar to that of the existing south gate of Al Jahili Inner Fort. Archaeological investigations by DCT uncovered the outer lines of the columns from the exterior and the height of the original gate. Since there was no information available about the interior face of the gate, examples of historic gates around Al Ain were studied to support the design process. These examples were Mezyad Fort's west gate, Muwaiji Fort's south gate, Al Jahili Inner Fort's gate, and Bin Suroor Eastern House's gate. Additionally, DCT's local craftspeople who specialized in earthen construction were solicited for their knowledge of traditional roofing and corbel arches to inform the construction details of the gate.

Analyzing Thesiger's 1948 Photo

The photo was analyzed and cross-referenced on the ground against the existing evidence of the fort's features. The approximate location of the camera was identified by trying to understand the play of shadows of the volumes using the 3ds Max sun simulation plug-in. The shadow of the right column of the gate hits the left corner, but there is still some light on the left side of the arch, which means that the solar azimuth angle was slightly to the north of the gate (this can also be noticed from the shadow of the gate along the boundary wall). We were able to deduce that the photo was most likely taken in the afternoon in early or late summer, when the sun's path is longer and reaches the north part of the gate. This is consistent with Thesiger's accounts of when he visited Al Ain, between April 6 and May 1, 1948 (Thesiger 1959). It is worth mentioning that the photo appears too bright from the inside part of the gate (fig. 2, point 1). This means that the gate opening was too wide on the south side toward the fort courtyard that would not be visible in this photo. This is confirmed by the fact that, from the upper crenellations on the right side of the gate, it appears that the structure extended toward the inside of the fort gate (see fig. 2, point 2), indicating that the interior face of the gate was wider and that the columns were thinner and rectangular in a shape similar to that of the existing south gate of Al Jahili Inner Fort. In any case, this clearly suggests that the interior facade of the gate was not the same size as that of the exterior arched gate, which most probably was rectangular in shape (see fig. 2).

Thesiger's photo was then rectified using Adobe Photoshop and rescaled in AutoCAD using only the length of the outer edges of the remaining columns as measurement references. The photo was then traced from outside and, amazingly, yielded similarities with the existing information and the existing south gate in Al Jahili Inner Fort. The size, height, and proportion of the tracing were similar to the traces of the original photo, taking into consideration the existing boundary wall and the available information on the ground (fig. 3). This demonstrated that both gates were built either in the same period or by the same craftspeople.

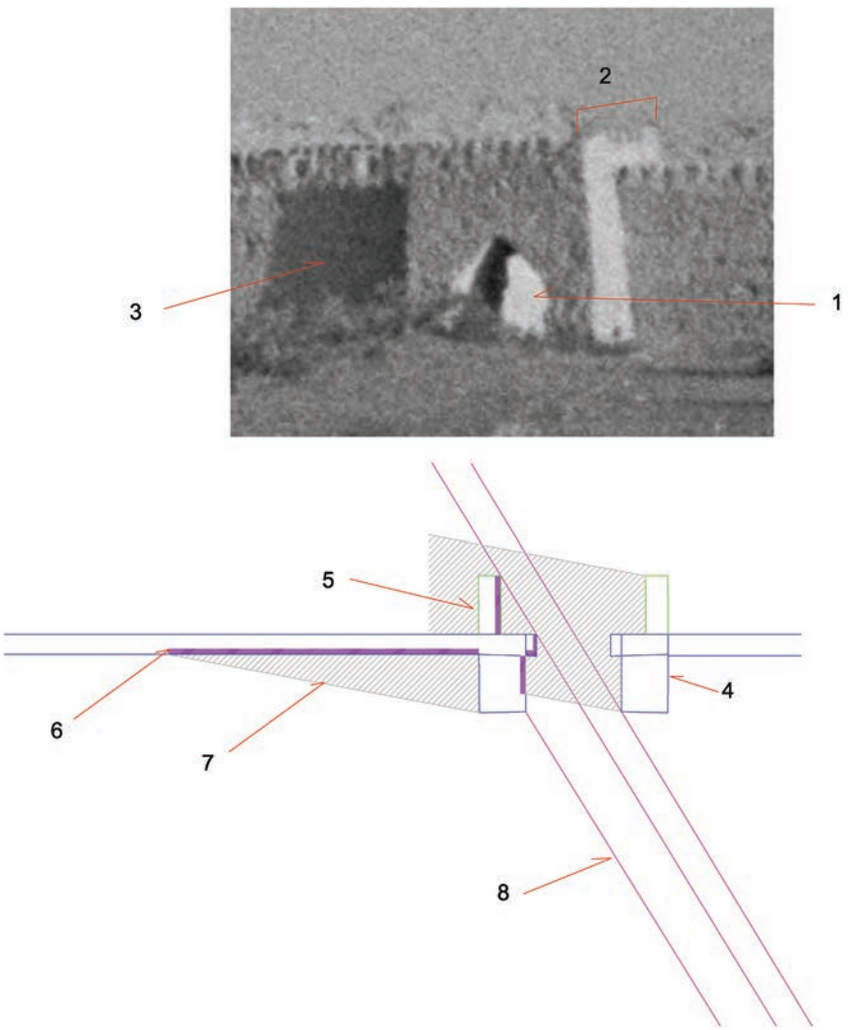


FIGURE 2 Analysis of light and shadow in Thesiger photo, considering the approximate location of the photographer: (1) very bright with no shadow on walls; (2) structure width showing the extension to the inner side of the fort; (3) shadow of the gate, showing the sun azimuth slightly north of the gate sometime in the afternoon; (4) north gate from outside; (5) possible hidden structure; (6) shadow hitting the structure; (7) shadow field; and (8) lines from Thesiger's camera (approximately). Illustration: A. Aqeel, © DCT Abu Dhabi.

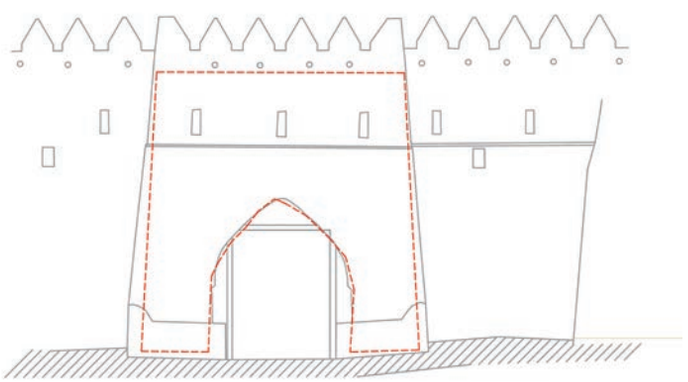


FIGURE 3 The red dashed line shows traces of the north gate from the Thesiger photo. Gray solid lines show the existing south gate of the inner fort. Illustration: A. Aqeel, © DCT Abu Dhabi.

Archaeological Research

As mentioned above, it was known that the gate was subject to major interventions during the 1950s, when the fort was used as an army base for the Trucial Oman Scouts. The gate was most probably widened to allow for trucks to pass through, making the two columns thinner. A focused archaeological investigation was carried out to help define the outer lines of the original gate and to find their traces. The boundary wall plaster was removed to study the fabric through building archaeological investigations. It was then clear that the existing boundary height is original, which helped to give a benchmark level for the original gate and link it to the 1948 photo. Additionally, traces of the foundation bases for the north side were uncovered as part of the adjacent small walls.

On the other hand, from the south facade facing the courtyard, little evidence survived of the gate footprint that is visible in the 1948 photograph, perhaps due to the heavy interventions and demolition done in the 1950s. Nevertheless, this challenge does not mean that no structure existed, as it clearly was apparent in the analysis of the Thesiger photo. It is worth noting that the visual reconstruction of the gate from the north facade, which was based on the Thesiger photo, matches these existing outer lines found under the plaster in the wall and confirmed that the gate was made of mud brick.

Architectural Study of Similar Gates in Al Ain

In parallel with the archival and archaeological research, an architectural study of similar existing gates in old forts and buildings in Al Ain was undertaken. Study of the south gate of Al Jahili Inner Fort helped significantly to understand the arch's building techniques. It was clear that the shape of this arch is almost identical to the one extracted and traced from Thesiger's photo. In addition, in a past plaster repair campaign of the south gate of Al Jahili Inner Fort, it was possible to observe that the corbel arch was built using mud bricks with thin mortar.

Other examples of gates helped to determine the shape of the gate from inside, where visual evidence was lacking. There was only one example of an independent gate such as this one. Most of the gates were usually built in an architectural context, connected to other spaces or rooms such as the gate of Bin Suroor Eastern House, the gate of Al Jahili Inner Fort, and the west gate of Mezyad Fort. The only example of an independent gate was Muwaiji Fort's south gate. This gate has a triangular arch shape that is supported by wooden lintels and has one waterspout along the outer left side. The design of the gate's shape from the inside was based on this example, albeit in a more abstract form without the arch. This will result in a gate similar to the south gate of Al Jahili Inner Fort, which also lacks an arch from the inside.

Mezyad Fort's west gate includes a corbel arch. Although its span is smaller than the one in Al Jahili Fort, the ratio is similar. However, Mezyad Fort's west gate context is different because it is within a boundary wall and is not a separate structure. It might have been inserted into a preexisting cut in the wall.

Design Rationale

Based on the above research and comparative analysis, a design rationale for reinstating the gate was developed by combining the data in different levels of information (figs. 4, 5). Every level contributed to achieving the final design as per the following process:

Level 1:

- Thesiger's 1948 photo confirms the presence of the gate and provides evidence of its external width and shape;
- Archaeological investigations confirmed:
  - The outer lines of the external face of the gate;
  - The height of the original top of the boundary wall.

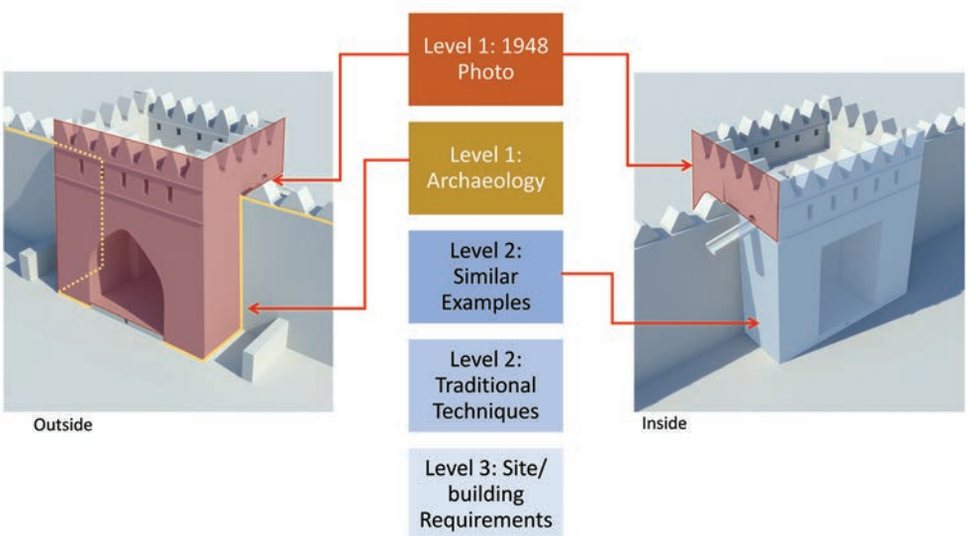


FIGURE 4 Design rationale using the Thesiger photo, archaeological findings, and similar examples. Illustration: A. Aqeel, © DCT Abu Dhabi.

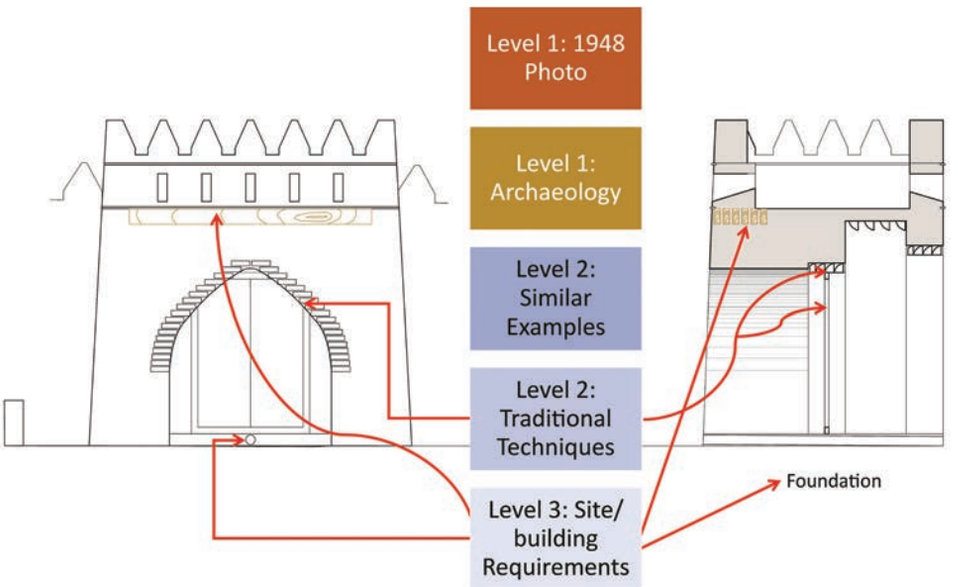


FIGURE 5 Design rationale using traditional known techniques and site requirements. Illustration: A. Aqeel, © DCT Abu Dhabi.

Level 2:

- Architectural study:
  - Al Jahili Inner Fort's south gate confirmed the arch shape and the corbel arch technique;
  - The interior facade of the gate was similar to Muwaji Fort's south gate but in a very abstract and plain style;
  - The corbel shape was similar to that of Al Jahili Inner Fort's gate and Mezyad Fort's west gate.
- Traditional techniques:
  - Using traditional materials for the different parts of the gate (such as mud bricks; earthen plaster, flooring, and mortar; palm roofs, traditional timber doors, etc.);
  - Using the building technique for the corbel arch, mud brick courses, palm lintel alignments, etc.

Level 3:

- Ensuring that the gate can be used as a public entrance by:
  - Putting six treated wooden beams over the arch gate to improve structural stability;
  - Raising the floor of the gate by 20 cm and inserting a water drainage pipe to allow for rainwater to flow and avoid any pooling near the gate;
  - Using plastic mats in the roof stratigraphy of the southern part of the gate for waterproofing;
  - Building foundations for the gate for structural stability.

Conservation Approach

In addition to the previous design rationale, it was essential to protect the existing fabric during the design and construction process and distinguish the old from the new. The remains of the existing old gate columns were covered and stitched carefully with the new construction without compromising their integrity. A geotextile membrane was used to protect and separate the archaeological remains under the new foundation. Plastic mesh was installed over the remaining parts of the columns as a separation layer. Different earthen plaster mixtures were tested to identify a final layer of render that would harmonize with the existing one at Al Jahili Fort while distinguishing it from the existing plaster.

Additionally, and as a common conservation practice in DCT, the reversibility and compatibility of the construction were considered. By using mud as a building material, which is a recyclable material consistent with local traditional practices, the impact of the new material would be minimal as the new earthen fabric would be homogeneous with the old one. The new construction avoided using any permanent or modern building materials such as cement or steel. Finally, the separation layers and detailed documentation ensured reversibility in the future.

Implementation Phase

The construction took approximately six months, from July to December 2013, with a one-month pause to test the structural stability of the corbel arch. The workforce counted an

average of eight craftspeople with one master craftsperson, all of whom are part of DCT's internal team and have extensive experience in building and conserving earthen sites in Abu Dhabi. This team was trained by earlier generations of craftspeople who were in UAE since the first earthen building restoration was commissioned in 1969, for Sultan Fort (Aqeel 2011).

The building techniques followed the traditional construction technique, using layers of sun-dried mud bricks and earthen mortar. The size of the mud bricks matched the common ones in Al Ain—they are square and measure 25 × 25 × 8 cm. The mud was extracted from nearby known and tested earthen layers found in the Al Sarooj area, just south of Al Ain Oasis.

After removing the 1980s section of boundary wall, the implementation started with protecting the existing archaeology and building the foundations over the separation layers of geotextile and earthen plaster. This was followed by building the columns by stitching them to the existing boundary wall and the remains of the original old gate (fig. 6). The structure's construction style was based on the "common bond" style of laying down the mud brick courses. Since the bricks are square, this was the logical style to follow as well as being the traditional one. In some special cases for stitching the new construction to the original or meeting the desired measurements in the corners, the bricks were halved or adjusted in situ.

Once done, a wooden arch frame was installed. This was followed by building the corbel arch as per the design (fig. 7). After reaching the level of the ceiling, the roof was built with one waterspout. The roof layers are similar to the traditional ones found in Al Ain, with the addition of a layer of plastic sheet to improve waterproofing. The roof consists of a series of quartered palm beams, a layer of palm leaf mats, a first layer of mud mortar, a plastic sheet, and a final layer of mud mortar. The roof was leveled in a way to direct the water to the waterspout. The wooden elements were treated with anti-termite material prior to installation.



FIGURE 6 Workers constructing the gate after building the foundation. The 1980s boundary wall has been removed, exposing the original. Photo: A. Aqeel, © DCT Abu Dhabi.



FIGURE 7 Construction of the arch using the arch frame. Weights were placed on the top to test the structural stability. Photo: A. Aqeel, © DCT Abu Dhabi.

Since arches in Al Ain are traditionally corbelled rather than true rounded (see previous section for similar examples), it was important to do a structural test during construction to ensure the stability and strength of the arch (see fig. 7).[2] This consisted of:

- Removing the wooden frame under the arch a few centimeters at a time and monitoring for any structural movement over the period of one week;
- Adding 3.8 tons of load on the top of the arch using dry bricks and sandbags and monitoring for any signs of structural failure or movement over the period of three weeks. The load was calculated considering the deadload of the arch itself, the other layers on the top of the arch that were to be added, and a 30% safety factor;
- Installing, after detecting no signs of structural failure or movement in the first two steps, six treated palm beams to reinforce the current structure as an additional precautionary intervention.[3]



FIGURE 8 Reinstated Jahili north gate after completion of site works. Photo: A. Aqeel, © DCT Abu Dhabi.

Once the test was completed, construction resumed by building the parapet and the crenellations, applying the final roofing layers, applying the different plaster layers, installing the wooden door, and building the final floor with traditional gypsum over the water pipe drainage.

To reach the desired plaster mix, several trials were undertaken to approximate the color and texture of the surrounding. The idea was to make it look similar yet subtly different from the existing boundary wall. Since little information was available on the wooden door in terms of its shape and details, the team referred to the shape and style of doors in other historic buildings. Similar to the wooden roof elements, the door was also treated with termiticide as well as a clear protection coating against weathering.

The implementation was completed with site drainage improvements and water tests at the ground level. Final touches involved replastering all exposed fabric from the boundary wall around the gate. The works were completed in December 2013 (fig. 8).

Conclusion

Reconstruction of historic buildings is not a usual conservation practice at DCT in Abu Dhabi. However, the significant values and availability of evidence made the reinstatement of Al Jahili Fort's north gate possible with little conjecture. The design relied on multidisciplinary research, was based on physical and photographic evidence, and followed international best practice in conservation. Building a corbel arch with mud bricks was a structural challenge that was made possible by adapting traditional building techniques. Al Jahili Fort's gate has been reinstated successfully and is still standing for future generations.

Interestingly, this project highlighted the fact that the three-pointed arch typology is only found in the Al Jahili area within Al Ain. Further research should be conducted to understand the reason for this or if that is, in fact, a true statement. Was this because the builders who built Al Jahili Fort's north gate also built Al Jahili Inner Fort's south gate and Al Jahili Mosque? Another interesting subject would be to research arches in historic buildings of Abu Dhabi Emirate. For example, the stone arches in Qasr al Hosn in Abu Dhabi were true rounded arches, not corbelled.

Acknowledgments

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Notes

1 Venice Charter (1964), Nara Document on Authenticity (1994), Burra Charter (2010).

2 It is known that the corbel arch, or "false arch," is weaker than the true rounded arch.

3 The construction of the gate was completed in 2013. Until today (2021), there is no sign of any structural failures.

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Earthen Architecture and the Idea of Conservation in São Paulo, Brazil

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Abstract: *Modernist intellectuals led the creation of Brazil's heritage preservation agency, the Institute of National Historical and Artistic Heritage (IPHAN), in 1937. This moment showed the construction of a national identity through its cultural heritage. These intellectuals disseminated a culture of preservation that connected Brazilian colonial architecture (produced mainly in the sixteenth and seventeenth centuries) to a modernist ideology. Such a vision can be seen in IPHAN's first actions, in the identification of Brazilian heritage, and in its restoration work. In the state of São Paulo in southeastern Brazil, the architect Luis Saia, along with the modernist writer Mário de Andrade, led the institute for almost forty years. During this period, earthen architecture was recognized as the state's main contribution to the national heritage. The technique called* taipa *(a type of rammed earth construction) was an adaptation of Portuguese structures to the conditions found in the region. This paper reflects on the initial approach taken by IPHAN to the preservation of earthen architecture. As a conclusion, changes in the approach to rammed earth restoration are presented, as well as some ideas on how this knowledge can contribute to establishing public policies for its protection.*

Resumen: *En 1937, la influencia de los intelectuales modernistas llevó a la creación de la agencia nacional de preservación del patrimonio de Brasil, el Instituto do Patrimônio Histórico e Artístico Nacional (IPHAN). Ese momento puso en evidencia la construcción de una identidad nacional por medio de la identificación de su patrimonio cultural. Los intelectuales a cargo de este organismo buscaron hacer eco de una cultura de conservación que conectara la arquitectura colonial de Brasil (construida principalmente en los siglos XVI y XVII) con una ideología modernista. Esta visión se puede observar en las primeras acciones del IPHAN, tanto en la identificación del patrimonio de Brasil como en sus trabajos de restauración. En el estado de São Paulo, al sureste de Brasil, el arquitecto Luis Saia, junto con el escritor modernista Mário de Andrade, dirigió el instituto durante casi cuarenta años. En ese período, se reconoció a la arquitectura de tierra como la contribución estatal más importante al patrimonio nacional. La técnica denominada* taipa *(un tipo de construcción con tierra apisonada) fue una adaptación de las estructuras portuguesas a las condiciones de la región. En este artículo se refleja el enfoque inicial que adoptó el IPHAN en la preservación de la arquitectura de tierra. Como conclusión, se presentan los cambios en el enfoque de la restauración de la tierra apisonada, al igual que algunas ideas sobre la manera en la que ese conocimiento puede contribuir a establecer políticas públicas destinadas a proteger este patrimonio.*

Keywords: Brazilian heritage, history of conservation, public policies, earthen architecture, Luis Saia

Introduction

> The rammed earth symbolizes São Paulo's civilization, giving a peculiar character to its cities and rural constructions.
>
> (Lemos 1989)

The first actions to identify and protect historical monuments around the world were driven by the search for national identity. In Latin America, an important component was added to this quest: the identification of elements that differentiated the newly independent nations from their colonizers. In Brazil, modernist intellectuals led the creation of the federal agency for the preservation of national heritage, associating colonial constructions (from the sixteenth to the eighteenth century) with the national identity.

Unlike Brazilian coastal cities (then important economic centers due to sugar production) or those in the gold exploration area, the region of São Paulo (in the southeast of the country) would only gain similar relevance in the nineteenth century with coffee production. That is, this region did not have a wealthy society during the colonial period (1500–1822), but on the contrary, its buildings maintained a fairly simple architecture, one essentially built of earth. What was the place of this earthen architecture in the first actions for Brazilian national heritage protection? And what is the treatment given to the preservation of this technique?

These are some issues that this essay intends to discuss, from the initial approach to identify and protect Brazilian heritage to the contextualization of earthen architecture to the changes seen throughout the twentieth century. With this purpose, the first part will present the earliest actions to protect heritage in Brazil, identifying the role of earthen architecture. A second part will be focused on the approach to preserving the earthen heritage in São Paulo through the restorations of rammed earth constructions led by architect Luis Saia. Finally, a brief conclusion presents some notes for reflection on possibilities of public policies for the preservation of earthen heritage in Brazil.

First Steps of Heritage Protection in Brazil

The first heritage protection initiatives in Latin America sought to identify the essence of local cultures, with a strong need to create bonds with their own history and their own landscape (Waisman 2013). Cerávolo (2013) presents that, at the end of the nineteenth century, the first protection initiatives emerged with the creation of the General Inspection of Monuments in Mexico, which was focused on archaeological monuments and the great concern about the illegal trade of antiquities from the pre-Columbian period. The debate continued and, at the beginning of the twentieth century, there was a strong dispute in Latin America between historicist and modernist groups seeking to define the conceptual and ideological bases for the identification of national cultural heritage (Fonseca 2005; Gonçalves 1996).

Among various points of divergence between modernists and historicists, one that stood out was understanding the production of neoclassical—or eclectic—architecture, identified with European matrices. Modernists saw such a moment as a hiatus in the authentic national culture, while historicists sought a continuity of their stories also in this period.

In Brazil, the modernist group stood out, integrated into a broader nationalist policy. Thus, in 1937, the current Institute of National Historical and Artistic Heritage (IPHAN) was created. This process was in the hands of modernist intellectuals led by Lucio Costa (architect), Mário de Andrade (writer and poet), and Rodrigo Melo Franco de Andrade (lawyer) (Fonseca 2005). Both Fonseca (2005) and Mota and Lopez (2015) relate that the creation of IPHAN took place within Getúlio Vargas's government, which had Gustavo Capanema as Brazilian minister of education and culture from 1937 to 1945. Both had a project to shape Brazilian nationality, with education as a key element in the process. The modernist vision of heritage contributed to this nationalist political project, with the glorification of the colonial past and the valorization of a future that would be modern (Fonseca 2005; Mota and Lopez 2015). So, national heritage recognition actions were based on the vision of a heritage that connected Brazilian colonial architecture with modernist ideology. The research of Cerávolo (2013) and Gonçalves (1996) shows how this concept can be seen in IPHAN's first actions in heritage recognition and in restoration works.

Internationally, Brazil was inserted into the debate on heritage protection mainly through the Organization of American States (OAS). Fonseca (2005), Silva (2012), and Cerávolo (2013), among other Brazilian researchers, agree that the Charter of Athens (1931) was a milestone for creating heritage preservation structures throughout Latin America mainly due to its discussion during OAS meetings held in 1935. Those meetings culminated in the signature of a Treaty for the Protection of Artistic and Scientific Institutions and Historic Monuments, known as the Roerich Pact. The main concern discussed in the meetings was the illegal commerce

of antiquities. To fight this, the OAS started a dialogue on the governmental level, leading not only to the Roerich Pact but also to the Norms of Quito, in 1967 (Silva 2012). On the other side, technicians inside IPHAN discussed ways to deal with the particularities of Brazilian heritage, keeping in mind the construction of national identity through cultural heritage. This mindset, along with the 1931 Charter of Athens, allowing the use of modern materials in traditional constructions, and an intense modernist architecture movement, created a perfect scenario for large-scale use of reinforced concrete as well as the manufacture of rammed earth constructions (as will be detailed further on).

The first buildings and works of art recognized as Brazilian cultural heritage were those in the Baroque style, found in the gold mining region (current state of Minas Gerais), as Indigenous populations in Brazil produced a nondurable architecture. The great emphasis given to the Baroque encouraged other regions of the country to search for a style that could integrate the Brazilian heritage.

In the state of São Paulo, the great writer and one of the mentors of the modern Brazilian literary movement, Mário de Andrade, was in charge of this task with the support of Luis Saia, then a young architect.

> The criterion for a profitable work of protection and conservation of what the past bequeathed to us must be guided, in the state of São Paulo, almost exclusively from the historical angle. The period that gave to Brazil our most beautiful colonial grandeurs, the eighteenth and nineteenth centuries until the end of the First Empire, São Paulo was downcast, or even unhealed from the setbacks it had suffered. It could not create art monuments. If it is certain that a very patient research can find details of beauty or architectural solutions of technical interest, in a ceiling or bell tower, on a porch or in a gridded window, it is even more undeniable, in my view, that São Paulo cannot present any documentation that, as art, is even close to the architecture or the Baroque statuary, painting, carvings and complete interiors of Rio, Pernambuco or Bahia. The criterion must be different.
>
> (Andrade 1937, 119)

As seen in the above statement, the heritage found in São Paulo did not stand out for its architectonical characteristics. In the first years of IPHAN's operations in São Paulo, a great deal of work was done to identify significant colonial remnants. These were found in earthen architecture. One of the first buildings discovered by Andrade was Sítio Santo Antônio, a rural property dating from the seventeenth century, followed by similar buildings located inside the city of São Paulo such as Casa do Bandeirante, Sítio da Ressaca, and Casa do Caxingui (fig. 1).



FIGURE 1 *Bandeirista* house at Sítio Santo Antônio, which had its restoration works coordinated by Luis Saia (city of São Roque, São Paulo State). Photo: Roger Rosa 2, CC BY-SA 4.0.

Such earthen architecture used a rammed earth technique and was widely disseminated in Brazil by the Portuguese, who taught it to enslaved Indigenous populations (Lemos 1989; Mayumi 2008). It is important to note that this was one of several mechanisms to reinforce Indigenous slavery. Historian John Monteiro, in his classic study about the role of Indigenous cultures in São Paulo's history, shows how colonial labor organization broke Indigenous traditions, creating a new social reality (Monteiro 1994). However, there is no research that can relate Indigenous slavery, either directly or exclusively, to earthen construction techniques.

The use of earthen architecture was consolidated far from the Brazilian coast, particularly in the regions of the current states of São Paulo, Minas Gerais, and Goiás, due to soil characteristics (Lemos 1989; Souteiro 2016). The contribution of Spanish techniques to rammed earth constructions can also be seen in São Paulo, considering the Spaniards' movements through the region due to the Indigenous paths crossing São Paulo, connecting the coast to the region of current Paraguay (Mota and Lopez 2015). According to Lemos (1989), considering the type of soil in the region and the difficulty in obtaining quality stone and wood, São Paulo was built using earthen architecture—mainly rammed earth technique—until the end of the nineteenth century, when constructions with baked clay bricks became common following European immigration.

Therefore, earthen architecture—specifically rammed earth—was recognized as São Paulo's typical heritage. As research on these buildings was carried out, a narrative emerged that reinforced (or even expanded) the value of such buildings, seen in an ideological construction with these houses built of rammed earth (Luis Saia registered this path in his book from 1972). Those constructions were named *bandeirista* houses, celebrating their role in the process of interiorization (from the Atlantic coast to the west) of the Portuguese colonization in Brazil, in expeditions called *bandeiras* (Reis Filho 1970). Restoration works of these buildings intended to reaffirm this idea, supporting the construction of an entire identity (national and local). Even if this is not the subject of this article, it is important to highlight that a large part of this narrative has been questioned within decolonial movements that seek a clearer comprehension of such accounts.



FIGURE 2 Rammed earth ruin with Itaim's *bandeirista* house in the background (city of São Paulo, São Paulo State). Photo: M. Rolim, 2019.

The Idea of Heritage in São Paulo and the Restorations of *Taipa*

After Mário de Andrade's death in 1945, Luis Saia replaced him as director at IPHAN's local office in São Paulo, leading the works there until his death in 1975. The approach adopted by Saia in rammed earth restorations became a reference throughout the twentieth century and is still present today. Most of the rammed earth constructions from the sixteenth to the eighteenth century were found severely degraded, leading to structural reinforcement works, partial reconstructions, or ruins conservation (fig. 2).

In other cases, the buildings were found uncharacterized, with additions that altered their original features. To reinforce the history behind the *bandeirista* houses, the restoration work sought to recover their original configurations. IPHAN's documents show that Lucio Costa and Rodrigo Melo Franco de Andrade (both led all interventions nationally) had the 1931 Charter of Athens as a reference regarding the use of reinforced concrete and the need for careful analysis of interventions and altered elements (Mayumi 2008; Cerávolo 2013). Nevertheless, concerning the removal of newer elements, the works that took place show otherwise, especially because of the high degree of mischaracterization. Thus, many interventions made in São Paulo to the *bandeirista* houses sought to recover their original features in a way they could represent the "legitimate national artistic production" (Andrade 1993).

In this context and considering the role of modernist architecture in the construction of national identity, the use of reinforced concrete was common in works of rammed earth restoration. Concerning the use of concrete in the restoration work at Embu's Convent, Luis Saia wrote to Mário de Andrade, "I have already sent the budget to Embu, with some indications about the process of strengthening the structure with beams and columns of reinforced concrete embedded in the *taipa*. It remains to be seen if IPHAN approves the process. It seems to me the only viable option" (Saia 1972; Rolim 2006).

The proposed intervention changed the structural configuration of the earth, transforming it into a finishing element of a concrete structure. Saia's position was not unique within IPHAN. On the contrary, it followed the logic of the institute in its broader project of valorization and dissemination of modernism—endorsed by the use of modern materials in the 1931 Charter of Athens (Fonseca 2005; Mayumi 2008).

Mayumi's careful research on *taipa* (2008) points out that some traces of these initial restoration works can still be seen. She highlights the continuity of the use of reinforced concrete in the consolidation of massive rammed earth walls and the complete application of lime plaster (understood as a sacrificial surface), which gives a homogeneous appearance to the construction after its restoration and camouflages the new, concrete intervention. While this theory could be accepted for most of the twentieth century, it no longer is today. Advocating for a renewal, or sterilization, of surfaces eliminates evidence of a building's life, contradicting a timeless heritage (Kühl 2004).

Conclusions

> Despite the confidence shown by Rodrigo [Melo Franco de Andrade] and the opinions of Lucio [Costa] and [José de Souza] Reis, I do not want to get myself into a restoration project (although it is only a recomposition study). [...] I think the work should be talked about extensively with the staff who have most familiarity with these works and with the documentation of other regions that the Institute should have.
>
> (Saia 1972; Rolim 2006, 88–89)

The sequence of Saia's letter to Mário de Andrade, regarding Embu's project, well illustrates the scenario in which rammed earth restorations of the last century were made: a time when everything was being discussed—and discovered.

Unfortunately, the approach of using reinforced concrete for different kinds of rammed earth interventions contributed to the acceleration of the disappearance of the traditional knowledge of earthen architecture, making it increasingly difficult to find rammed earth masters in Brazil. It is also difficult to find architects and engineers willing to forgo reinforced concrete. Thus, it is necessary to seek alternatives in the understanding of earthen architecture and to consider interventions of less impact, those which no longer have a cleansing character but rather one of recomposition, maintaining the traces of time.

On the other hand, new approaches are developing, as it is possible to see in initiatives in recent years. Regarding direct interventions on rammed earth structures, there are restoration projects that include reconstitutions without the use of reinforced concrete. Examples include the research conducted by Penido de Rezende (2012) and Salmar and Tognon (2020). In both cases, the authors worked on rammed earth buildings in different Brazilian regions, considering studies of material diagnosis, soil composition, and the monitoring of drying time, among others. Also, both mentioned a lack of debate on methodologies for this type of intervention.

Another aspect of this new approach is valuing the traditional knowledge of rammed earth. A project carried out in 2010–11 worked on intangible heritage inventories related to traditional constructive techniques (Castriota and Souza 2015). The research group was able to identify masters' and practitioners' groups holding specific knowledge related to rammed earth construction. The challenge presented is that of continuity, with the establishment of public policies that can encourage the endurance of such practices.

In brief, the valorization of *taipeiros*—rammed earth masters—becomes essential, as well as encouraging preventive conservation actions that include traditional knowledge. Public policies that can expand knowledge about the technique may contribute to drastically reducing the use of reinforced concrete on rammed earth structures, in a movement that can reclaim not only the earthen architecture but also several traditions related to it.

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PART 11

Modern Buildings / Edificios modernos

Under a Modernist Skin: Preventive Conservation of Traditional Adobe at Georgia O'Keeffe's Home and Studio

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Abstract: *In 1945, Georgia O'Keeffe (1887–1986), one of the most significant artists of the twentieth century, acquired a nineteenth-century adobe ruin in Abiquiú, New Mexico. Over forty-one years, she restored, extended, and remodeled the building, incorporating her unique modernist aesthetic. Wide-span window openings offer expansive views of the landscape but interrupt structural continuity in bearing walls. In 1959, to reduce maintenance, she directed that the traditional mud stucco on exterior walls be covered with wire-reinforced cementitious stucco. These modernist elements introduced new risks to the traditional adobe walls. In addition, cement stucco and wire lath make it more difficult to identify conditions and track potential change using typical visual or nondestructive methods. In 2018 the Georgia O'Keeffe Museum (GOKM), owner of the National Historic Landmark site, engaged a multidisciplinary team to identify immediate and long-term risks to the site posed by the cementitious stucco and large openings, as well as increased visitation, climate change, soils and surface drainage, and other factors. This paper summarizes approaches and outcomes related to site risks, testing methods (infrared imaging, surface-penetrating radar, drill resistance measurement, interval photography, high-resolution crack monitoring), and long-term monitoring methods. It reports promising findings related to drill resistance measurement and adobe condition, as well as a window repair completed in 2022.*

Resumen: *En 1945, Georgia O'Keeffe (1887–1986), una de las artistas más importantes del siglo XX, adquirió unas ruinas de adobe del siglo XIX en Abiquiú, Nuevo México. A lo largo de 40 años, restauró, amplió y remodeló el edificio, al que le incorporó su estética única y modernista. Las grandes ventanas ofrecen amplias vistas del paisaje, pero interrumpen la continuidad estructural de los muros de carga. En 1959, para reducir el mantenimiento, ella ordenó que el revoque tradicional de barro de los muros exteriores se cubriera con un estuco de cemento reforzado con alambre. Estos elementos modernos generaron riesgos nuevos para los muros de barro tradicionales. Además, el estuco de cemento y los listones de alambre dificultaron la tarea de identificar las condiciones y de detectar los posibles cambios mediante los métodos visuales típicos o los no destructivos. En 2018, el Georgia O'Keeffe Museum, institución propietaria del sitio declarado Monumento Histórico Nacional, contrató a un equipo multidisciplinario para identificar los riesgos inmediatos y a largo plazo que el estuco de cemento y las grandes aberturas suponían para el sitio, así como el aumento de las visitas, el cambio climático, los suelos y el drenaje superficial, entre otros factores. En este artículo se resumen los enfoques y los resultados relacionados con el riesgo del sitio, los métodos de pruebas (imágenes infrarrojas, radares de penetración terrestre, medición de resistencia a la perforación, fotografías a intervalos, monitoreo de control de grietas por medios de alta resolución) y los métodos de monitoreo a largo plazo. Se incluye información acerca de descubrimientos prometedores relacionados con las mediciones de la resistencia a la perforación y el estado del adobe, así como de un proyecto piloto de reparación de las ventanas previsto para 2021.*

Keywords: adobe, cement stucco, modernism, New Mexico, risk assessment, drill resistance measurements, nondestructive examination



FIGURE 1 The Georgia O'Keeffe Home and Studio is situated on a bluff at the north edge of the village of Abiquiú, New Mexico, overlooking US Highway 84 below and across the Chama River valley. Site plan, 2018. Photo: Aaslestad Preservation Consulting, courtesy of the Georgia O'Keeffe Museum.

Introduction

Georgia O'Keeffe (1887–1986) was one of the most significant artists of the twentieth century. For the last half of her life, she owned two homes in Abiquiú, New Mexico, USA (Lynes and Lopez 2012). A nineteenth-century traditional adobe home in the village of Abiquiú acquired at the end of 1945 became her primary residence from 1949 to 1984 and inspired many paintings (fig. 1). The restoration and remodeling of the Home and Studio through forty-five years of ownership also demonstrate O'Keeffe's modernist aesthetic. The singular relationship between the artist, her work, and the landscape was recognized by National Historic Landmark designation in 1998.

O'Keeffe's modernist interventions in the traditional architecture have made the Home and Studio vulnerable. Large windows—some almost 16 ft. wide—offer expansive views of the landscape, yet greatly exceed the narrow openings typical of adobe construction (fig. 2). Adobe walls and parapets are concealed by two exterior applications of cementitious stucco. The initial layer was applied by O'Keeffe in 1960, after



FIGURE 2 The highly textured surface of the stucco suggests that this view, titled "Salita Door," was taken by Georgia O'Keeffe in 1960, just before the cementitious stucco was applied that year. The artist said: "That door is what made me buy this house. I waited ten years to get the house, because of that door" (Kotz 1977). Photo: Georgia O'Keeffe, Gift of the Georgia O'Keeffe Foundation, © Georgia O'Keeffe Museum.

she experienced increasing difficulty sourcing local materials and labor to maintain the traditional earthen plaster finish. Thus, conservation philosophy must be considered as well as conservation goals.

Goals

The Georgia O'Keeffe Museum (GOKM) commissioned a multidisciplinary team to identify immediate and long-term risks to the historic resource. In addition to the authors, the consulting team included Peter Aaslestad, Aaslestad Preservation Consulting (documentation); Anthony Crosby, Conservation LLC (adobe conservation); Dorothy Krotzer, Building Conservation Associates (finishes conservation); David Woodham, PE, Atkinson-Noland & Associates (structural engineering). Ed and Jess Crocker of Crocker Ltd. were engaged by the Museum to perform selective removals and restoration of the cement stucco.

The scope of the December 2019 Conservation Assessment was framed to complement Part II of the Historic Structure Report and a Cultural Landscape Report being executed concurrently by Jonathan S. Craig Architect LLC and Julie McGilvray (Jonathan Craig Architect 2018; see also note in References). Tasks included:

- Observe the large-scale contexts and risks of climate, climate change, soils, landscape, and moisture above and below grade;
- Assess long-term stability of the adobe walls and impact of cementitious stucco;
- Investigate long-span openings in the adobe walls and skylight openings in the wood roof structure;
- Identify novel, minimally invasive methods to assess the condition of adobe walls;
- Consider the impact of increased visitation and interpretive activities on historic finishes and adobe flooring;
- Recommend methods for long-term monitoring of key risk and performance factors in the site and buildings and strategies for risk mitigation.

This paper summarizes approaches and outcomes related to the first three goals: risk identification, testing methods, and long-term monitoring.

Overview and Methodology

Long-term integrity of the adobe walls is critical for the structural functionality and longevity of the Home and Studio. Many owners and managers of adobe buildings in the US and elsewhere shared O'Keeffe's opinion that cement stucco was a cost-effective way to protect adobe walls and reduce maintenance. However, this approach has led, in many instances, to unseen, accelerated deterioration of the adobe wall below the hard plaster. The rendering itself is normally not the problem, but it exacerbates the deleterious effect of moisture by restricting the normal evaporative process; retarding drying of moisture absorbed by the adobe from other sources, such as soil moisture or roof leaks; and causing capillary moisture to rise higher in the adobe walls. It also hides conditions that may only be detected when significant damage has occurred.

The wire-mesh reinforcement of each stucco layer at the O'Keeffe Home is secured to the adobe by nails. Some detachment of the nails or recession of the adobe has left voids. If unsupported by the adobe, the considerable weight of the stucco may cause differential movement. The stucco, wire reinforcement, and voids prevent use of testing methods requiring thermal, acoustical, or electrical continuity to assess or monitor changes in adobe condition.

Thus, a central goal of the Conservation Assessment was to identify methods that could benchmark existing conditions and detect slow change with acceptable resolution and precision. The Museum could then monitor the "health" of the adobe walls and assess the efficiency of preventive conservation strategies, such as source moisture control.

The project team visited the site on three progressively focused assessment campaigns during 2018 and 2019. Based on collaborative review of available records and well-documented observations, the team narrowed its attention to examples where causative factors and deterioration were potential "leading indicators" of problems that could occur elsewhere in the future.

Data Collection

The following data were fundamental in the investigation (all data privately held by the Museum):

- A topographic site survey by Bohannon Huston to assess surface water drainage;
- A geotechnical investigation by GeoTest to assess soils composition and subgrade hydraulic properties;
- High-resolution architectural documentation prepared by Aaslestad Preservation Consulting using laser scanning;
- Mapping of prerestoration adobe and adobe reconstruction by Scattergood Design and Building

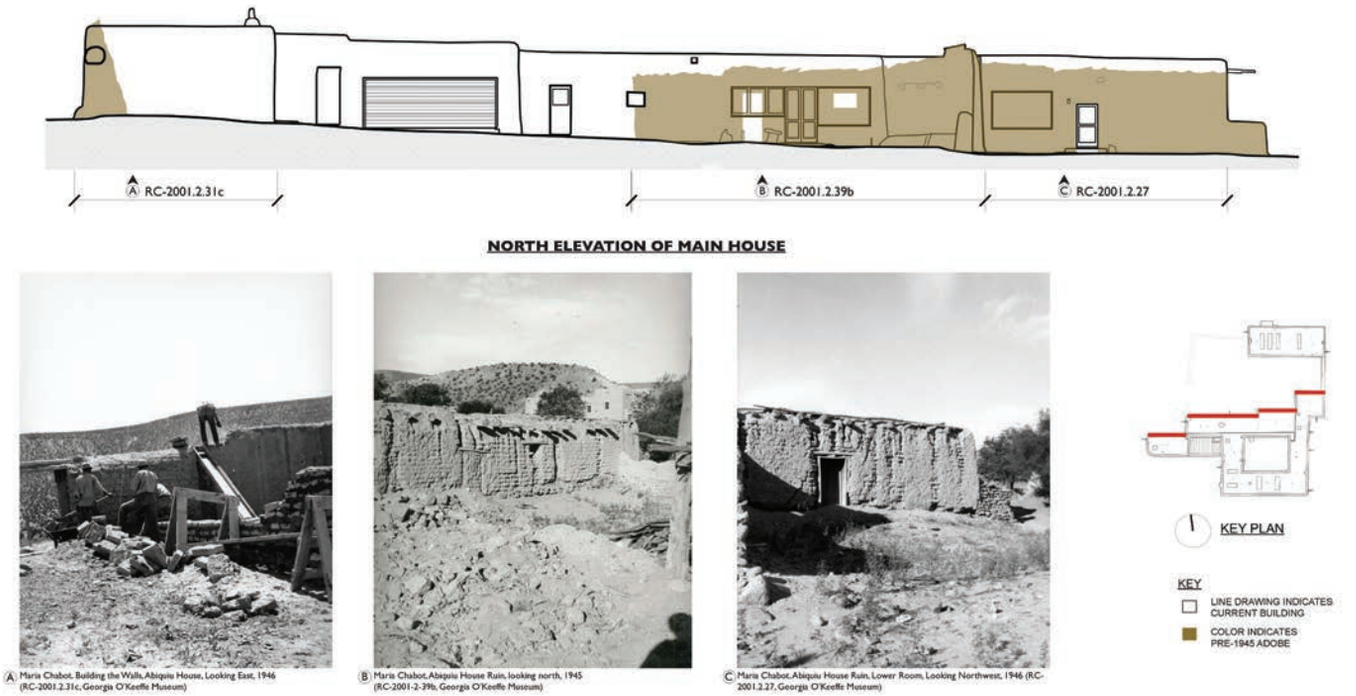


FIGURE 3 Composite view of north elevation of O'Keeffe Home. The authors documented the extent of material in place before restoration by analyzing historic views. These were mapped by Building Conservation Associates on a new, extremely accurate set of plans, elevations, and section drawings created by Aaslestad Preservation Consulting from 3D laser scanning and photogrammetry, completed October 2018. Exterior elevations, interior elevations, floor plans, and reflected ceiling plans were further enriched by the inclusion of high-resolution ortho-photographic imagery. Illustrations: Building Conservation Associates, courtesy of the Georgia O'Keeffe Museum.

Conservation Associates based on chronological study of 1940s photos (fig. 3);

- A weather monitoring station that uploads data to a secure website, including air temperature and relative humidity, wind speed and direction, rain, and solar radiation;
- Visual monitoring using interval cameras to track wetting patterns from snow and rain in key areas to supplement quantitative data captured by spot readings or sensors.

Testing and Data Collection Methods

Several non-destructive examination (NDE) and minimally destructive technologies were tested at the Home and Studio to determine suitability for measurement of slow change over time. Notes on effectiveness are provided below and sample results for key locations are indicated in table 1:

- Infrared Thermal (IRT) Imaging, under appropriate conditions of evaporative cooling or thermal transmission, can indicate voids or moisture in cement stucco, adobe, or wood. However, discontinuities between the stucco and the adobe limited usefulness of IRT to the stucco, preventing assessment of adobe moisture;
- A Capacitance-Type Moisture Meter can indicate the moisture just below a surface and therefore confirm moisture indicated by the IRT camera, but discontinuities between the stucco and the adobe limited usefulness of capacitance measurements in assessing adobe moisture;

Table 1 Selected Results of Mechanical Drilling and Resistance Drilling (Atkinson-Noland & Associates)

Location	Sample (Drill Hole) #	Date	Height above Grade	Depth in Wall	Moisture	Manually Perceived Resistance	Mean Drilling Resistance	Comments
N wall of Room 13 (Lower Bedroom)	1	4/15/19	11″	12″	Dry	High	16%	Cement stucco 1¼″ thick with 3⁄16″ gap between stucco and adobe. Drill bit hit hard object at 9″ depth
S wall of Room 13 under windowsill	3	4/15/19	13″	3″				Drill went through the crack easily with surrounding cement fragments filling the drilled hole
W wall of Room 10 (Sitting Room) above buttress	4	4/15/19	13″	9″	Dry	High	14%	51¼″ from the south wall of Room 12, above the contra pared. 1⅜″ stucco thickness — no gap between stucco and adobe
W wall of Room 10	5	4/15/19	66.75″	12″	Dry	High		106½″ from south wall of Room 13. 1¾″ thickness of stucco. No gap between stucco and adobe
W wall of Room 10	13	6/18/19	32″	14″	Dry	High	23%	52″ S of Hole #5. 1¾″ stucco thickness
W wall of Room 10	14	6/18/19	29″	16″	Dry	High	18%	15¾″ N of chimney. 1½″ stucco thickness, ¼″ gap between stucco and adobe
W wall of Room 10	15	6/18/19	29″	16″	Dry	High	95%	1¼″ stucco thickness. No gap between stucco and adobe. Gap of 1″ at ~10″ depth
W wall of Room 1 (Studio)	21	6/17/19	28″	16″	Dry	Med.		Stucco 1″ thick. Less consolidated to 10″ but denser from 10″ to 16″
W wall of Room 1 (Studio)	22	6/19/19	56″	16″	Dry	Med.		Stucco 1½″ thick. Soft spot at 3½″ to 4½″. More consolidated for last few inches
W wall of Room 10	26	6/19/19	16″	9″	Dry	High		Located under *canale* at possible previous repair. Consolidated to 8″ depth, hit stone at 9″ and stopped drilling
W wall of Room 10	Drill Hole 27	6/19/19	12″	16″	Dry	High		Drilled through hard section (rock?) to 16″ depth

- Surface-Penetrating Radar (SPR) can measure wall thickness, indicate voids within adobe walls, or detect other anomalies or embedment. Unfortunately, the two layers of metal wire mesh reinforcement reflected the radar signal and prevented imaging of the adobe material beyond the stucco. However, SPR was useful in locating the steel lintels spanning wide window openings in the Studio and in O'Keeffe's bedroom.

The following methods are considered minimally destructive:

- Manual Resistance Drilling (MRD) is commonly used to qualitatively gauge the relative density of an adobe brick. Low resistance indicates low density, which is an indicator of moisture damage. Areas where observations suggested likely deterioration were probed with MRD. Unfortunately, MRD lacks the resolution and repeatability necessary for long-term monitoring, though samples taken from the 0.5 in. drills were tested for moisture content;
- Drill Resistance Measurements (DRM) tabulate resistance to a drill as it advances in a bore. Resistance can be correlated to material density or compressive strength based on laboratory testing and has been used extensively for wood, mortar, and stone. In a trial for adobe assessment, the project team used a Rinntech Resistograph (fig. 4) designed for timber, which required drilling a small pilot hole through the stucco. The field test provided qualitative documentation of apparent density that is superior to the qualitative assessment of MRD (fig. 5). Thus, it appears promising as a long-term monitoring method at the Home and Studio, but laboratory testing is required



FIGURE 4 Dave Woodham of ANA drilling with a Rinntech Resistograph at the corner of the Sitting Room. Photo: Dale Kronkright, courtesy of the Georgia O'Keeffe Museum.

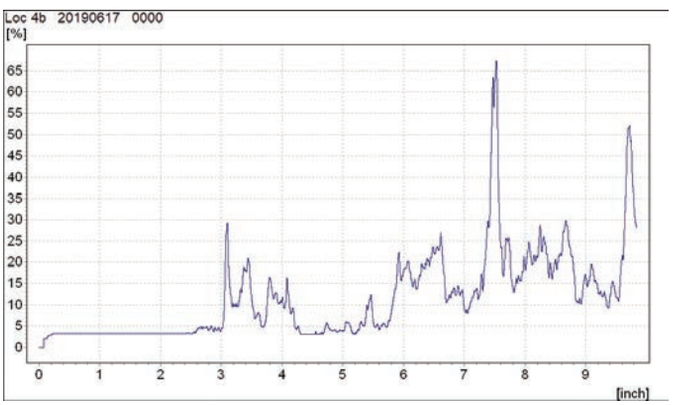


FIGURE 5 Plot of drilling resistance vs. wall depth at Hole 4 on west elevation of the Sitting Room. Depth scale along x-axis is in inches. Vertical scale is resistance in percent of maximum. Photo: David Woodham, Atkinson-Noland & Associates.

to correlate DRM readings to adobe density and moisture content;

- A fiber-optic videoscope provides axial and sideways views of a hole drilled through the wall assembly, permitting observation and images of materials, material condition, voids, and discontinuities. Although the observable surface area in the drilled bore is small, the fiber-optic videoscope may provide sufficient information to eliminate the need to remove large areas of stucco. The images were especially helpful in assessing adobe surface condition and the withdrawal and corrosion of the nails securing the stucco to the adobe (fig. 6);
- Exposure of adobe by removal of a cement stucco panel allowed close examination, sampling, and documentation of the adobe bricks and joints and any remnants of mud plaster (fig. 7). Panels measuring 24 × 24 in. were removed in two locations selected after anomalies were identified during the manual resistance drilling and non-destructive examination.



FIGURE 6 Videoscope image showing view downward in the small cavity between the stucco and adobe wall near the base of the wall. This condition was typical at locations up to 2 ft. above grade. Hole 13 on the exterior of the west wall of the Sitting Room [10], June 18, 2019, 9:07 am MDT. Photo: David Woodham, Atkinson-Noland & Associates.

Key Findings

Site Context and Risks

The regional, local, and site contexts of the Home and Studio pose a variety of present and possible future risks to the buildings and contents. The team reviewed historical data for risks such as seismic activity, flood, lightning, hail, and wind, as well as the potential consequences of present and future climate change. The assessment was not limited to single events but also included consideration of coincidental events, such as the impact of flooding of the Rio Chama and the response time and access to the site by the Abiquiú Volunteer Fire Department. Key findings were that:

- Fire and collateral damage from smoke and water present the greatest risk of loss to the Home and Studio. Risk factors to the buildings included internal



FIGURE 7 Removal of two layers of cement stucco by Crocker Ltd., revealing earlier-repaired adobe and mud stucco layers. Photo: Pamela W. Hawkes, Scattergood Design.

or external ignition sources such as electrical wiring, village fireworks, or wildfires, rapid fire spread in the highly combustible wood ceiling/roof cavity, delayed fire department response and deployment of fire-fighting apparatus, and combustible materials and fuels stored on-site or in the garage. The absence of a comprehensive, very early detection system for wildfires and structural fires is a particular concern;

- Climate change is likely to introduce new factors or exacerbate existing factors that pose direct or indirect risks to the Home and Studio. For example, increased intensity and frequency of rain events may overload roof drains and site drainage, increasing the availability of soil moisture to be absorbed by the adobe or generate more extreme shrink/swell cycling of soils. Wind events of higher frequency and speed may overload large windows and frames and cause uplift and damage to the roofing membrane;
- Seismic action may result in lateral forces that cannot be resisted by poorly braced walls or walls interrupted by large window openings. Both structures are assigned to Seismic Design Category D assuming Risk Category II (Applied Technology Council 2022).

Adobe Walls

Despite the low permeability of exterior cement stuccos and concrete floor slabs, adobe materials in the majority of the drilled holes were dry. There are gaps and soft spots at the contact surface between the adobe wall and the exterior cementitious stucco. This is a typical phenomenon in stucco-clad walls, the rule rather than the exception in similar conditions. Where examined, the adobe material was judged to be in reasonable to good condition and suspect areas were identified for future monitoring.

- However, pre-renovation photographs (see fig. 2) indicated the original adobe walls had been in poor condition, and the lack of information on structural repairs posed the prospect of multiple discontinuities in wall repairs in all nineteen rooms of the Home. These discontinuities and variations in wall thicknesses throughout the building, new wall openings for doors and windows, and lack of information regarding continuity at intersecting walls present concerns for structural performance during seismic events.
- As expected, wind stresses in the adobe walls at the Home and Studio are low due to the large wall cross sections and the cellular construction (in plan) typical of adobe structures. All walls meet the maximum height-to-thickness criteria established in the 2015 *New Mexico Earthen Building Materials Code*, with some exceptions to be studied further (Construction Industries Division of the Regulation and Licensing Department 2015).

Windows and Doors

The windows (fig. 8) and doors constitute the most vulnerable areas with respect to adobe durability and performance. The intersections of adobe and cement stucco with wood and metals must accommodate different rates of expansion/contraction or deflection of each material as they respond individually to thermal, moisture, and wind loads on the exterior.



FIGURE 8 View of Fita's bedroom window, one of the wider window openings at the Home and Studio, though not the widest. Note cement stucco has lapped over sill and frames. Photo: Pamela W. Hawkes, Scattergood Design.

Historic photos of windows before the stucco application suggest a clear demarcation between the wood frame and adobe, with projecting sills to protect the walls below. This detail is important, as wood and adobe have different service lives based on durability and maintenance. When the cement stucco was applied in 1959 and reapplied in 1995–96, the layers were lapped over the wood frames and sills, creating the potential for water to penetrate the stucco/wood intersection and enter the adobe. Thus, water drainage at sills is poor and the drying surface of the wood is reduced.

As a result, many of the sills and jambs are in poor condition, some completely rotted, providing more opportunities for water to enter the adobe behind the stucco. Downward capillary flow and restricted drying can result in concealed deterioration of the adobe. Deterioration of the wood frames reduces their capacity to resist wind loads and can weaken the vertical support of the glass.

Key recommendations to be implemented by the Museum:

- Continue monitoring the condition of the adobe. Implement a testing protocol for the DRM in adobe. Apply it to adobe walls of the structures at six-month intervals for the next five years, then adjust the interval based on the rate of change in the condition of the adobe. Compare the adobe results to the moisture monitoring results and develop appropriate actions to improve the effectiveness of source moisture control. A grant was awarded to ANA in 2021 by the National Center for Preservation Technology and Training to further develop the DRM method in earthen structures. One product of the study will be a test protocol that Museum staff could use to evaluate adobe conditions;
- Monitor moisture content at critical "leading indicator" wall locations representing the full range of possible moisture conditions. Monitor weather conditions, soil moisture, and temperature at vertical intervals in the wall adobe, temperature and relative humidity of the stucco/adobe cavity, soil moisture and temperature at the wall foundation, and interval photography of wetting/drying of the wall and ground surfaces. Compare four seasons of data to find correlations and causalities in moisture uptake by the adobe and to assess efficacy of interventions (to be completed by consultants when funding is available);
- Implement source moisture control to reduce the moisture risk to the adobe, including engaging a professional engineer to analyze the roof drainage, flow capacity of the *canales* (that channel rainwater from the roof through the parapet and extend beyond the wall face), effectiveness of the at-grade catchments, and the drainage piping. Implement the necessary improvements to resolve immediately observable locations for ponding or soils saturation;
- Monitor structural movement (rate of change and directional movement) of adobe walls with Accugage and Moire crack gauges where lateral or vertical movement has occurred. This was initiated during the last site campaign, but monthly recording of the monitors was impacted by staff limitations during site closure for the COVID-19 pandemic. Once recording resumes, a professional engineer will analyze the recorded data and determine the appropriate remedial action.

2021 Pilot Project

The study postulated that progressive damage to adobe or wood frames at the large windows would have serious structural implications for supporting the vigas and roof framing above the window opening. Damage could also interfere with the structure's ability to resist lateral loads from wind. Developing an assessment and repair strategy for the large

windows was identified as a high priority, and the Museum engaged the conservation study team to undertake a pilot project, which was started in the summer of 2020 and completed in the spring of 2022 with the assistance of Crocker Ltd.

Work focused on the twentieth-century window in the north wall of the Lower Bedroom, where cement stucco was removed to examine the adobe and window conditions and construction details, supplementing previous investigations. Key findings of on-site and laboratory testing were:

- A built-up 12 × 27 in. timber header spans the opening with approximately 16 in. of bearing on the adobe walls. The top of the window frame is connected to the header with larger diameter nails that penetrate the window frame, an approximately 0.25 in. gap, a nominal 1 in. block, and then the wood header;
- A leveling course of formed concrete was placed immediately below the wood sill plate for the window. The depth of the course varies between approximately 4 and 6 in. The wood sill may have been "wet set" into the concrete while it was still plastic and there appear to be six to eight nails in the sill in a staggered pattern that could have been partially driven into the sill's bottom face and then pressed into the freshly placed concrete. A similar concrete course was detected by SPR at all the large windows created during the 1946 restoration;
- No wood blocks or possible window frame connections of any kind were found at the jamb;
- The resistance drill proved to be a good way to investigate condition of the wood lintels over the large openings and thus a valuable tool to assess areas where cracks or other evidence of movement appear. The lintel was relatively intact;
- The adobe is not particularly strong, with 220–30 psi at ambient moisture content, and shrinkage is relatively high. Water vapor transmission of the stucco indicates that it is somewhat, but not very, breathable. The adobe loses compressive strength at around 10% moisture content and falls rapidly above that;
- The wood quarter rounds holding the glass to the wood frame appear adequate to support the glass given anticipated wind loads.

The lack of rigid connections between the window frame and adobe was felt by the team to be a positive feature, providing a transition between the adobe, which has high movement due to swelling and shrinkage, and the glass, which does not tolerate movement of the surrounding opening. The team's goal had been to develop new window details that could improve maintenance and performance. Given the relatively good performance of the assembly over seventy years, however, the team selected a conservation approach and this limited the number of enhancements that can be made, but interventions will include:

- Using stainless steel screws to improve the connection of the frame to the wood header;
- Tooling the new stucco at the edge of the opening at the window's head to provide a drip edge;
- Removing select adobe bricks to install wood blocks of a naturally rot-resistant wood at roughly third points of the jambs and fasten to the jambs;
- Attaching a new strip of wood on the outer edge of the existing frame to receive the lath and create a recess for sealant;
- Installing copper flashing under sill.

No long-term monitoring sensors will be installed, but the window assembly and stucco will be observed for movement. Work was completed in the spring of 2022 and presented as part of the Terra 2022 13th World Congress tours.

Note

The Library and Archives of the O'Keeffe Museum (https ://okeeffemuseum.libguides.com/library) include digital copies of correspondence between Georgia O'Keeffe and Maria Chabot, as well as photos of the house before, during, and after construction by Chabot and O'Keeffe. This paper summarizes extensive research into those primary source materials, which are cited in more detail in the Conservation Assessment.

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Nineteenth-Century Earthen Architecture of Southern Ontario

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Abstract: *In terms of geology, Upper Canada (now Southern Ontario) is characterized by expansive terraces of flat land with vast deposits of heavy clay interspersed with stretches of sand and gravel, formations that were once the beds and beaches of glacial lakes that antedated the current geography of the Great Lakes. The suitability of this clay for many homesteading tasks was recognized early on by European- and American-born colonists during the provincial settlement period. As homesteading gave way to prosperity, these prevalent clay soils were chosen by some for the construction of permanent homes and other buildings, resulting in no fewer than 234 earthen dwellings across the territory of Upper Canada. The architectural styles were identical to those of frame or brick and included both common and polite structures. The period of earthen building lasted from the early to mid-nineteenth century, and from it emerged two principal typologies of load-bearing earthen wall construction that are directly traceable to the vernacular traditions of British Isles immigrants: mud brick and shuttered earth. At least nineteen of these structures survive today. This paper investigates the scope, impetus, and origins of Ontario's earthen building trend by analyzing historical census data, primary and secondary accounts, and extant structures.*

Resumen: *En términos geológicos, el Alto Canadá (ahora el sur de Ontario) se caracteriza por terrazas expansivas de tierra plana con vastos depósitos de arcilla pesada intercalados con tramos de arena y grava, formaciones que alguna vez fueron los lechos y las playas de lagos glaciares que antecedieron a la geografía actual de los Grandes Lagos. Los colonos europeos y aquellos nacidos en el continente reconocieron de forma temprana la adecuación de esta arcilla para muchas tareas de construcción durante el período de asentamiento provincial. A medida que la construcción dio lugar a la prosperidad, estos suelos compuestos principalmente de arcilla fueron los elegidos para la construcción de viviendas permanentes y otros edificios, lo que dio como resultado 234 edificaciones de tierra en el territorio del Alto Canadá. Los estilos arquitectónicos eran idénticos a los de ladrillo e incluyeron estructuras comunes y más refinadas. El período de construcción de tierra duró desde el inicio hasta mediados del siglo XIX, y surgieron dos tipologías principales de construcción de muros de carga de tierra que se relacionan directamente con las tradiciones vernáculas de los inmigrantes de las Islas Británicas: el adobe y la tierra compactada. En la actualidad, al menos diecinueve estructuras se mantienen en pie. En este artículo, se investiga el alcance, el ímpetu y los orígenes de la tendencia de construcción de tierra en Ontario mediante el análisis de datos de censos históricos, cuentas primarias y secundarias, así como estructuras existentes.*

Keywords: mud brick, shuttered earth, Ontario, Canada

Introduction

The Upper Canadian settlement period is classically represented by log cabins or frame cottages in thickly wooded settings. Furthermore, earthen buildings are not normally associated with humid continental climates, where hot summers and cold winters are accompanied by year-round precipitation. Yet today, at least nineteen mud brick and shuttered earth (a form of cob) structures with construction dates ranging from ca. 1816 to 1850 are known to be extant. Dotted across a 200 × 75 mile stretch of Ontario, they include seventeen dwellings of various stature, a church, and a former blacksmithery. Personal census returns for Upper Canada taken in 1851 and 1861 confirm that these buildings were part of a wider phenomenon of vernacular construction that included at its zenith no less than 234 earthen dwellings across the territory. This paper investigates the scope, impetus, and origins of Ontario's earthen building trend by analyzing census data, primary and secondary historical accounts, and extant structures.

Background

Southern Ontario was originally named Upper Canada for its position along the St. Lawrence River, which drains the Great Lakes Basin eastward to the Atlantic Ocean. In terms of geology, the region is characterized by expansive terraces of flat land with vast deposits of heavy clay interspersed by stretches of sand and gravel, formations left by glacial lakes from over 14,000 years before the present (Larson and Schaetzl 2001).

With the signing of the Treaty of Paris in 1763, France ceded all of Canada to Great Britain, ending the Seven Years' War in the Americas. The long-settled eastern portion was upheld as culturally French Catholic under protection of the Quebec Act while the western portion was set aside as a reserve for Indigenous inhabitants. This western territory stayed largely untouched by white settlement until the American Revolution (1775–1783) spurred loyalist refugees to flee northward. As land and governance were needed to accommodate increasing numbers of loyalists, the former Indigenous reserve was officially opened to settlement as the Province of Upper Canada in 1791.

Foreign-born migration began to outpace American-born migration to Upper Canada in the early nineteenth century. Britain's literate classes were attracted by land grants for half-pay officers, positions in the colonial government, and positive reports back in the form of books and letters (Miller 1968). Economic changes brought on by the Industrial Revolution prompted subsequent waves of migration from all social classes. By 1851, the population of Upper Canada had reached 952,000.

In Ontario, the prevalence of clay soil and the challenges to early pioneers are well documented in accounts of the province's development; by the 1830s, the capital city, Toronto, had earned the epithet "Muddy Little York" (Smith 1923). However, settlers found the clay suited for many tasks in building temporary and, later, permanent structures. Examples of non-load-bearing clay use included log cabins daubed with earth putty to stop wind and wooden walls coated with earth plasters and renders. Chimneys for cooking hearths were built of "sticks and puddled clay," which hardened as fires were made (Smith 1923).

Settlers typically homesteaded on land grants of 200 acres, quickly erecting shanties, followed by log cabins. Log dwellings were typically intended by their inhabitants as temporary structures, necessary and expedient to the process of settlement (Macrae and Adamson 1963). As homesteading gave way to prosperity, unfired clay was chosen by some families for the construction of the first permanent dwellings to replace log cabins. According to an 1843 article in the *British American Cultivator*, an agricultural journal published in Toronto, houses of unburnt brick construction were "admirably adapted to the peculiar circumstance of Canadian settlers," for both their economy and their ease of construction (Edmundson 1843, 21). One year earlier, the same journal had reported that over 200 such homes stood within a 40-mile radius of Toronto (Edmundson 1842).

Census Returns

The 1851 and 1861 Canadian population censuses collected data concerning dwellings, including the construction material and number of stories. Due to the date range for construction of earthen structures (ca. 1815 to 1855, with most structures built between 1835 and 1845[1]), the 1851 census returns formed the focus of study. Returns were reviewed township by township for each county in Upper Canada. As not all 1851 returns have survived (including the whole of Simcoe County), 1861 returns were used to fill in the gaps such that each township surveyed is represented by one dataset only (fig. 1).

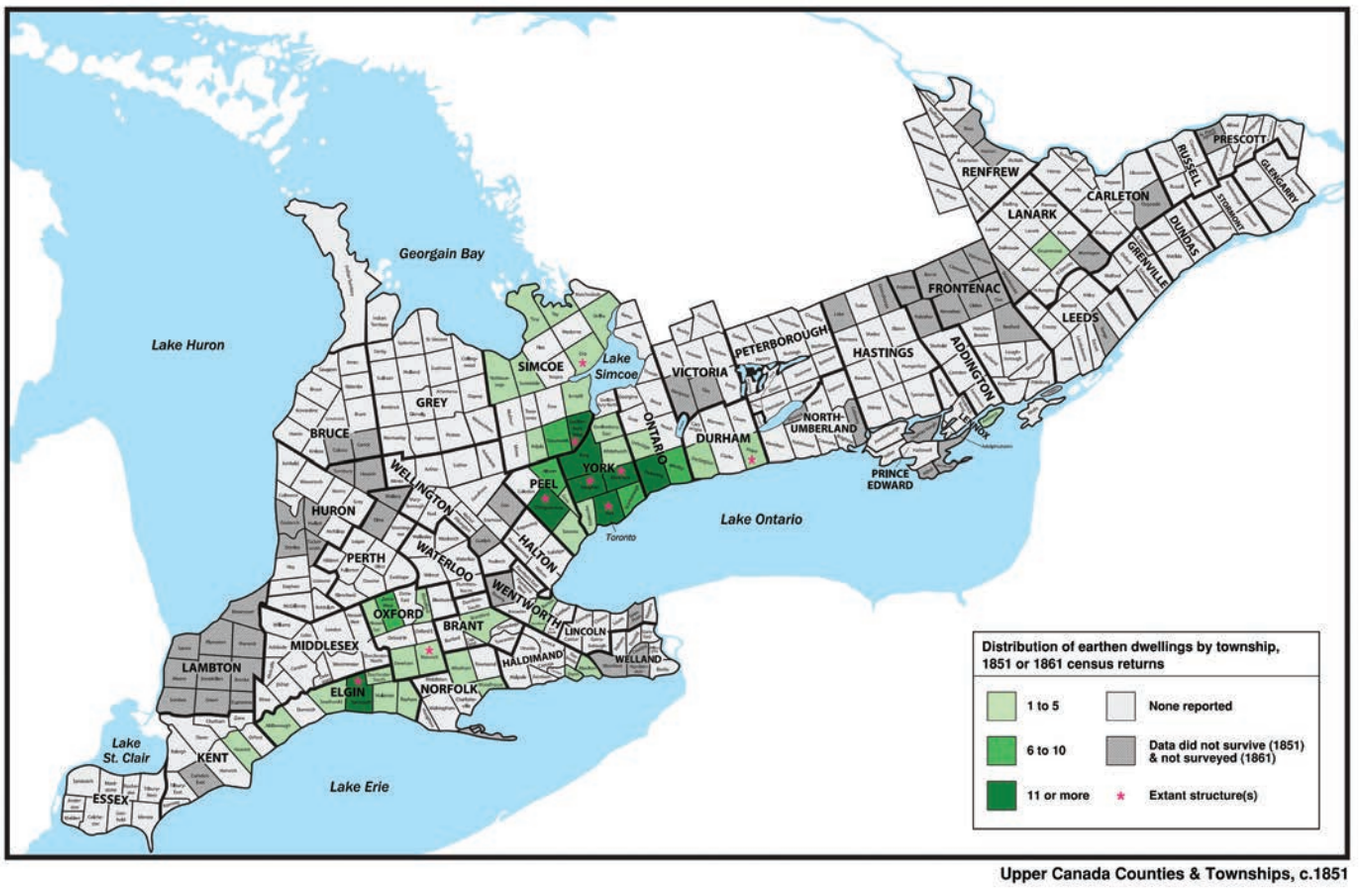


FIGURE 1 Distribution of earthen dwellings by township in Upper Canada, 1851 and 1861. Illustration: Lauran Drown.

Among forty-one counties included in the study, fourteen contained one or more specific entries for earthen dwellings. In total, 234 entries for earthen dwellings were found, including 179 within a 40-mile radius of Toronto. Within this radius, the largest cluster of forty-three dwellings occurs within the township of York, where modern Toronto is located. This cluster includes five of the nineteen known extant structures, including the Stiver House, pictured in figure 2. One hundred miles west of Toronto, a lesser cluster of earthen dwellings was constructed, loosely centered on Oxford County. Four of the nineteen extant sites are included among this cluster, including Sparta Regency Cottage (fig. 3) and the Forge and Anvil Museum, originally a blacksmithery (fig. 4). The greatest concentration of extant structures occurs in West Gwillimbury Township, 40 miles north of Toronto, an area still relatively rural though rapidly developing. The two-story Armson-Wood House (fig. 5) is included among these structures, as is the 1.5-story Richardson-Wilson House, where exposed mud



FIGURE 2 Stiver House, Markham Township, York County, constructed in 1829. Single-story mud brick with hip roof. Photo: Lauran Drown.



FIGURE 3 Sparta Regency Cottage, Yarmouth Township, Elgin County, constructed in 1830. Single-story shuttered earth with hip roof. Photo: Sally Martyn.



FIGURE 4 Forge and Anvil Museum, Yarmouth Township, Elgin County, constructed in 1827. Shuttered earth blacksmithery with mortis-and-tenon hip-framed roof. Photo: Sally Martyn.



FIGURE 5 Armson-Wood House, West Gwillimbury Township, Simcoe County, constructed in 1843. Two-story mud brick with gable roof. Photo: Lauran Drown.



FIGURE 6 Mud bricks exposed at fireplace, Richardson-Wilson House, Bradford West Gwillimbury Township, Simcoe County, constructed ca. 1850, 1.5 stories with gable roof. Photo: Lauran Drown.

bricks are visible in the fireplace surround (fig. 6). A few sites stand alone, including the Peters House in Durham County (fig. 7). Townships containing known, extant structures are denoted by red star on the map (see fig.1).

Census entries for earthen buildings frequently appeared over consecutive pages, with multiple entries often provided on the same sheet, indicating that geographic clustering of earthen buildings occurred frequently. Community "bee" labor was a factor for this clustering in Yarmouth Township (Davis 1979) and may have been so in other places as well.

Population census figures show only dwellings and do not enumerate the various earthen outbuildings, churches,



FIGURE 7 Peters House, Hope Township, Durham County, constructed in 1832. Shuttered earth, originally single story. Photo: Tom Cruickshank.

schools, or shops that would have accompanied them. Moreover, the total of 234 listed buildings is conservative because it comprises only entries given in unambiguous terms, such as mud brick or raw brick, and does not consider other potentially plausible entries, such as roughcast or block (table 1).

Census returns also shed light on earthen household demographics. Just under half (43%) of Upper Canada's population in 1851 were born in the British Isles, while roughly three-quarters (73%) of the heads of household for earthen dwellings listed their place of birth as England, Ireland, Scotland, or Wales. This shows a strong correlation between these immigrants and earthen dwellings.

Eight out of every ten Upper Canadians lived in rural areas at the time, with just over half the population (54%) employed in agriculture (Lewis 1997). In 1851, the heads of household for earthen dwellings shared the same percentage of the population (55%) that was employed in agriculture,[2] indicating that earthen householders were economically on par with their counterparts in the new province. Apart from farmers and laborers, earthen homes belonged to various tradespeople as well as to merchants, ministers, and members of the gentry (table 2).

Upper Canadian earthen buildings were stylistically similar to those of frame or brick and included both architecturally common and polite structures. The majority of earthen homes were single story, though one-and-a-half- and two-story homes were also common. Their exteriors were typically

Table 1 Construction Terms (not including "house")

Construction Type	1851	1861	Total
Clay	1	2	3
Clay Solid Wall	1		1
Clay & Plastered	1		1
Dried Brick	2		2
Frame / Clay	1		1
Frame & Mud	1		1
Log / Mud	1		1
Mud	54	17	71
Mud Brick / M. Brick *	95	23	118
Mud Hut	2		2
Mud Roughcast	1		1
Mud Wall	4	1	5
Raw Brick / R. Brick	6	10	16
Raw Brick & Frame	1		1
Raw Mud Brick	1		1
Sun-Dried Brick	1		1
Unburned Brick	8		8
	181	53	234

*Includes one church in York.

Table 2 Most Common Occupations among Earthen Homeowners

Occupation	1851	1861	Totals
Farmer	90	30	120
Laborer	22	7	29
Yeoman/Gentleman	14	3	17
Widow	4	6	10
Shoemaker	7	1	8
Blacksmith	4	2	6
Innkeeper	5	1	6
Wagon Maker/Wheelwright	4		4
Carpenter	3		3
Reverend/Minister	3		3
Attorney/Agent/MD	3		3
Cooper/Tanner	2		2
Merchant	2		2
Miller/Millwright	2		2
Other/Not given	16	3	19
	181	53	234

roughcast, though later improvements often included siding, brick veneer, or cement stucco.

British Isles Origins

The earliest documented construction date for earthen buildings includes the mud brick McGlashan Tannery built by Scotsman Andrew McGlashan in 1815 (Hopkins 1998). McGlashan was among the first of many British Isles immigrants to import earthen construction methods to Upper Canada. An 1899 obituary printed in the *Acton Free Press* eulogized the 101-year-old Wm. Goulding, a native of Cardiff, Wales, as the stonemason who built many of the "old time mud brick houses" in the Snellgrove neighborhood (*Acton Free Press* 1899).

A collection of letters by English-born Mary O'Brien includes two firsthand accounts of another earth walling construction technique practiced in Upper Canada. The first, in 1836, was a replacement to her log cabin's kitchen annex: "They are preparing, at Hunt's suggestion, and the recommendation of all the Irishmen, to rebuild it of mud" (Miller 1968). In October of the same year, O'Brien wrote: "Our mud wall is now completed and gives perfect satisfaction, though we are a little anxious lest for want of being sufficiently dry it should be injured by the frost . . . the whole of the time that it was left to harden it rained almost incessantly" (Miller 1968). A mud wall that needed to harden is unlikely to have been mud brick, but a form of cob called shuttered earth, a technique used elsewhere throughout the province, including at the St. Thomas of Shanty Bay church building, which still stands in Simcoe County, Ontario (fig. 8).

In 1938, O'Brien sketched a diagram of St. Thomas, with inside dimensions of 37 × 29 ft. The church was designed by her husband and built on land donated by the O'Briens. Included in the epilogue to O'Brien's letters is an account by Bishop John Strachan upon his visit to Shanty Bay: "The walls of the mud church have scarcely reached half their height and advance slowly but they will be finished and the building roofed and wholly enclosed before winter" (Miller 1968). The builders of the kitchen annex, as stated, were Irish, like O'Brien's husband, and it is likely that these same workmen were engaged in the construction of St. Thomas (Miller 1968).

Terminology and Traditions

There is a rich and diverse tradition of building with earth in the British Isles. Four major typologies of load-bearing earthen wall construction are of historical significance: cob, shuttered earth, clay lump, and, to a lesser extent, pisé. Monolithic cob walling was the most popular technique throughout the British Isles, with the greatest concentration of cob structures surviving in Devon, in the west of England, some from as early as the sixteenth century (McCann 1995).



FIGURE 8 St. Thomas of Shanty Bay, Oro Township, Simcoe County, constructed 1838–1841; Shuttered earth construction with 28 in. thick walls. Photo: Lauran Drown.

Shuttered earth is a variant on cob that utilizes board formwork, i.e., shutters, to contain the clay-straw matrix until it has cured. This method allowed for walls to be thinner and to have perfectly vertical surfaces and right angles, and for the use of less-than-ideal material (McCann 1995). Shuttered earth was commonly practiced in Norfolk and Suffolk, England, in northeast Scotland (McCann 1995), and in Ireland (Hurd and Gourley 2000).

While shuttered earth had been in practice in Upper Canada since at least the 1820s, a description of the method appeared in an 1841 agricultural journal article titled simply "WALLS" (Dwyer 1841). The author, Charles B. Dwyer, was described as an architect, "lately arrived in Kingston from England" (15). The article did not reference prior use of the

technique in Canada. Offered as a way to "see the use of timber in constructing houses lessened," Dwyer's specification included the building of a rubble plinth 1 ft. high topped with lime and gravel. Stakes were then set at the plinth corners to which boards were nailed on the inside. Baskets of clay mixed with lime, straw, and water were thrown in from an exterior scaffold, and the building was left to dry for two days. Windows and doors, including lintel placements, were to be cut with a spade after the removal of the board forms. The walls, inside and out, were to be rendered with lime.

The clay lump process is akin to adobe or mud brick, with walls formed of individual masonry units and clay-sand mortar. Clay lump was a late eighteenth-century development in Britain and Scotland. This technology was not adopted on a wider scale until the 1830s, which is the same decade it took off in Canada (McCann 1987). It was also practiced to some extent in Ireland (Hurd and Gourley 2000).

Pisé, or rammed earth, introduced from France through architectural writings, was never significant as a vernacular tradition in Britain (McCann 1995). It was unknown to Ontario prior to the twentieth century, though some existing shuttered earth buildings, including St. Thomas, have been mistakenly called rammed earth.[3]

The terms *clay lump* and *shuttered earth* never made it to Upper Canada as far as census records, agricultural journals, and historic accounts show. It can be difficult to determine whether literary references represent mud brick or shuttered earth structures, since during the height of practice in the nineteenth century the methods were not known by exclusive terms. Census returns illustrate the case in point. Under the column heading for construction type, entries for earthen materials vary widely. Among 234 positive entries, seventeen different terms denoting earthen buildings appear (see table 1). Certainly, the terms *mud brick*, *dried brick,* and *raw brick* all denote the same thing. Less certain is what technique generic entries such as *mud wall, clay house,* or simply *mud* represent, though some extant shuttered earth buildings have been correlated with such census entries.

At least one print reference in 1846 differentiated between the two methods, referring to shuttered earth as cob: "Dear Sir," wrote a subscriber to the *British American Cultivator*, "I now request you to inform me whether the *unburnt brick wall* or the *cob wall* is most preferable as regards durability, cheapness and neatness?" In reply, the *Cultivator*'s editor drew the term in quotations: "We would state that of the two, the unburnt brick wall is preferable to the 'cob wall.'" His was the last of six mentions on earthen construction published in the *Cultivator* between 1841 and 1846. It was also the least enthusiastic.[4] By the late 1840s, its popularity had begun to sunset.

Conclusion

The need to protect unfired clay walls from weather necessitated features that both informed the regional vernacular and concealed the wall matrix from the curiosity of future generations. Though vacancy or abandonment undoubtedly gave way to erosion and decay for some, unchecked urban development has, in more recent decades, been a contributing factor to the disappearance of southern Ontario's earthen building heritage. And unlike frame or brick structures, unfired clay structures have faced the added disadvantage of being too friable to be moved.

Legislation to conserve Canada's heritage properties was first adopted in the 1970s; however, these laws have been notably ineffectual. Canadian property rights, including heritage protection, come under the jurisdiction of provincial or territorial governments. In Ontario, heritage protection status must generally be requested by a property owner. Economic incentives for owners to seek designation are virtually nil despite there being restrictions to making changes placed on the properties, causing designations to be viewed as burdensome. Where made, formal designations can seem to do little to protect heritage structures from redevelopment; while change requests require potentially lengthy bureaucratic approvals, fines for the unauthorized demolition of a heritage property are capped at C$1 million (Ontario Heritage Act 1990). Currently, nine of the nineteen extant sites in this study are protected by bylaw and included on the Ontario Heritage Act Registrar. Where favorably sited and continuously maintained, Ontario's earthen structures have successfully withstood the tests of over 170 years of time.

Notes

1 Determined from a sample of fifty-one construction dates for earthen buildings reported across numerous secondary historical sources and including extant structures.

2 The same calculation used in the above study was used to calculate employment in agriculture: all farmers plus half of those reported as laborers.

3 Blair Burrow's home, built in 1937, is the earliest-known rammed earth structure in Ontario. The bronze historic plaque at St. Thomas describes its construction as rammed earth.

4 Harkening to unburnt clay's popularity and misuse, the last line of the editor's response reads, "What annoys us so much is, to see so many foolishly build would-be castles out of a material that is only calculated for low cottages."

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The Southwestern US Modern-Era Adobe, 1910–1960: A Conflict of Materials and Methodology in Adobe Resurgence

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Abstract: *What does a conservator do when the very historic fabric one is to preserve is deteriorating the structure? Modern-era (1910–60) southwestern US adobe block construction was initially fabricated by builders and later shaped by building codes that promoted the incorporation of bitumen, portland cement, and concrete in the structure. The building trades and reference codes promoted the use of concrete foundations, bond beams, lintels, and wall capping. Further, they promoted cement and bitumen mixtures in mortar, plaster, and the adobe block. The promotion of the mixture of these materials both as building components and as assemblages was done without regard to the material incompatibilities of earth and cement. Earth and cement have an intrinsic difference in their rate of hygroscopic (moisture absorptive) swelling and shrinking and thermal expansion and contraction. The San Diego, California, area has a long history of Spanish- and Mexican-era adobe construction. However, under the American influence and with the onset of the modern era, some architects and builders sought to build with the charm of the bygone Hispanic era but with their modern material sensibilities. This case study examines a 1923 Pueblo Revival structure built with unstabilized adobe block and cementitious mortars, plasters, wall caps, foundations, and canals. The study examines the multi-year effort to investigate the best materials for restoration.*

Resumen: *¿Qué hace un conservador cuando el propio tejido histórico que debe conservar es el que deteriora la estructura? La construcción con adobes en el suroeste de los EE.UU. durante la Edad Moderna (1910-60) fue primero creada por los constructores y, luego, moldeada por los códigos de construcción que fomentaron la incorporación de bitumen, cemento Portland y hormigón en la estructura. Los oficios de la construcción y los códigos de referencia promovieron el uso de los cimientos de hormigón, las vigas de unión, los dinteles y los revestimientos en los muros. Asimismo, fomentaron el uso de combinaciones de cemento y asfalto en el mortero, los revoques y los adobes. La promoción de la combinación de estos materiales como componentes de la construcción y como elementos de ensamblaje se hizo sin tener en cuenta las incompatibilidades materiales entre la tierra y el cemento. Existe una diferencia intrínseca entre la tasa de dilatación y contracción higroscópica de la tierra y el cemento, y en su expansión y contracción térmica. El área de San Diego, California, tiene una larga historia de construcciones de adobe de la época española y mexicana. Sin embargo, debido a la influencia estadounidense y al inicio de la Era Moderna, algunos arquitectos y constructores edificaron tratando de preservar el encanto de la época hispana pasada, pero con su sensibilidad material moderna. En este estudio de caso se examina una estructura de estilo Pueblo Revival, construida en 1923 con adobes no estabilizados, pero con morteros de cemento, revoques, revestimientos de muros, cimientos y canales. En el estudio se analiza el esfuerzo realizado durante varios años para determinar cuáles serían los mejores materiales de restauración.*

Keywords: southwestern USA, bitumen, cement, adobe, conflict of material, additives

Introduction

What does a conservator do when the very historic fabric one is to preserve is deteriorating the structure? Modern-era southwestern US adobe block construction, from 1910 to 1960, was initially fabricated by novice builders and later shaped by building codes and practices that promoted the incorporation of portland cement, concrete, and bitumen into the structure. The resurgence of earthen architecture during the 1910–60 period was culturally driven to be new and modern in all things, without regard to the material incompatibilities of earth, cement, and bitumen (Guillaud 2017). A 1923 Pueblo Revival structure in San Diego, California, serves as an example in the continuum of the stutter-step inclusion of modern additives to earthen construction. The inclusion of these additives, while seeking to improve on known physical limitations of adobe, inadvertently led to intrinsic material conflicts and premature deterioration. The study examines the multiple influences and the resulting changes that have led to an entire subset of buildings with unique material characteristics and complications in their preservation and material conservation.

Earthen Architecture in the Southwestern US

Earthen architecture in the US dates back at least to 1000 CE, to pre-contact, Indigenous building practices. Repeated inflection points in the continent's evolution since 1565, via the repeated waves of occupation by European explorers, missionaries, and settlers, brought some vestiges of earthen construction practice and knowledge. These waves of knowledge allowed earthen architecture to be "lost" and rediscovered numerous times (Guillaud 2017) throughout US history. In present-day California, earthen construction knowledge was disseminated through the construction of the chain of twenty-one California missions (1769–1823) and associated buildings by the Spaniards, who brought the building technology. In the rest of the desert Southwest,[1] the Spanish tradition of adobe construction coexisted with various Indigenous traditions of earthen construction, including Arizona's Casa Grande and the Pueblos of Acoma and Taos in New Mexico.

Earthen construction in the southwest, of which adobe was the most common, was the primary construction method from the 1600s through the early 1800s.[2] Beginning around 1850, as California gained US statehood, an influx of white American citizens brought with them a preference for wooden construction. Notably, in California, adobe construction went from 50% of the built structures in 1850 to 8% of the built structures in 1910 (Gerbrandt and May 1986). As the US reeled from the tumultuous impact of two world wars and a financial collapse, the 1910s through 1960s saw a modern resurgence in earthen construction.

Parallel Paths for Construction in Earthen Materials: Traditional and Modern

Two parallel paths emerged for those building with earth during the twentieth century: those using the form from a traditional or heritage perspective and those influenced by modern values and shifting contemporary philosophical beliefs. The traditional construction methods continued in communities that had a long legacy of adobe construction while, in the 1910s and 1920s, numerous newspapers and magazines extolled the properties of using "modern adobe" to construct residential properties to a new audience. The self-reliant viewpoint proliferated in the media. "Out in California where adobe is coming back, women and girls have turned builders and are rearing some attractive bungalows," motivating twentieth-century practitioners to build in adobe ("New Adobe Dwellings" 1920). The motivation stemmed from the not-mutually-exclusive beliefs in efficiency, affordability, availability, self-reliance, and an environmentally responsible ethos (fig. 1).

To achieve wide public acceptance as a construction method, adobe construction needed the backing of the Federal Housing Administration (FHA). In 1936, the FHA issued its first adobe building requirements, which included a single-story height, wall and partition ties, bituminous waterproofed and stabilized blocks, block compression and strength testing, concrete footings with structural rebar, concrete foundations extending 6 in. above grade, and designs for structural lateral loads (Cullimore 1942) (fig. 2). While these innovations were responsive to well-known construction maintenance issues present with traditional adobe construction, they created their own inherent construction flaws over time.

Starting in the 1940s, a series of books and pamphlets was written for the do-it-yourself homeowner. In 1941, Professor J. D. Long authored *Adobe Construction* and Paul and Doris Aller wrote *Build Your Own Adobe* in 1946, to name just two of the more prominent publications. The do-it-yourself tradition continued in 1964, when Associate Professor L. W. Neubauer wrote *Adobe Construction Methods*, emphasizing lateral wall stabilization and seismic reinforcement principles. In addition to countless books, pamphlets, and manuals, several prominent magazines like *Sunset* and *Popular Mechanics* fostered the do-it-yourself movement in adobe construction.



July, 1920

Build Your House Out of Your Own Back Yard

Adobe mud and straw, mixed together, kneaded, placed in frames, smoothed, and dried, will turn into bricks with which houses are now being built in Southern California, reviving the method of old Spanish days

HOME seekers in Los Angeles are literally grasping at straws—and mud. Their slogan is "build your house out of its own back yard." Due to lack of building materials, adobe clay mixed with straw, in Mexican fashion, is now being used in the construction of southern California bungalows.

Mexicans knead the mud and straw with their bare feet. After it is properly mixed they put it in frames, smooth it with their hands, and leave it on the ground to dry. One day in the hot sun will turn the muddy dough into bricks.

These resulting bricks are so durable that they will withstand a pressure of four hundred pounds to the square inch. Adobe is one of the most non-conductive materials known and thus houses made from it will not respond readily to heat in summer or to cold in winter. The bricks are put through a waterproofing process that removes the dampness sometimes found in adobe buildings. Owing to the large size of the bricks the houses can be erected in a very short time, and adobe houses last a long time.

The Pala Mission was built of adobe one hundred and thirty-five years ago and it is still standing. Modern adobe structures may be finished off in concrete to look just like other bungalows. But if owners prefer the picturesque baked clay finish, concrete is omitted.

Placing squares of clay in frames, to be baked into adobe bricks

A number of country homes of this type have recently been erected in southern California where, in the old days of the Spanish régime, homes were built exclusively of the adobe clay.

Since this material is plentiful in California, thousands of people may soon be moving out there to build homes without encountering the high cost of lumber.

Modern adobe houses are sometimes finished with concrete, which is an improvement on the old way. The new bricks undergo a process that prevents dampness in them

FIGURE 1 "Build Your House Out of Your Own Back Yard," *Popular Science Monthly* article, July 1920.

In the later 1960s, the adobe construction movement also meshed with the counterculture movement in the US and the call to return to nature. For the first time in the evolution of adobe construction in the US, adobe was chosen explicitly over the more dominant wood frame construction types for its perceived efficiency, affordability, availability, sense of self-reliance, and environmental responsibility. This new group of adobe construction activists had no traditions or experience to rely on, and they embraced incorporating both traditional and contemporary materials and methodology into their structures. A series of materials was studied by Eyre and others in the US during the period of 1920 to 1950. Among the suggested stabilizing agents are blood and protein, vinyl acetate, sawdust, casein glue, vinsol resin, and aniline (Clifton 1977, 16) (fig. 3). While multiple additives were attempted, bitumen and cement soon became the most common.

Inherent Conflict of Materials: Material Additives

The building trades and reference codes, especially those from the FHA, promoted incorporating concrete foundations, bond beams, lintels, and wall capping. They further promoted cement, emulsified asphalt, and bitumen mixtures in mortar, plaster, and the adobe block. Many of the "improvements" of the time were incorporated to manage moisture.

Cement in adobe block and mortar was promoted to both repel moisture and strengthen the material. Mixing cement and earth does not inherently cause a conflict of materials, but their combination can degrade the nuance of materials strengthening and disrupt the need for equivalent coefficients of heat expansion in all components of a wall's assemblage. For example, when mortar is strengthened with more cement content than the adjoining adobe block, intrinsically, the blocks are "hugged to death" by the difference in thermal coefficient of expansion. Another pitfall common for the do-it-yourself cadre of builders was small-batch mixed cementitious adobe block. Such blocks would have invariably uneven mix percentages, leading to blocks within the same wall exhibiting conflicting strengths and coefficient of expansion characteristics, compromising the wall's structural integrity.

The addition of bitumen to adobe blocks had its own cascade of effects, as too much bitumen could affect the compression strength of the block. While adding 5–8% significantly improved the water resistance of the blocks themselves, it also deterred the adhesion of the mortar and the attachment of the blocks to concrete foundations, lintels, and bond beams,

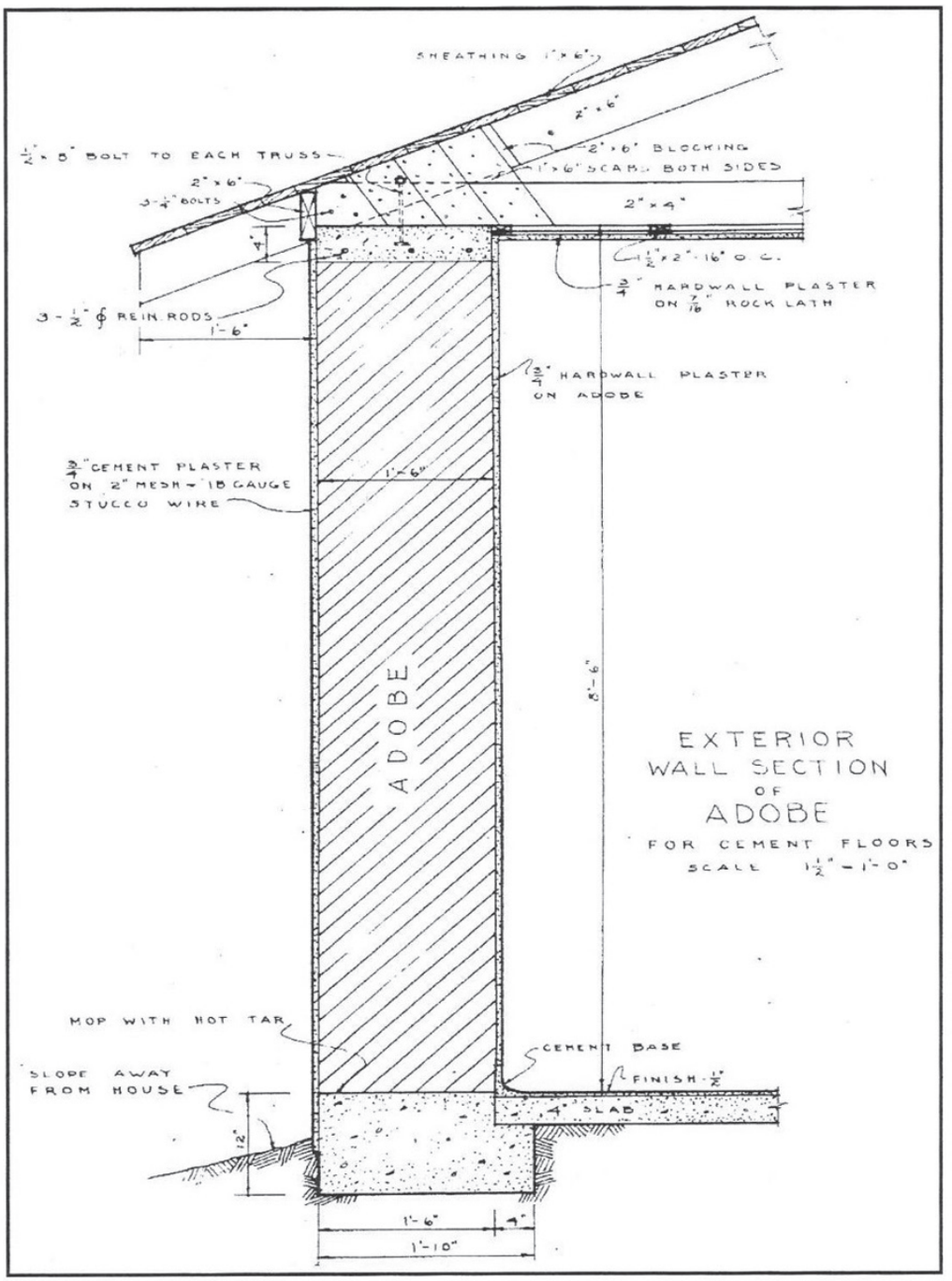


FIGURE 2 Exterior wall detail of O. W. Hunsaker house. Photo: Clarence Cullimore, ca. 1934.

necessitating further additives of asphaltic emulsions to the mortar and concrete structural members to enhance the adhesion of materials. As explained in the American Bitumuls Company brochure of 1946:

> On asphalt stabilized adobe brick, lime tends to cause deterioration of the asphalt which results in reduced adhesion to asphalt-stabilized bricks, particularly when subjected to cycles of wet and dry weather . . . Experience and tests have proven the necessity of using only waterproof cement mortar, made with clean sand suitable for concrete, in the joints between bricks. 'Hydropel' Emulsified Asphalt is supplied by American Bitumuls Company for waterproofing such cement mortar, and its use insures [*sic*] that the mortar will be equally water resistant as the blocks themselves . . .



The Mud House Comes Back

New Weatherproofing Process Revives Ancient Building Art

This modern home was built of adobe, treated to withstand moisture, and then covered with stucco

THROUGH the discovery at Leland Stanford University, Calif., of a new weatherproofing compound, the ancient building material of the Southwest, adobe, is coming back into favor. Applied to adobe bricks, the chemical solution protects them against decay and makes the material suitable for use in any climate.

Although developed principally as a means of preserving the ancient adobe ruins in the national parks of the Southwest, the amazing compound is now finding widespread use in the construction of new buildings. As this is written, more than 180 "mud houses" are being constructed by one branch of the Government alone, the Resettlement Administration, and each is being weatherproofed with the new mixture.

Three years of laboratory and field work preceded the discovery of the compound by Frederick T. Martius of the U. S. National Park Service. The mixture he evolved, consisting of vinyl resin, acetone, and toluene, is insoluble in water, will not peel, and does not change the original color of the adobe.

Throughout the Southwest, adobe buildings have long sheltered both white and red men. The mud of which they are made is formed of a combination of eroded volcanic rock and lime from the shells of sea animals. Mixed with straw and weeds, and dried in the sun, it produces bricks of unusual lasting qualities, particularly in warm, dry climates. Now, through the discovery of Martius' compound, the mud house will be durable under any weather conditions.

Packing the mixture of adobe clay into wooden brick forms

A builder laying mud bricks to form the walls of a house. More of the bricks are piled in the foreground

Cliff-dweller ruins in Mesa Verde National Park. The new process for weatherproofing adobe was first used for preserving such historic walls

30 POPULAR SCIENCE MONTHLY

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FIGURE 3 "The Mud House Comes Back," *Popular Science Monthly* article, June 1937.

Hydropel Emulsified Asphalt should be used in all other concrete portions of the building in contact with bricks, such as the upper 6" portion of foundation walls, lintels, bond beams, etc. (American Bitumuls Company 1946)

When addressing deterioration in a historic building built with bitumen-emulsified adobe, conservators today need to question the material composition of all the components that create the wall assembly. Critical questions include whether the wall was built before the harmful effects of lime mortar on

bitumen-stabilized block or if the adhesion issues to concrete structural members were known.

During this time, cementitious plaster was thought to be an improvement as a material that easily forms to the surface of an adobe wall and provides a protective moisture repellent covering. However, due to different thermal coefficients of expansion diurnally, as well as when the plastered walls are exposed to the sun, the materials expand at different rates and eventually lose any cohesion. The daily movement of the material inevitably leads to stress fractures in the plaster coat. These lead to cracks that allow moisture to accumulate under the cementitious plaster coat, trapped by the same moisture repellency that was thought to be a helpful characteristic. However, the plaster is now trapping moisture, and the blocks cannot transpire. As the moisture content rises, the adobe soil can reach its modulus of elasticity and literally slump and deform behind the plaster. Attempts to resolve cementitious plaster's lack of cohesion led to innovations to mechanically tie the cementitious plaster to the adobe block. A common attachment method included setting nails in the wet mortar joints during construction, attaching chicken wire to the nails, and then plastering the chicken wire. Again, this method would fail as it could not resolve the thermal expansion difference, and it introduced rust into the unresolved adhesion issue. While the initial impetus for a protective coat in the form of cementitious stucco was well intended, it inevitably failed.

Inherent Conflict of Materials: Building Methodology

In addition to the material composition undergoing a shift during the twentieth century, so did the overall building methodology of earthen architecture. Changes in building methodology were primarily driven by modern structural engineering and an increased awareness identifying the need to resist lateral forces from seismic events. For example, it was traditional for walls to be built on cobble trench footings with 24–36 in. thick walls, with wooden lintels and a roof of wooden members. Often, assemblages like this were held together with mass and gravity and forgave the expansive nature of adobe block. The "modern" assemblage experimented with 12–18 in. wall thicknesses, steel reinforcing, and added concrete foundations, bond beams, lintels, and wall capping. Other new systems used "wood or steel post and beam construction . . . designed to carry and support the structural load and stabilized adobe brick was used only as a non-load-bearing curtain wall" (Calarco 2008, 58). The new, modern assemblage was not as forgiving of the expansive movement of adobe, and cracks and gaps occurred at the junctures of materials.

While the twentieth century saw a resurgence in adobe construction due to cementitious and bituminous additives, many of the remaining structures of this time are intrinsically compromised with material degradation and threatened structural integrity. The additives used in the adobe blocks, mortar, and plaster and the evolving "modernizing" construction methodologies existentially threaten the preservation of these structures. The following case study examines a 1923 Pueblo Revival structure built with unstabilized adobe block but with cementitious mortars, plasters, wall caps, and foundations and introduces the multiyear effort to investigate the best materials for plaster restoration.

Torrey Pines State Reserve Visitor Center (Torrey Pines Lodge): Case Study

Torrey Pines Lodge is a Pueblo Revival building designed by architects Requa and Jackson (figs. 4, 5) and "built under the direction of adobe expert John Byner between 1922–23 for use as a restaurant/cafe and gift shop." The building is a one-story U-plan constructed from nonstabilized adobe blocks pointed with lime and portland cement mortar and finished in smooth lime and portland cement plaster with a mineral-tinted surface coloring (built on a concrete foundation with wooden door and window lintels). The overall roof is flat with blunt parapet walls constructed out of adobe block pointed with concrete mortar and capped with 4–6 in. of ¼ in. steel bar reinforced rough concrete coping finished in 1 in. plaster (Stiegler and Crane 2013, 11). The study used the existing original plans and specification booklet, site visits, and minor



FIGURE 4 Torrey Pines Lodge construction photo, 1923, courtesy of Torrey Pines Conservancy.

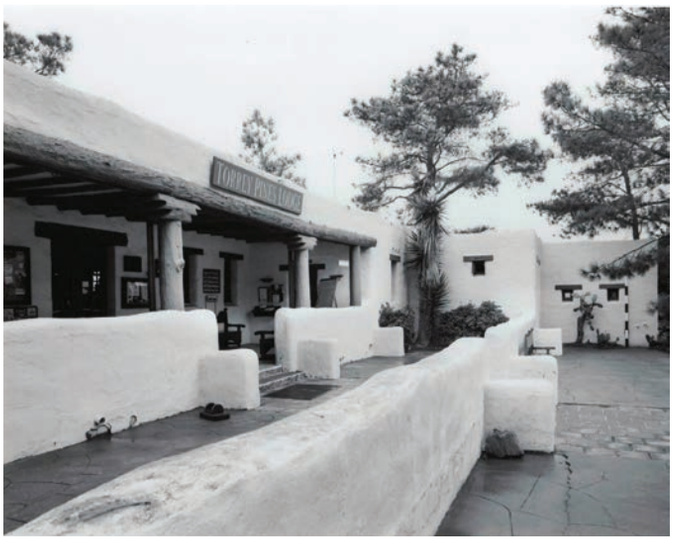


FIGURE 5 Torrey Pines Lodge front elevation. Photo: IS Architecture, 2011.

exploratory investigations and testing of adobe block, mortar, and plaster finish samples.

The Torrey Pines Lodge follows the typical characteristics of contemporary adobe construction from the 1920s. Of grave concern was the written specification to construct the exterior walls from nonstabilized adobe blocks pointed with a "cement" mortar. Extensive materials analysis was completed. The adobe block analysis, as specified, revealed the block as unstabilized, meaning the blocks were sun dried and no chemical additives were added to the mixture to increase the materials' durability. Testing the mortar revealed a ratio of 1 part portland cement, 4.3 parts lime, and 12.6 parts sand. With relief, the ratio represents a relatively low-strength mortar acceptable for use with unstabilized adobe block. However, analysis of the exterior plaster revealed a generally high percentage of cement to lime ratio, 1 part portland cement, 1.9 parts lime, and only 4.2 parts sand. The walls were mortared with the pointing pressed out from the joints between adobe blocks to form a key bond for the plaster. However, due to the surface plaster having more cement than mortar, delamination inevitably occurred between the keyed mortar and plaster.

As a result, cracks formed on the exterior plaster, allowing water to encounter the adobe brick. The moisture caused the cement plaster to bulge, delaminate from the adobe substrate, and crack, further introducing moisture to the adobe brick. In addition, the moisture under the exterior plaster cannot evaporate, raising the moisture level trapped in the adobe bricks. Over time, if the extant plaster is kept in place, the adobe brick will deteriorate due to excessive moisture content.

The California State Parks, Southern Services Center, is currently pretesting for proposed repairs. Due to the inconsistency of repair efforts, the unknown condition of plaster adhesion, and the unknown condition of the adobe block, a set of tests was recommended on all walls. A series of small holes is to be drilled to locate delamination and note any patterns. Observing the detritus and resistance from the drill will show material strata and the width of the delamination. If the delamination is severe, then a small area of exterior plaster, no smaller than 3 × 3 ft., should be removed from the facade of the building and a lime-based plaster applied, preferably a dispersed hydrated lime (DHL) and an iron-oxidized pigment per the original specifications. After a year of observation, if the test patch successfully adheres to the adobe block and holds its color, a complete restoration should be performed to the remainder of the building.

The foundation incorporates the practical improvement of concrete as a separation from ground moisture. The building does not suffer from rising damp or base coving. The roof parapet adobe wall has been repointed with a high cement content mortar and capped with a concrete coping. The concrete has led to a persistent crack where the coping meets the adobe parapet wall, resulting in severe deterioration between the unstabilized adobe block and the cementitious repointing mortar (fig. 6).



FIGURE 6 Detail, Torrey Pines Lodge. Note continuous horizontal separation at parapet between concrete cap and adobe wall. Photo: IS Architecture, 2011.

In summary, this case study represents the early introduction of cement in adobe building methodology. In this example, the adobe blocks themselves persisted as unstabilized components within mortar substrates that have started to incorporate cement and plaster renders that have fully integrated cement in their composition. Conservators working on buildings of this era must test for multiple varieties of additives so the physical properties of the restoration material can be compatible or identified for intrinsic failures that could lead to structural failure.

Conclusion

Proponents of adobe construction in the US from 1910 to 1960 altered the construction material and methodology, inadvertently leading to an entire subset of buildings with unique material characteristics and complications for their preservation and how conservators can work with the built fabric. Conservators working on buildings of this era must test all materials for multiple types of additives to determine the compatible physical properties of restoration materials and identify the material for intrinsic failures that could lead to structural failures. Regrettably, some of these material conflicts will inevitably lead to the early loss of buildings constructed with modern additives and to the difficulty in preserving the buildings of this era.

Notes

1 In this paper, Southwest refers to the Southwest Desert regions and the broader Southern California region.

2 Even the term "adobe" is a Spanish word derived from the Arabic *atob*, or "sun-dried" brick (Hattersley-Drayton 2008).

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PART 12

Risk and Vulnerability / Riesgo y vulnerabilidad

Developing and Testing Environmental Risk Mapping and Spatial Analysis for Site Monitoring: The Case of Çatalhöyük's South Area

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Abstract: *Çatalhöyük, Turkey, is a UNESCO World Heritage Site and an exceptional archaeological earthen settlement in terms of physical and temporal scale. Central to Çatalhöyük's preservation strategy was the fabrication of two permanent shelter structures. A comprehensive monitoring system was developed between 2012 and 2017 to gain a nuanced understanding of the earthen buildings' material behavior under the shelters. The methodology is innovative and significant as it employs environmental risk mapping and spatial analysis to inform conservation practice. Essential to the study was collecting year-round environmental data and performing a qualitative assessment of the mud brick walls. New ways to utilize these quantitative and qualitative data in a Geographic Information System (GIS) were implemented for documentation and diagnosis purposes. The proposed approach enables spatial and visual analysis of the state of preservation of the site and increases understanding of the threats that affect the earthen structures once excavated. This study utilized GIS to generate spatial-temporary climate maps of temperature and humidity distribution under the shelter covering Çatalhöyük's South Area. Specifically, the Inverse Distance Weighted (IDW) interpolation technique was used to investigate mud bricks' vulnerability and identify higher-risk areas. Our results demonstrate that our spatial analytical model can provide conservators with effective data-driven tools for planning future conservation interventions and documentation. Conservators at Çatalhöyük successfully used this methodology to identify which areas are at greater environmental risk within the microclimate generated by the protective shelters, establish a baseline for future evaluation of conservation interventions, and inform site management policy.*

Resumen: *Çatalhöyük, Turquía, es un sitio declarado Patrimonio de la Humanidad por la UNESCO y constituye un asentamiento de tierra excepcional en cuanto a aspectos como su escala física y temporal. La fabricación de dos estructuras permanentes de protección fue fundamental en la estrategia de preservación de Çatalhöyük. Entre 2012 y 2017, se desarrolló un sistema de monitoreo integral para lograr una comprensión matizada del comportamiento material de los edificios de tierra dentro de las estructuras de protección. La metodología es innovadora e importante, ya que emplea el mapeo de los riesgos ambientales y el análisis espacial para brindar información que sirve a las prácticas de conservación. La recopilación de datos ambientales durante todo el año fue fundamental para el estudio, al igual que el hecho de haber realizado una evaluación cualitativa de los muros de adobe. Se implementaron formas nuevas de utilizar estos datos cuantitativos y cualitativos en un Sistema de Información Geográfica (GIS) con fines de documentación y diagnóstico. El enfoque propuesto permite realizar un análisis espacial y visual del estado de preservación del sitio y también permite comprender mejor las amenazas que afectan a las estructuras de tierra una vez que son excavadas. En este estudio, se utiliza el GIS para generar mapas climáticos espacio-temporales donde se pueda observar la distribución de la temperatura y la humedad dentro de las estructuras de protección que cubren la parte sur de Çatalhöyük. Específicamente, se utilizó la técnica de interpolación de distancia inversa ponderada (IDW) para estudiar la vulnerabilidad de los adobes e identificar las zonas que se encuentran en mayor riesgo. Los resultados obtenidos demuestran que nuestro modelo analítico-espacial puede brindar a los conservadores herramientas eficaces basadas en datos que les permitirán planificar las futuras intervenciones de conservación y documentación. Los conservadores que trabajan en Çatalhöyük utilizaron esta metodología exitosamente y lograron identificar las zonas que presentan un mayor riesgo*

ambiental dentro del microclima que producen las estructuras de protección, al igual que establecer un punto de partida para la evaluación futura de las intervenciones de conservación e informar la política de gestíon del sitio.

Keywords: Çatalhöyük, Anatolian Neolithic, earthen architecture conservation, comprehensive site monitoring, GIS, environmental risk mapping, vulnerability analysis

Background on the Comprehensive Monitoring System

Earthen archaeological sites present complex challenges for conservators due to their fragile composition, the adverse effects of a rapidly changing climate, and the impact of active excavations and visitation (Matero and Moss 2004; Avrami, Guillaud, and Hardy 2008; Rainer, Bass Rivera, and Gandreau 2011; Matero 2015; Joffroy, Guillaud, and Sadozaï 2018). This study produced and field tested a set of qualitative and quantitative methods for the protection and preservation of ancient earthen architecture. The methodology provides a framework for conservators to utilize in the development of comprehensive monitoring and predictive modeling. The proposed approach leverages geostatistical analysis in a Geographic Information System (GIS) to identify where conservation issues are most likely due to environmental threats. This work's main aims were to produce nuanced information on areas at immediate risk of deterioration, evaluate conservation strategies and the permanent shelters' performance, and plan targeted conservation interventions (fig. 1).

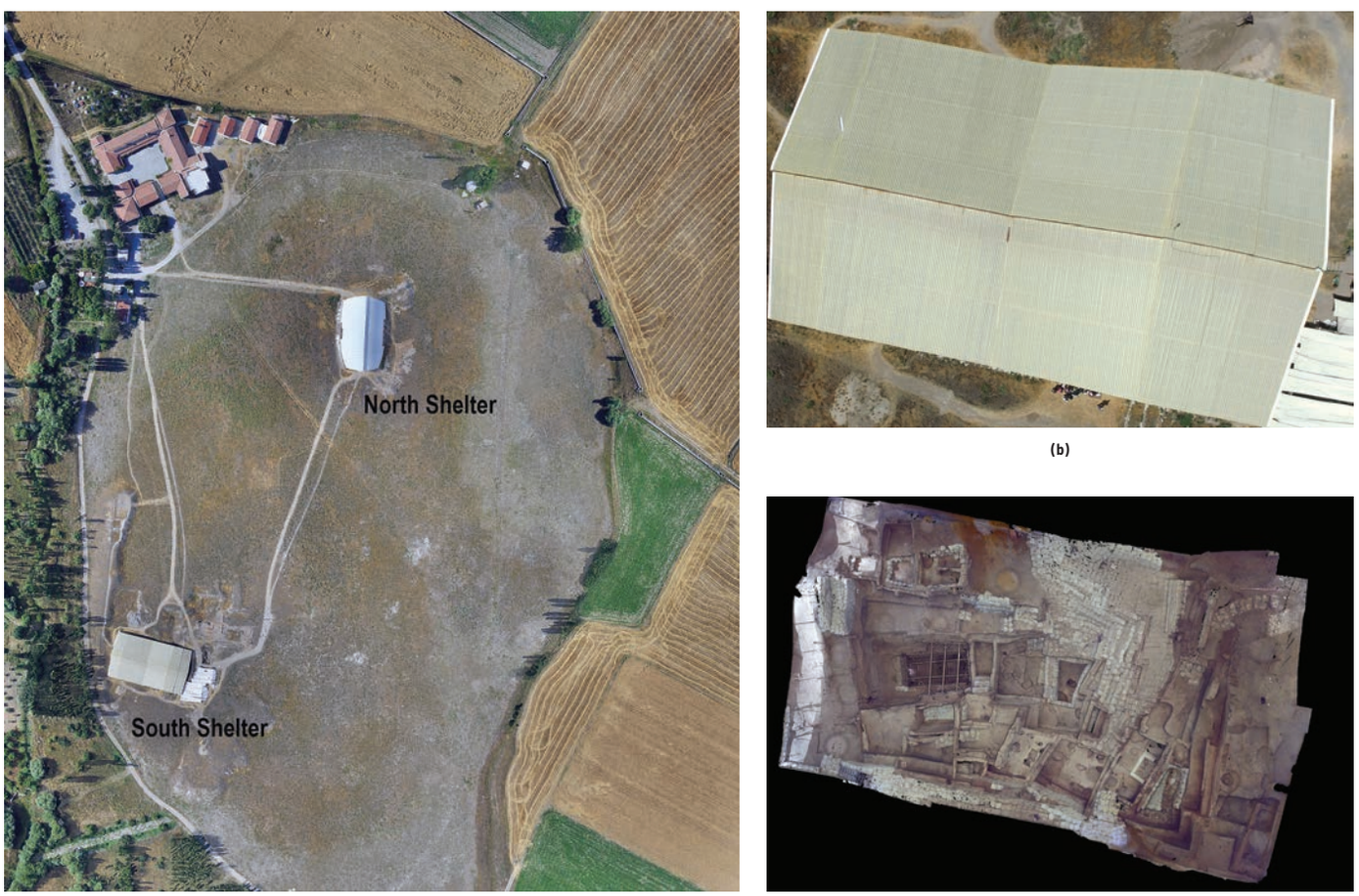


FIGURE 1 (a) Çatalhöyük's East Mound as seen in an aerial survey–derived Digital Elevation Model, (b) aerial photo of the permanent shelter covering the South Area, and (c) the 2017 South Area's Terrestrial Laser Scanning data seen from a top view. Photos (a, b): Nicola Lercari, Rendering (c): Nicola Lercari.



FIGURE 2 Virtual reconstruction of the northeast part of South Area's Building 17, phase D. Rendering: Nicola Lercari and Grant Cox.

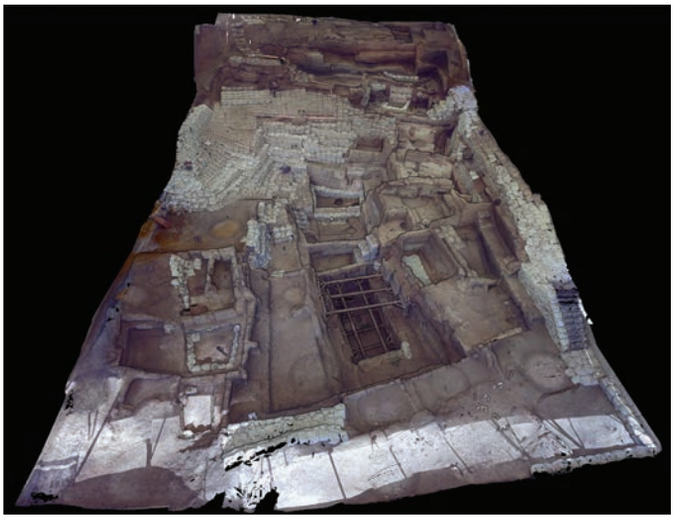


FIGURE 3 The 2017 South Area's Terrestrial Laser Scanning data as seen from a west to east perspective view. Rendering: Nicola Lercari.

The archaeological site of Çatalhöyük, Turkey, serves as the case study to develop this methodology. Operational and analytical solutions were sought to address ongoing issues with preserving this complex earthen site, and the Çatalhöyük Digital Preservation Project was established to develop a comprehensive monitoring program from 2012 to 2017 (Lingle and Lercari 2017). Çatalhöyük (7100–5900 BCE) is located in the Konya Plain in central Anatolia and is considered a key site for understanding human prehistory (Bayliss et al. 2015). Given its exceptional relevance and outstanding conservation state, this Neolithic settlement was inscribed in the UNESCO World Heritage List in 2012. The site's rectangular buildings comprise large mud brick walls that were generally plastered on internal faces and often painted or decorated with plastered features. The flat roofs were made of reeds and earth and were supported by timber posts and wooden beams (fig. 2).

Two permanent shelter structures were erected in 2002–3 and 2007–8 over the South Area and North Area to mitigate the harsh continental climate's effects on Çatalhöyük's earthen structures. Although central to Çatalhöyük's preservation strategy, these permanent shelters are affected by constant environmental fluctuations that exacerbate the wet/dry and freeze/thaw cycles of water and moisture in the mud brick, causing surface material loss and erosion (Campiani, Lingle, and Lercari 2019). Year-round environmental data were collected, and multi-temporal 3D measurements of the surfaces of wall features were recorded annually by Terrestrial Laser Scanning (TLS) to gain a nuanced understanding of the earthen buildings' material behavior. A curated collection of the TLS data and real-time visualizations of Çatalhöyük's area-wide data are available online through the University of California, San Diego, Digital Collections portal (Campiani et al. 2018) (fig. 3). A qualitative assessment of mud brick walls' vulnerability was also performed annually.

This paper presents the newest results from this study regarding the site's South Area, while our previously published work presented our results from Çatalhöyük's North Area (Lercari 2019; Campiani, Lingle, and Lercari 2019) and precisely described our data acquisition, processing, and spatial analysis workflow (Campiani, Lingle, and Lercari 2021). Environmental data were obtained by collecting area-wide humidity and temperature data using Gemini Tinytag data loggers over one year (2017), in conjunction with qualitative building assessments during the same period. Additionally, an innovative analytical method in the GIS was employed to produce environmental risk and vulnerability maps for the South Area. Our comprehensive monitoring program produced a spatial and visual analysis of the state of preservation of the South Area, which increased our understanding of the threats that affect its earthen structures and its permanent shelter performance. Specifically, this paper focuses on the South Area's environmental risk and qualitative vulnerability assessment in the GIS through geostatistical analysis of our 2017 data. The choice of mostly focusing on quantitative environmental data and qualitative building assessment was made, as our previous work showed that the spatial-temporary climate maps of temperature and humidity distribution under the shelter used in combination with vulnerability maps are

the most effective tools to inform conservation intervention at the area-wide scale.

Environmental Monitoring: Quantitative Data

As part of our comprehensive monitoring program, we placed a total of eight Gemini Tinytag data loggers at different elevations in the South Area buildings that were not undergoing excavation in 2017. Their locations were then recorded with centimeter-level accuracy using a total station and then imported into our GIS. In particular, three Tinytag Plus 2 TGP-4500 loggers, with built-in temperature and relative humidity sensors, and five Tinytag Plus 2 TGP-4017 loggers, with built-in temperature sensors only, were deployed in the study area (Gemini n.d.). These environmental data loggers captured temperature and percentage of relative humidity (RH) variation daily, at 30-minute intervals, between January and December 2017. Our study used this high-frequency data to explore the incidence of RH fluctuations and estimate their impact on the earthen architecture relating to temperature.

Previous work analyzing the incidence of relative humidity fluctuations on mud brick and soils provides well-defined thresholds for salt deliquescence and desiccation point (King 2014; Ravi et al. 2004). Our previous study at the site confirmed that critical conditions at Çatalhöyük happen above 65% RH and below 20% RH (Campiani, Lingle, and Lercari 2019, 2021). At about 65% RH, soluble salts in the mud brick begin to deliquesce; below this humidity threshold, the salts recrystallize and fluoresce. Thus anytime the percentage of relative humidity goes above the deliquescence point and then below the recrystallization point, we expect adverse effects on the mud brick, namely material loss and erosion. Alternatively, when the RH drops below 20%, the mud brick begins to desiccate and erosion and surface spalling occur.

Processing the 2017 South Area environmental data in a tabular form, we computed how many days a year our Tinytags registered values above and below those thresholds. For instance, in June and July 2017, the daily % RH data present the biggest monthly variation, suggesting that the mud brick's highest mechanical stress potential occurred in these summer months (fig. 4).

As part of the proposed comprehensive monitoring approach, % RH must be related to temperature fluctuation that produces wet/dry cycles in mud bricks (Uviña Contreras 1998; Oliver 2008). Therefore, we explored the daily temperature fluctuation range captured by the eight Tinytags (fig. 5). Our South Area results show a maximum yearly temperature fluctuation of 19.16°C, which is about 2.5°C less than the maximum variation usually registered in the North Area. These results suggest a better performance of the permanent shelter on top of the South Area, which guarantees a more stable environment than the North Area.

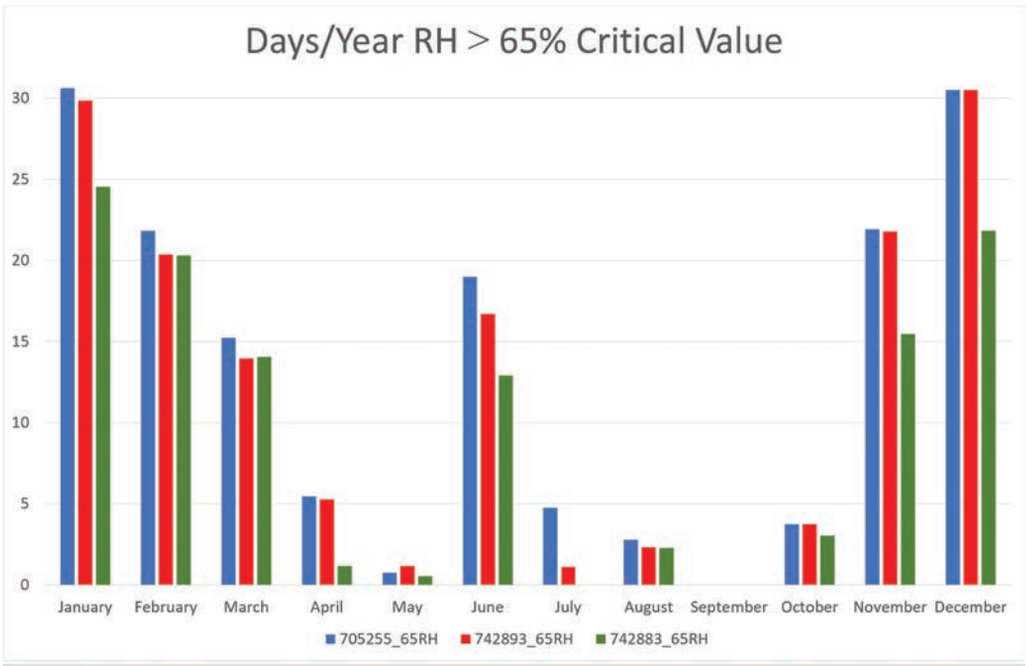
Vulnerability Analysis: Qualitative Conservation Assessment

The qualitative conservation assessment is centered on the collection of observational information from the condition of the site. Conservators visually inspect buildings across the site to assess the state of preservation and the outcome of previous conservation work. The vulnerability of mud brick features is evaluated by identifying deterioration patterns common to the site, such as vegetation and animal burrowing. Additionally, pathologies that affect adobe structures, like salt efflorescence, plaster delamination, surface erosion, wall undercutting, and collapse, are noted and scored. An absolute damage value was given to all deterioration variables affecting each monitored feature at the site, totaling 25 points, and establishing a risk threshold as ≥ 12 points. Typically, features with five or more deterioration patterns scored above 12 and needed urgent conservation intervention, thus setting the benchmark. The survey is conventionalized, with most categories being either present/not present or showing a severity rating between 1 and 4 (negligible to very severe).

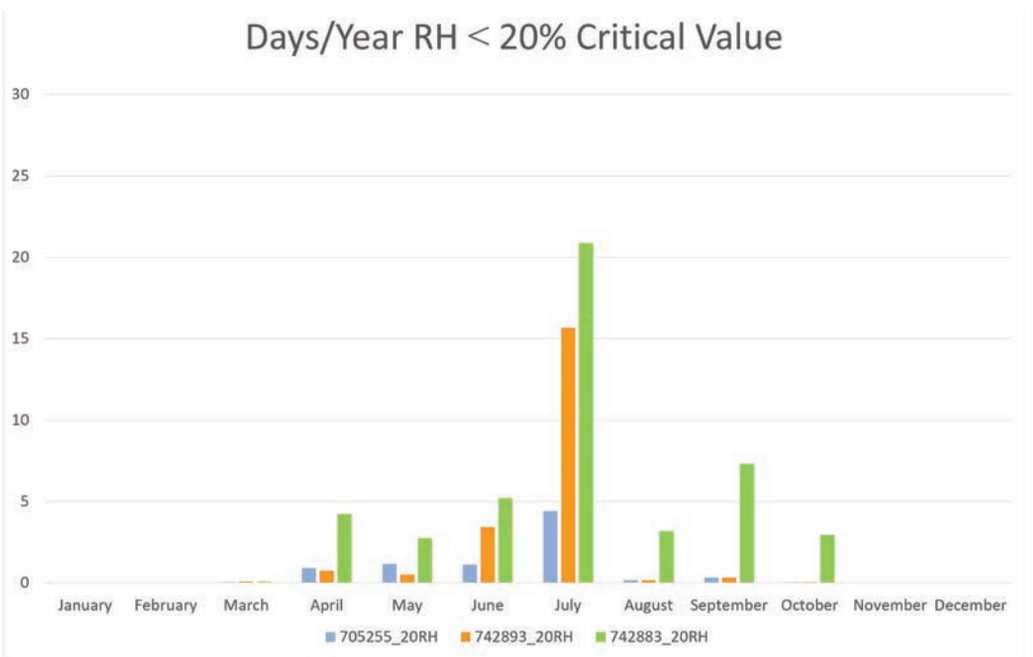
Furthermore, to help avoid issues due to language or definition, an illustrated glossary was produced in conjunction with the survey. This methodology's greatest limitation is the assessment's subjectivity, particularly as there is very little team continuity each year due to staffing and budget issues. While this subjectivity does create issues with data reliability (Taylor 2013), our spatial representation of the qualitative assessment data in the GIS through a vulnerability map (fig. 6) serves as a method of data validation when related to environmental data (Campiani, Lingle, and Lercari 2021).

South Area Environmental Risk Discussion

Our study considered the spatialized impact of the average temperature fluctuation and relative humidity on the South Area's mud brick buildings, using the Inverse Distance Weighted (IDW) deterministic interpolation method in the GIS. This method was chosen due to fewer available interpolation points in our temperature and humidity data and the



(a)



(b)

FIGURE 4 Histograms comparing (a) the days/year the % RH was > 65 and (b) < 20 critical values in Çatalhöyük's South Area in 2017. Charts: Arianna Campiani.

uneven distribution of vulnerability values throughout the South Area (area = 1214.24 m²).

Regarding average temperature excursion, our results show that the South Area's east and southwest sectors registered the highest variation while the northwest and central sectors, where the excavation is deepest at 10 m below the excavation's highest point, are the coolest (see fig. 3). Our calculations also confirm that in 2017 there was a tendency to a lower % RH where the average temperature was the highest and to a higher % RH where the temperature fluctuation was the lowest.

To assess the impact of relative humidity and temperature fluctuation in a comprehensive fashion and estimate threats to the earthen architecture, we combined these data into an environmental risk map (fig. 7). As explained in detail in our previous paper (Campiani, Lingle, and Lercari 2021), this map

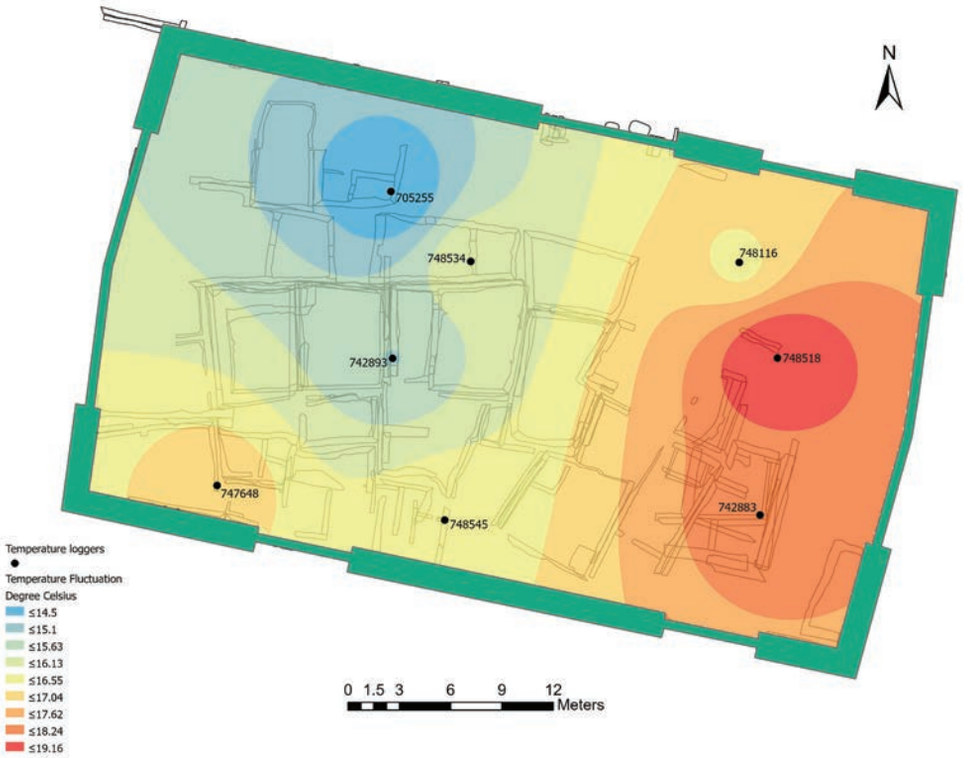


FIGURE 5 2017 South Area average temperature fluctuation map. The locations of the data loggers are displayed with black dots. The footprint of the permanent shelter is displayed as a green polygon. Map: Arianna Campiani.

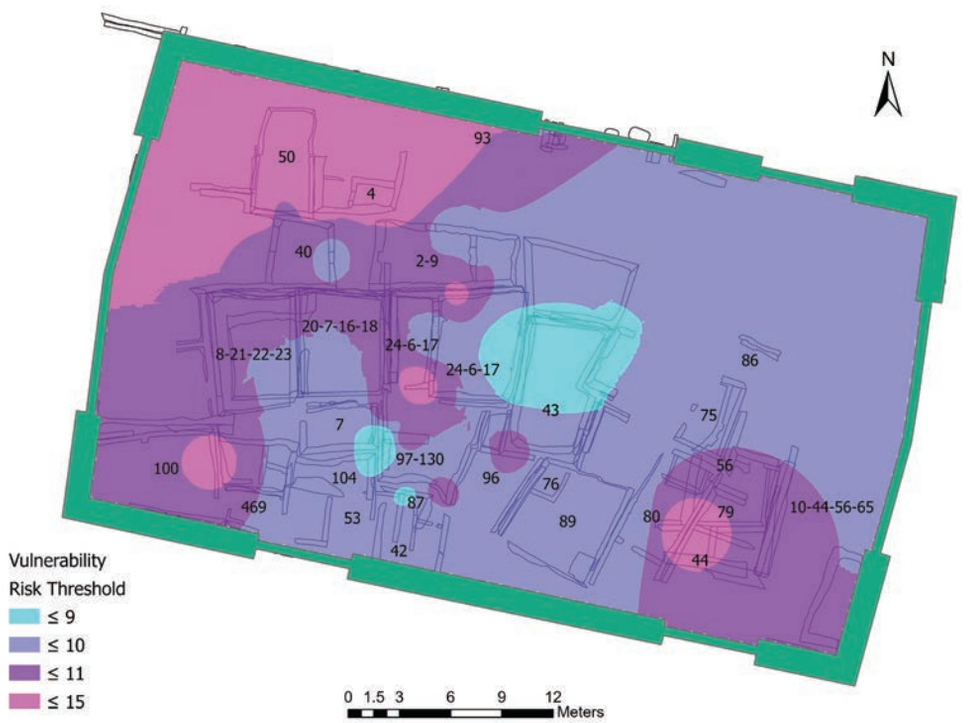


FIGURE 6 2017 South Area vulnerability map, displaying wall features (gray lines) and building numbers. The footprint of the permanent shelter is displayed as a green polygon. Map: Arianna Campiani.

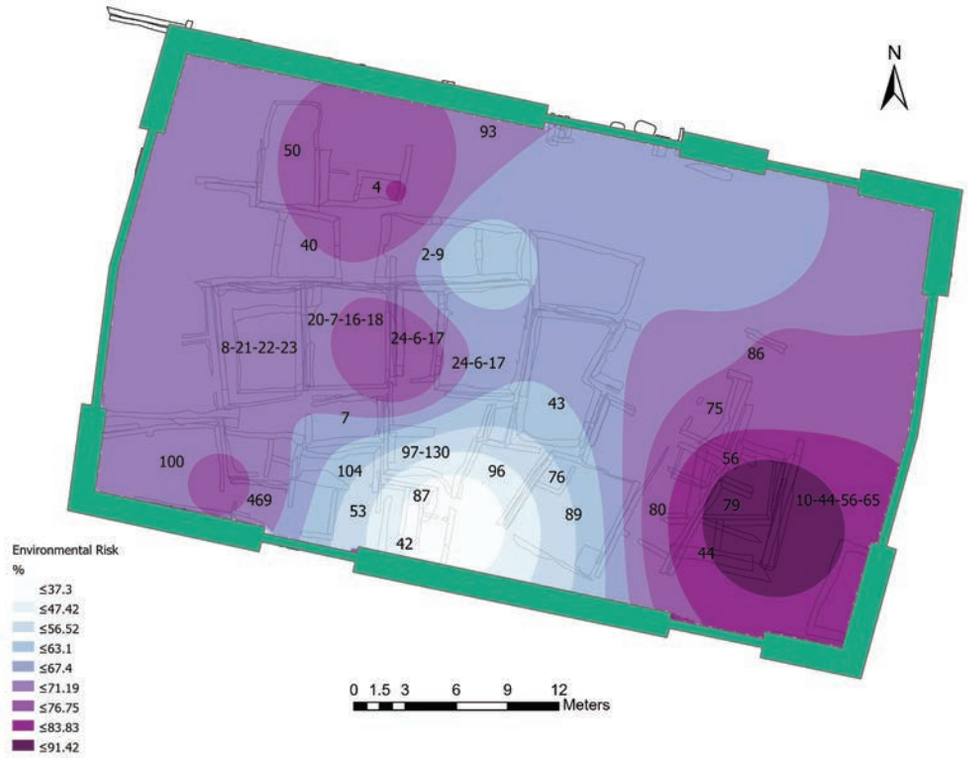


FIGURE 7 2017 South Area environmental risk map, displaying % of environmental risk, wall features (gray lines), and building numbers. The footprint of the permanent shelter is displayed as a green polygon. Map: Arianna Campiani.

was produced using a multi-step method spanning the following calculations: (1) feature scaling normalization, (2) 3D Euclidean distance, and (3) centered squared distance. The centered squared distance results were then spatialized in the GIS using the IDW method and finally reclassified to identify four risk areas spanning low, medium, medium to high, and high. According to our environmental risk map, the South Area's central sector is characterized by the lowest % of risk (i.e., from ≤ 37.3 to ≤ 67.4%), while the buildings in the east and west sectors are most likely to experience more severe damage caused by temperature and humidity (from ≤ 71.19 to ≤ 91.42%).

As another condition that might promote microclimatic variations within Çatalhöyük's South Area, we examined the role of excavation depth in propagating cold and heat throughout the shelter. In the GIS, environmental risk and elevation were related using a Raster Calculator operation (fig. 8). This spatial analysis corroborates that the most superficial buildings in the southeast and northwest sectors are the most at risk, while the central sector is less affected by environmental threats. Importantly, this observation is in line with the vulnerability assessment of the performance of buildings in 2017 when compared with prior years.

Conclusion

Our study showed the importance of understanding the relations between Çatalhöyük's earthen architecture and its changing environment. The information created in this study has been instrumental in understanding the microclimate under the protective shelters and the efficacy of evolving conservation interventions. The synthesis of the conservation and environmental data has also been essential for effectively communicating site management strategies at the national and international levels. Combining quantitative and qualitative data through geostatistical analyses, the proposed comprehensive monitoring system enhanced the mitigation of Çatalhöyük's environmental risks and other conservation threats and provided insights into its future. This study concluded that the enhanced understanding of microclimate and environmental risk are key elements in helping conservators and site managers understand how to prolong this exceptional Neolithic city's life span. Moreover, our methodology can be adapted to the specificity of other earthen sites presenting similar conservation challenges to establish comprehensive site monitoring and conservation performance assessments

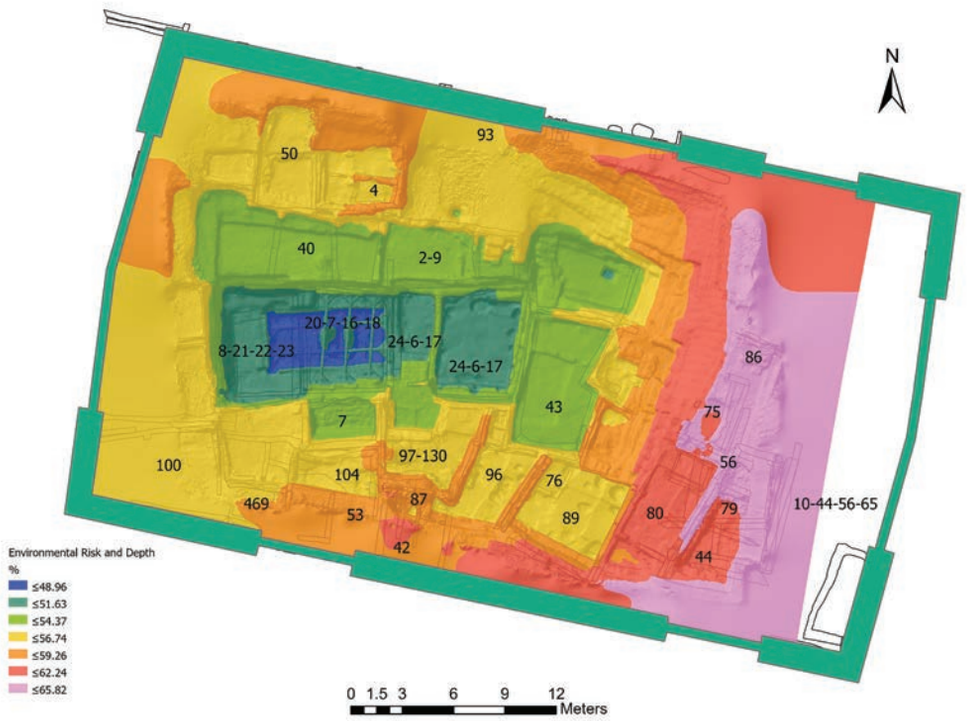


FIGURE 8 2017 South Area environmental risk map combined with excavation depth data derived from a drone survey–based Digital Elevation Model (DEM). The white area to the right, inside the shelter's polygon, was produced using the Raster Calculator operation in the GIS as the DEM lacked data in that sector. Map: Arianna Campiani.

that ensure these fragile places of the past can continue to be protected, investigated, and visited for generations to come.

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Authors' Contributions

Project co-directors: NL, AL; funding acquisition: NL, AL; writing, original draft: NL, AC, AL; writing, review and editing: NL; data visualization and figures: AC; formal analysis: AC, AL; methodology: AC.

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A Framework for Identifying and Monitoring Site Vulnerabilities and Establishing Sustainability Indices for Earthen Ruins in the Arid American West

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Abstract: *The work presented here details the process of developing a framework for identifying and monitoring site vulnerabilities and establishing sustainability indices for earthen ruins in the arid west. To date, this process has been implemented by the Center for Architectural Conservation (CAC) on the adobe ruins at Fort Union National Monument in northeastern New Mexico. Once tasked to fortify and supply the Santa Fe Trail, Fort Union is now preserved and interpreted as a ruin alongside it. It hosts the largest collection of nineteenth-century adobe buildings in the US and presents an intractably complex series of challenges in the face of climate change, with nearly 300 wall segments spread across a site that is nearly a square mile in area. The preservation of climate-sensitive historic fabric in the Anthropocene has presented significant challenges to established methods of identifying, characterizing, and monitoring the performance of these structures. The challenges stem from concerns of scale in both time and scope. Conventional strategies have biased a* reactive *perspective that emphasize the immediacy of impact based on apparent condition and microscale assessment, while shifting climate baselines demand a proactive perspective that instead emphasizes* potential *for impact and multiscalar, anticipatory, and evidence-based assessment. This work extends a legacy of efforts to characterize and mitigate loss at Fort Union; however, the methodology presented here describes a feasible and purposefully self-sustaining approach based on a process of modeling, surveying, and monitoring. In this way, the Fort Union case study has begun to pave the way for a procedural approach to vulnerability assessment for similar climate-sensitive earthen sites across the arid west.*

Resumen: *El trabajo presentado aquí detalla el proceso de desarrollo de un marco para identificar y controlar las vulnerabilidades del sitio de Fort Union y establecer índices de sostenibilidad para las ruinas de tierra situadas en el oeste árido. En la actualidad, el Centro de Conservación Arquitectónica (CAC) ha implementado este proceso en las ruinas de adobe del Monumento Nacional de Fort Union, en el noroeste de Nuevo México. Una vez empleado para fortificar y abastecer la Santa Fe Trail, Fort Union ahora se preserva e interpreta como una ruina. A su alrededor alberga la colección más grande de edificios de adobe del siglo XIX de los Estados Unidos y presenta una compleja variedad de desafíos frente al cambio climático, con casi trescientos segmentos de muro ubicados alrededor de un sitio que tiene un área de aproximadamente una milla cuadrada. La conservación del tejido histórico sensible al clima en el Antropoceno ha presentado dificultades significativas para los métodos establecidos de identificación, caracterización y control del desempeño de estas estructuras. Las dificultades surgen de preocupaciones de escala en tiempo y alcance. Las estrategias convencionales se han inclinado hacia una perspectiva* reactiva *que enfatiza la inmediatez del impacto basándose en la condición aparente y una evaluación a microescala, mientras que los puntos de referencia climáticos cambiantes exigen más bien una perspectiva proactiva que enfatice el* potencial *de impacto con una evaluación multiescala anticipatoria basada en la evidencia. Este trabajo amplía un legado de esfuerzos para caracterizar y mitigar la pérdida en Fort Union; sin embargo, la metodología que se presenta aquí describe un enfoque viable y autosostenible basado en un proceso de modelado, encuestas y control. De esta forma, el estudio de caso de Fort Union ha comenzado a sentar las bases para un enfoque procesal en la evaluación de vulnerabilidades de sitios de tierra con climas similares en el oeste árido.*

Keywords: climate change, earthen architecture, risk and vulnerability analysis, climate sensitive materials, environmental monitoring, building diagnostics, scenario planning, Fort Union National Monument

Introduction

After nearly five years, in February 2020, Fort Union National Monument (FOUN), once the largest military establishment in the American Southwest (Oliva 1993) and today among the largest nineteenth-century adobe ruins in North America, experienced the first of several substantial wall failures (fig. 1).



FIGURE 1 Fort Union National Monument Hospital Structure (HS-57) southwest corner, after collapse, ca. 2020. This wall sector had previously collapsed in the 1960s, was subsequently reconstructed, and was eventually stabilized with interior steel reinforcement that could be seen internally detaching from the adobe masonry in the years leading up to its recent collapse. Photo: Authors.

Before that, the last major collapse occurred in August 2015. Each of these events took place either during or immediately following atypically severe weather, including increased precipitation and extreme wind gusts. Monthly park superintendent reports beginning in the 1960s confirm an intensifying relationship between wall collapses and extreme weather events (fig. 2). Park staff determined that walls collapsed because they were unable to dry out between wetting events. Although these walls were fragmentary and out of plane for many years since the establishment of the monument, a new weather normal caused a change in the response of these adobe walls, resulting in a loss of structural integrity and wall collapse. The instability of the massive adobe walls caused by these high-magnitude climatic events is of great concern to the park, from both a resource preservation and safety perspective. Despite previous efforts to monitor wall condition through annual survey, a better anticipatory model was needed to understand wall vulnerability as a first step to preventive conservation.

Developing a Vulnerability Framework

Heritage professionals have long sought solutions to the preservation of earthen structures. The most ancient of building techniques, the repairability, constructional flexibility, and architectural ubiquity of earthen architecture marks it also among the most resilient (Guillaud 2017). At the same time, its preservation requires a sound understanding of its material, structural, and environmental vulnerability. Ruined structures, fragmented and open to the weather, present an even greater challenge (Matero 2015). Today, heritage specialists

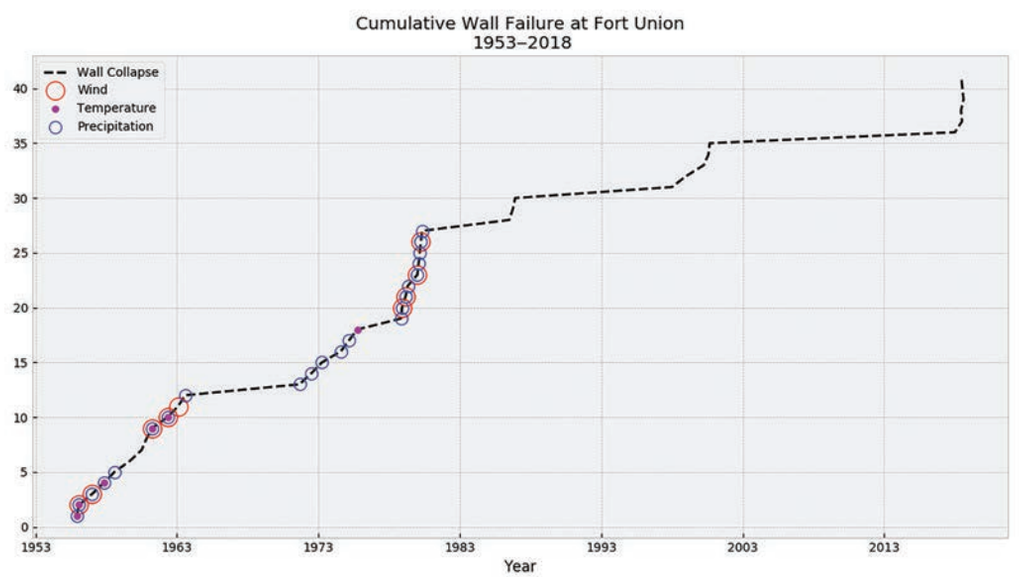


FIGURE 2 Frequency of extreme environmental exposure and collapse language used in park superintendent reports dating back to 1953 up through 2018. A clear trend is visible that traces the incidence and severity of such language correlating to an increase in adobe ruin damage related to environmental exposure, including precipitation and wind events. Chart: Authors.

in earthen architecture have a good understanding of soil properties, performance, and deterioration as well as the current limitations in rendering earthen materials resistant to environmental deterioration (Agnew 1990; Coffman, Selwitz, and Agnew 1990; Selwitz, Coffman, and Agnew 1990). More holistic approaches that invest in retaining stable architectural forms as much as original fabric and the mitigation of environmental effects hold the promise for greater success (and less unintended consequences) in earthen ruins preservation. Recent advances in non-destructive evaluation (NDE) and structural and environmental monitoring offer the potential to deliver the kind of integrated assessment and risk and vulnerability analyses that are now needed to diagnose and intervene in ways that are far more sustainable.

The road to accurate and effective building diagnosis begins with recognizing that deterioration can be defined at different scales or levels. There are many monitoring systems now in place that capture how climate is changing. They do not, however, address the impacts of that changing climate on built cultural resources at the site level. Only with a better understanding of damage mechanisms in terms of their severity, frequency, location, and rate of occurrence can we begin to consider how changing climate is affecting those damage thresholds and the process of establishing monitoring programs that can measure projected impacts to these cultural resources over time (Rainer 2008).

The challenge for cultural resource managers is to develop an illustrative suite of indicators, methods, and metrics across scales that is essential for understanding climate impacts on various built heritage systems. Because it is not feasible or necessary to measure every phenomenon present on a site, it is important to identify a resource's "vital signs," or those critical indicators that can be used for anticipating future problems (Rockman et al. 2016).

These indicators should be directly linked to an observable problem (i.e., degradation) that is measurable and ideally exists in the past and present. Such information could be used to develop a coordinated monitoring strategy for any site by focusing on a representative set of metrics that can be used as indicators of site vulnerability and sustainability.

In the context of cultural heritage, *vulnerability* is a gap in our protection efforts, the degree to which a system is susceptible, and unable, to cope with adverse effects. *Resilience* means any act that allows a resource exposed to hazards to resist, absorb, accommodate, or recover from the effects of that hazard in an efficient manner.

Sustainability is a function of the vulnerability and resilience to a system's threats. As with natural ecosystems, cultural resources also have the capacity to adapt and evolve in response to changes in the environment, but this capacity is limited in terms of time and space as well as the intensity of the change. For example, annual summer "monsoons" will continue to differentially erode the adobe walls of FOUN; however, changes in the frequency of these extreme weather events due to climate change will potentially stress the walls beyond their moisture threshold limits, causing a new, unrecoverable catastrophic failure mode due to adobe's wet strength vulnerability. The aim here is to provide a conceptual framework for defining site vulnerability and threshold limits based on site monitoring that integrates across a wide range of conditions, sensitivities, scales, and time.

Case Study: Fort Union National Monument

The third Fort Union was established in 1862 and began to deteriorate almost immediately after construction, requiring constant maintenance and repair by the Army. Military abandonment in 1889 only worsened the situation, creating the serendipitous ruins the National Park Service finally designated in 1959 as a National Monument. Over 300 standing adobe walls or approximately 5000 linear feet and an estimated 50,000 square feet define the third Fort.

Understandably, over sixty years of preservation efforts have focused on keeping the walls standing. Following the initial "stabilization" efforts that attempted to address structural and surficial damage through the use of both traditional and novel chemical treatments, since the 1980s the park has settled into a cyclical and remedial maintenance program of preserving the weathered walls that is dedicated to maintaining the status quo, using earthen "mud" shelter-coats. While this approach has proved largely effective for many years, the recent wall collapses have understandably caused resource managers to question whether current methods are still adequate to address what appears to be a changing environmental context.

The process of protecting adobe ruins with sacrificial mud shelter-coats is initially effective but obscures evidence of serious subsurface structural failure. The nuance of the structural and environmental performance of these walls requires a *systems-based approach* that incorporates observational evidence alongside a fundamental understanding of their construction, maintenance history, and material-specific deterioration mechanisms. The primary objective of this vulnerability framework is to prioritize remedial and cyclical preservation and stabilization interventions based on an established hierarchy of risk. This allows for near-term planning but can also be used to evaluate the performance of

interventions over time. Sustainable solutions are "smart," as they conserve and redirect staff time and fiscal resources and ultimately result in improved resource integrity.

The Integrated Vulnerability Assessment Methodology

This methodology, developed and implemented at the third Fort, is composed of three components:

- A rapid assessment survey (RAS);
- A profilometry methodology for validating and expanding RAS findings;
- Passive embedded monitoring.

These three components provide the foundation for both qualitative and quantitative survey and monitoring, the latter when performed over specific intervals of time. Each dataset complements and reinforces the other.

Rapid Assessment Survey (RAS)

The RAS establishes the framework for implementing a seasonal site-wide assessment, the results of which substantiate year-to-year maintenance, stabilization, and more targeted monitoring decisions. The primary objective of the RAS is to prioritize walls based on observed conditions and vulnerability factors unique to each individual wall. It does not, however, replace or supersede the appropriate application of expert judgment to actualize its findings. The validity of the RAS is derived from consistent annual implementation. It provides an observational approach that replaces the various informal annual "surveys" that focused on tracking preservation work rather than change over time.

The RAS centers on a distinction between intrinsic and extrinsic factors that define a wall's vulnerability. Intrinsic factors are physical in nature and relate to composition and construction. Examples include wall geometrics (e.g., shape, height, length, attitude, cross section) and construction (e.g., masonry coursing, wythe configuration, presence of openings). At FOUN these intrinsic factors are often difficult to identify given the long-standing practice of shelter-coating, which conceals construction information. For ruins this is even more complex, as the as-built condition, now lost, may have affected the earlier performance of the wall, resulting in the differential conditions seen today. The portions of the survey dedicated to these factors aim to identify deterioration or failure of the underlying fabric and structure of the wall. The risk posed by any one, or combination, of these factors is therefore inherent to a wall and will determine its response to extrinsic factors like weather.

Extrinsic factors affect the performance of a wall from beyond the boundaries of the wall itself and include environmental exposure, architectural and geophysical context, and the performance of ongoing preservation and maintenance strategies. In contrast to intrinsic factors, efforts are often made to influence or eliminate extrinsic elements. For example, deterioration of a shelter-coat due to weathering is a function of not only shelter-coat performance but also environmental exposure (e.g., prevailing weather patterns) and context (e.g., aerodynamic and solar shading from adjacent walls). A prioritized list of walls captures the risk related to intrinsic factors; however, such a tabular evaluation cannot incorporate extrinsic factors. The conditions recorded during the RAS do not ascribe causality to intrinsic or extrinsic factors since most observed conditions are the result of combined factors. Each element of the RAS builds on establishing a hierarchy of vulnerability related to both categories.

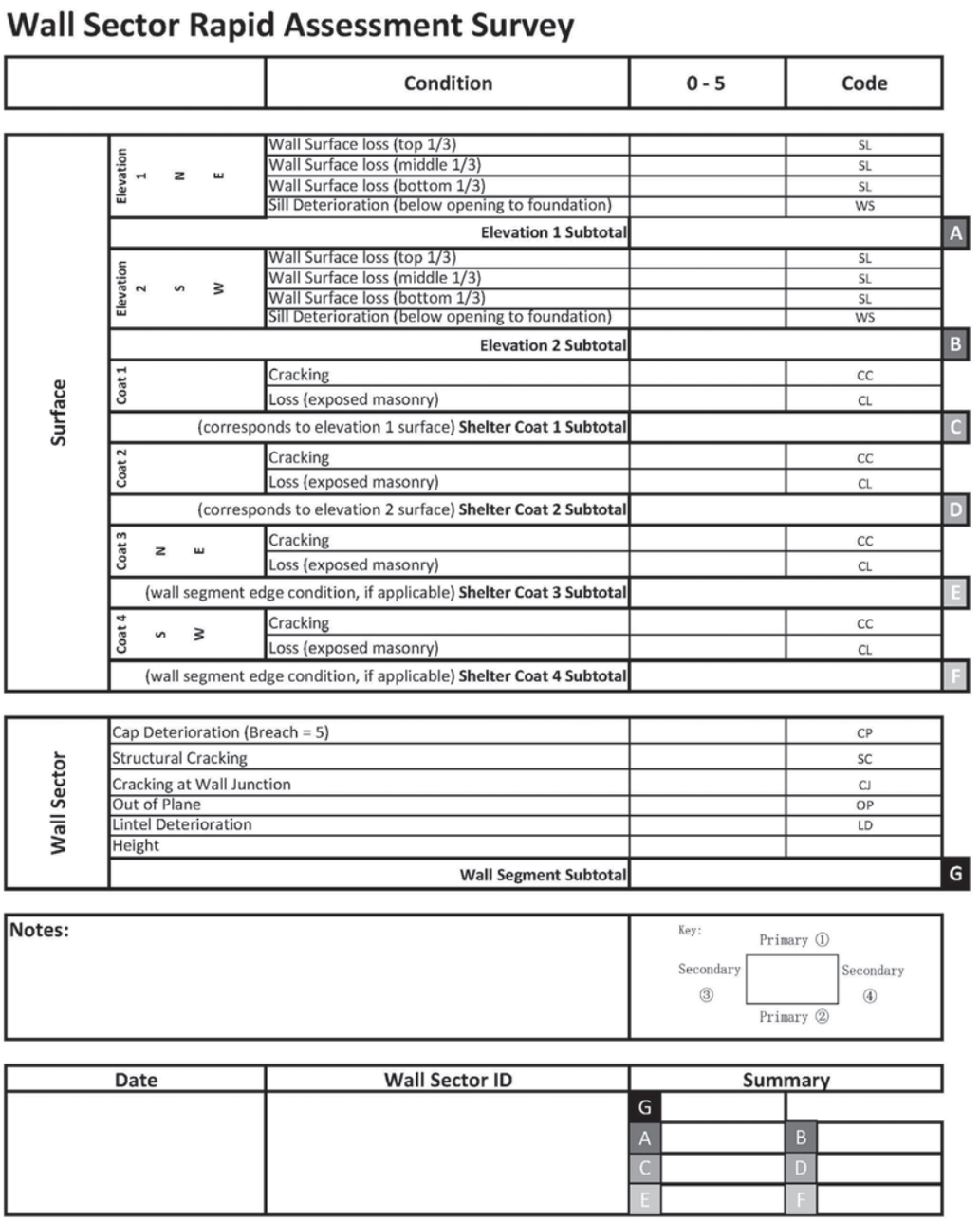
The RAS form is composed of three subsections (fig. 3):

- Categories A and B pertain to elevational characteristics, including loss of wall cross section, and can indicate possible avenues for catastrophic failure;
- Categories C through F pertain to surficial conditions and the exposure characteristics discerned from them. These categories do not suggest risk of imminent or abrupt structural or catastrophic failure, but point to damage from slow, anticipated erosional loss;
- Category G pertains to overall geometrics and is weighted the most because input from National Park Service (NPS) Vanishing Treasures Program (VT) structural engineers suggests these factors are most directly related to collapse risk.

Attached to these categories is an inherent risk hierarchy through a series of weights. This hierarchy is visualized on the form by the shaded label tabs to the right of each category; a darker shade indicates a heavier weight.

These categories provide the information needed for resource managers to analyze risk and wall sensitivity, determine overall wall vulnerability, and develop prioritized preservation plans. The RAS format also allows preservation crews to use the results to inform seasonal work.

The top 5% most at-risk walls are spatially distributed across the third Fort but are mainly concentrated in the Hospital



Wall Sector Rapid Assessment Survey

		Condition	0 - 5	Code	
Surface	Elevation 1 N E	Wall Surface loss (top 1/3)		SL	
		Wall Surface loss (middle 1/3)		SL	
		Wall Surface loss (bottom 1/3)		SL	
		Sill Deterioration (below opening to foundation)		WS	
		Elevation 1 Subtotal			A
	Elevation 2 S W	Wall Surface loss (top 1/3)		SL	
		Wall Surface loss (middle 1/3)		SL	
		Wall Surface loss (bottom 1/3)		SL	
		Sill Deterioration (below opening to foundation)		WS	
		Elevation 2 Subtotal			B
	Coat 1	Cracking		CC	
		Loss (exposed masonry)		CL	
		(corresponds to elevation 1 surface) **Shelter Coat 1 Subtotal**			C
	Coat 2	Cracking		CC	
		Loss (exposed masonry)		CL	
		(corresponds to elevation 2 surface) **Shelter Coat 2 Subtotal**			D
	Coat 3 N E	Cracking		CC	
		Loss (exposed masonry)		CL	
		(wall segment edge condition, if applicable) **Shelter Coat 3 Subtotal**			E
	Coat 4 S W	Cracking		CC	
		Loss (exposed masonry)		CL	
		(wall segment edge condition, if applicable) **Shelter Coat 4 Subtotal**			F
Wall Sector		Cap Deterioration (Breach = 5)		CP	
		Structural Cracking		SC	
		Cracking at Wall Junction		CJ	
		Out of Plane		OP	
		Lintel Deterioration		LD	
		Height			
		Wall Segment Subtotal			G

Notes:

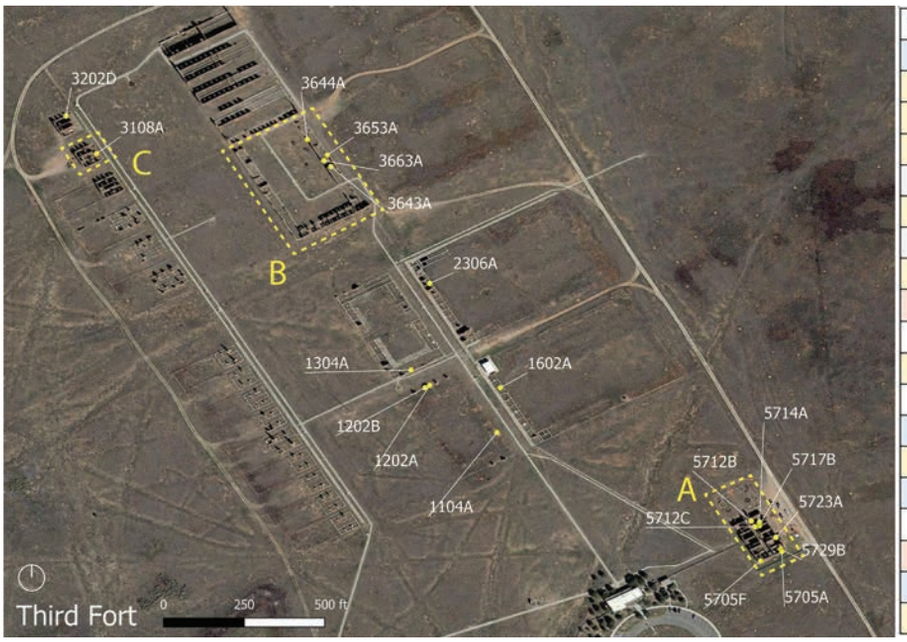
Key: Primary ① Secondary ③ Secondary ④ Primary ②

Date	Wall Sector ID	Summary			
		G			
		A		B	
		C		D	
		E		F	

FIGURE 3 Rapid Assessment Survey (RAS) form, developed by the Center for Architectural Conservation (CAC) and the foundation of the integrated vulnerability assessment methodology implemented at FOUN. The form was developed to address surficial erosion, indicative of shelter-coat performance and environmental exposure (categories C–F); elevational loss, which suggests the influence of extrinsic factors, such as basal erosion from rising damp or soil-bridging and coving below a soil-cement cap (categories A and B); and systemic failure of the wall overall, related to intrinsic factors, such as inherent vice in construction or the geometrics of the massing (category G). Illustration: Authors.

(HS-57) and Mechanics' Corral (HS-36) (figs. 4, 5). The data show that north- and south-facing walls are generally at higher risk than east- and west-facing walls, most likely due to increased moisture differential. Southern elevations, exposed to wind-driven rain and basal snow drifts, will dry much more regularly and rapidly than northern elevations, since north elevations receive little or no drying effect from solar gain. It is important to note, however, that not only do north-south walls score higher overall, but the contribution of category G is also consistently elevated, suggesting that north- and south-facing walls are more structurally vulnerable (intrinsic), while east- and west-facing walls are more vulnerable from exposure (extrinsic).

Given the unique and uncertain nature of vulnerability analysis, absolutes should be avoided and findings should be viewed from several relevant perspectives to learn as much as possible about the underlying nature of the system. Thus, the categories of the RAS were designed to be viewed as a composite or individually.



SECTOR	RANK	SCORE	BUILDING
3663A	1	1139	Mechanics' Corral
5705F	2	1134	Hospital
5723A	3	1133	Hospital
5717B	4	1128	Hospital
3108A	5	1119	Commissary's Office
5712C	6	1101	Hospital
1304A	7	1093	Company Quarters 13
5729B	8	1081	Hospital
1204B	9	1059	Company Quarters 12
1602A	10	1048	Laundresses' Quarters 16
5712B	11	1046	Hospital
3202D	12	1044	Clerks' Quarters
3643A	13	1035	Mechanics' Corral
5705A	14	1032	Hospital
3653A	15	1024	Mechanics' Corral
2306A	16	1015	Laundresses' Quarters 23
1204A	17	1008	Company Quarters 12
3644A	18	1004	Mechanics' Corral
5714A	19	1003	Hospital

FIGURE 4 Map showing the top 20% most at-risk walls identified by the RAS for the third Fort complex: (A) Hospital (HS-57); (B) Mechanics' Corral; (C) Officers' Quarters (HS-31). Wall sector 5705F is the wall that collapsed in 2020 (see fig. 1). The legend indicates adjusted (normalized and weighted) score and rank. Walls of the Hospital (HS-57) are highlighted in yellow, Mechanics' Corral in blue, and other in white. Illustration: Authors; Aerial Satellite Imagery provided by Map Data © 2020 Google.

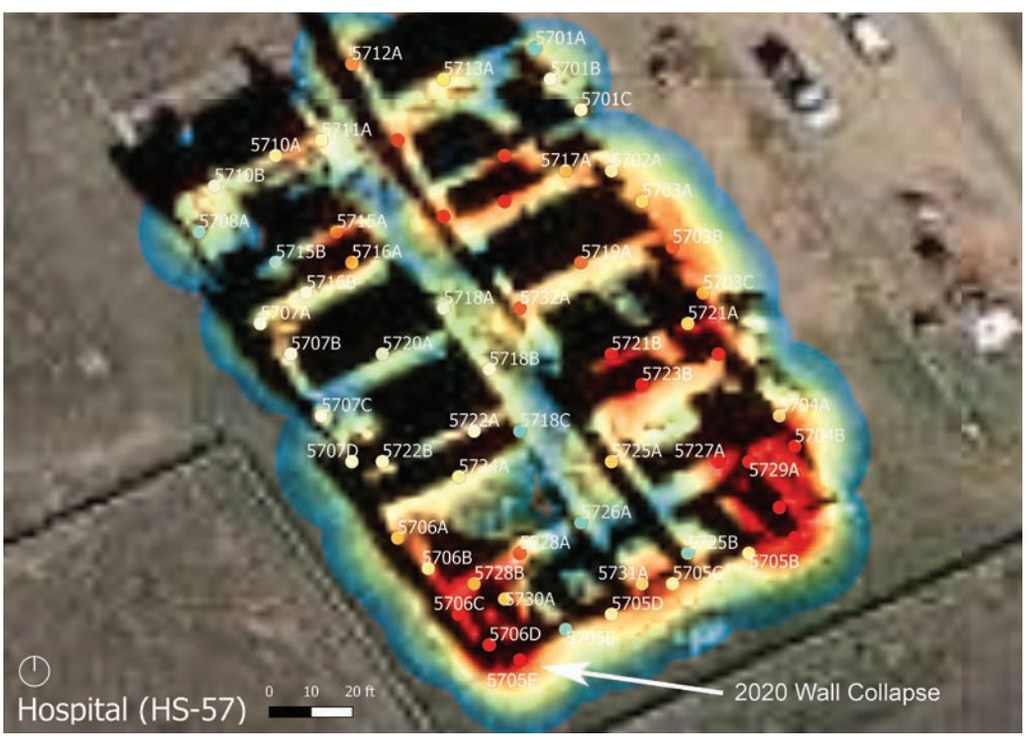


FIGURE 5 Detail plan of the Hospital (HS-57) depicting the corresponding walls of the top 20% most at-risk walls identified by the RAS. Wall sector 5705F is the wall that collapsed in 2020 (see fig. 1). Illustration: Authors; Aerial Satellite Imagery provided by Map Data © 2020 Google.

Wall Profilometry

Wall profilometry was also utilized to validate RAS results by providing targeted data related to geometrics and differential surface deterioration at the exact locations needed (compared to e.g., wholesale laser-scanning methods) in a cost-effective way requiring limited technical knowledge. A corresponding pair of wall profiles can efficiently provide height-width ratios, weight distribution, and eccentricity. In addition to height, cross-sectional characteristics are most critical. A snapshot of a wall's vulnerability can be synthesized from deductions made about exposure, active and latent deterioration, and movement. Profile information is also critical to maintenance and preservation of FOUN walls as forms in the landscape, while the surface deterioration typologies gathered from the analysis can be beneficial to understanding surface erosion and the influence of specific geometries to gradual weathering of adobe ruins across the region.

Sixty-three wall profile pairs were collected from the Mechanics' Corral (fig. 6). Results indicate a general coving trend that biases the middle and upper thirds of west-facing walls. This phenomenon, related to differential weathering of soil-cement wall caps, causes water to gradually erode the wall surface directly below it. Depending on the condition on the obverse face, extreme cases can generate eccentric loading that could cause failure of upper sections. East-facing walls display a wider range of loss severity, possibly caused by differential influence of environmental factors such as early morning, low angle solar gain during winter months, exacerbating freeze-thaw conditions.

South- and east-facing wall sectors display greater variation of surface typologies compared to their composite averages. This would suggest that there are additional contributing variables to wall surface deterioration beyond orientation.

Ultimately, the top 5% most at-risk walls of the third Fort identified by the RAS correlated with an independent structural analysis of the profilometry data (fig. 7). These walls all exhibited a level of eccentricity that indicates areas within the cross section may be subject to dangerous tensile stresses and are at risk of catastrophic failure. However, this purely geometric wall profilometry analysis cannot provide the depth of risk evaluation based on documentation of the full range of unique vulnerability factors. Rather, these two methods are complementary.

Passive Embedded Monitoring

This methodology, combined with a feasible long-term monitoring approach that leverages low-cost, passive sensing, like radio identification (RFID) moisture sensors that easily dovetail with maintenance efforts, provides a sustainable approach for vulnerability assessment. RFID technology was explored as an alternative to the industry standard, costly active (powered) embedded data-logging systems (Crosby 1978). RFID leverages knowledge of primary failure modes and the advantages of a passive "install-and-forget" embedded moisture

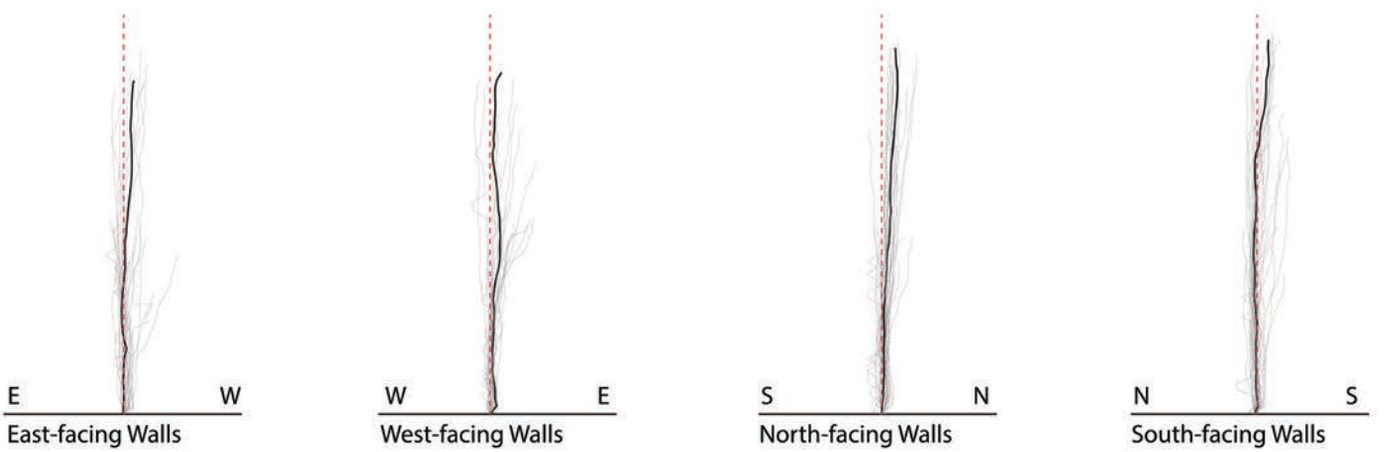


FIGURE 6 Wall profilometry results for the Mechanics' Corral, grouped by orientation. The dark black line indicates the average profile of the group, and the red dashed line indicates a centered vertical reference line. From left to right: east-facing walls (n=35), west-facing walls (n=35), north-facing walls (n=26), south-facing walls (n=26). Illustration: Authors.

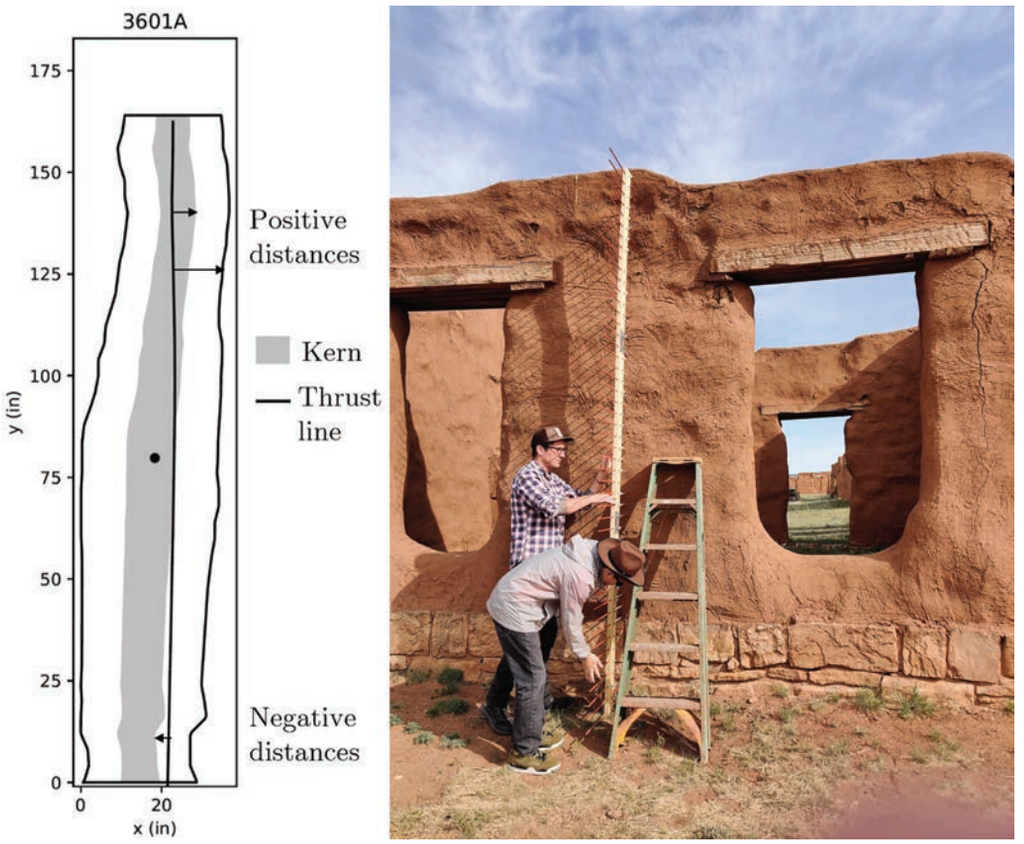


FIGURE 7 Photo of the CAC team collecting wall profile pairs of the Mechanics' Corral (HS-36) using a purpose-built profile gauge. At left of photo is an example of the structural analysis of the resulting profile pair. Illustrated is the center of mass, the kern (or middle third of the cross section), and the resulting thrust forces generated from eccentricity. Photo: Authors; Illustration: Wesley Reinhart and Rebecca Napolitano, nap@psu.edu, Department of Architectural Engineering, Pennsylvania State University.

detection technology. The system focuses specifically on the wall cap as the most critical "vital sign" of FOUN walls as identified by the RAS. The tags cannot quantify moisture content but can detect its presence. Preliminary readings from the tags, after shelter-coating over them, indicate the system was able to detect a wetting event compared to a controlled dry test (fig. 8). Thus, when paired with the strategic location of the tag, conclusions can be made regarding the fitness of that system.

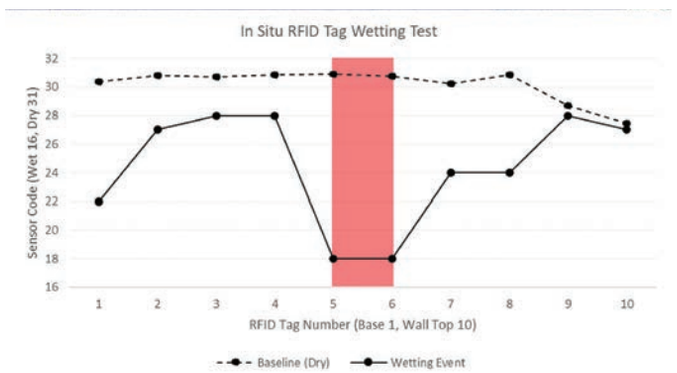
Conclusion

The Integrated Vulnerability Assessment Methodology identifies distinctions between different modes of deterioration based on their symptoms as well as their degree and frequency of treatability. Certain treatments, such as the application of shelter-coats, are preventive, low impact, and cyclical in nature; however, this mode of treatment does not address other conditions such as structural deformation, which require more invasive, remedial, and enduring interventions. A sustainable conservation and management plan for climate-sensitive cultural resources, particularly those maintained as ruins, clearly must identify the type, rate, and location of deterioration, what interventions are necessary to reduce or remove root causes, and a monitoring protocol to track their performance.

RAS data gathered at the third Fort, particularly regarding extrinsic factors, provide for constructing and validating performance (i.e., deterioration) scenarios that suggest certain combinations of both intrinsic and extrinsic factors, where combined, have an exacerbating effect on both active and inactive deterioration conditions and therefore overall performance. This is the essence of understanding risk and threat and their effect on site vulnerability. The framework detailed here can lay the foundation for NPS to develop an updated, unique, and lasting site preservation and management plan for FOUN, one that may act as a model for similar resources elsewhere in the region, and one that can respond to the coming needs related to a changing climate and diminishing fiscal reserves.



(a)



(b)

FIGURE 8 (a) Ten passive RFID tags were installed on the east face of wall sector 5732A of the Hospital (HS-57). The tags were spaced 12 in. apart, beginning from the top of the stone foundation. Tag 1 is at the base of the wall, tag 11 at the top. This, and other walls of the hospital, were re-coated later, in the summer of 2019. (b) The area highlighted in red indicates the tags to which water was applied. This parallels a noticeable reduction in the tag reading (corresponding to increased moisture) compared to the dry, baseline test. Preliminary readings from the tags, after shelter-coating, indicate the system was able to detect a wetting event compared to a controlled dry test. Photo and chart: Authors.

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[Pluvia Ex Machina] Rain in the Desert: Baseline Climate Change Impacts on Adobe Architecture

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Abstract: *In recent years, cultural resource managers have noted archaeological site damage caused by seasonal rain events. Standing earthen architecture, such as adobe, appears to be most vulnerable to weather-related damage, particularly extreme rainfall events, which are increasing in frequency in the American Southwest. Efforts to efficiently document and assess storm damage, however, currently rely on anecdotal and qualitative descriptions of material loss. In the current study, we built twenty miniature adobe test walls to run controlled testing of various rainfall intensity levels. The walls were not treated, capped, or plastered so as to give a baseline for material loss and damage of an archaeological proxy. Rainfall intensity, including droplet size, was controlled with a rain machine run by the US Department of Agriculture's (USDA) Agriculture Research Service, using precipitation frequencies for Tumacácori National Historical Park (TUMA). Precise measurements of material loss were taken using terrestrial laser scanning, also known as Light Detection and Ranging (LiDAR). Results demonstrated substantial damage to the adobe test walls after simulated 30-minute rain events and showed increasing rates of material loss and affected surface area with increasing rain intensity. The increasing frequency of high-intensity storm events has management implications, including increased cyclical maintenance, increased monitoring of rainfall events and their impact on earthen architecture, and reviews of long-term management strategies.*

Resumen: *En los últimos años, los gestores de recursos culturales han notado daños en sitios arqueológicos provocados por lluvias estacionales. La arquitectura de adobe parece ser muy vulnerable al daño relacionado con el clima, en particular, con las lluvias extremas, cuya frecuencia está aumentando en el suroeste de los Estados Unidos. Sin embargo, los esfuerzos para documentar y evaluar de forma eficaz el daño provocado por las tormentas actualmente dependen de descripciones anecdóticas y cualitativas de pérdidas materiales. En el estudio actual, construimos veinte muros de adobe en miniatura para hacer pruebas controladas de varios niveles de intensidad de lluvia. Los muros no se trataron, reforzaron ni revocaron para ofrecer un punto de referencia a la pérdida y al daño material de una representación arqueológica. La intensidad de la lluvia, incluido el tamaño de las gotas, se controló con una máquina de lluvia supervisada por el Servicio de Investigación Agrícola del Departamento de Agricultura de los Estados Unidos (USDA), empleando las frecuencias de precipitaciones del Parque Nacional Histórico Tumacácori. Las mediciones precisas de las pérdidas materiales se tomaron con un escaneo terrestre con láser, también conocido como LiDAR. Los resultados demostraron daños importantes en los muros de adobe de prueba después de lluvias simuladas de treinta minutos, mostrando tasas mayores de pérdida material y mayor área de superficie afectada con una intensidad de lluvia mayor. El incremento de la frecuencia de tormentas de alta intensidad tiene implicaciones en la gestión, lo que incluye el aumento del mantenimiento cíclico, una mayor supervisión de las lluvias y su impacto en la arquitectura de tierra, así como el análisis de estrategias de gestión a largo plazo.*

Keywords: American Southwest, adobe, climate change, hydrology, earthen architecture

Introduction

Ever since cultural resource managers started caring for architectural remains, they have been trying to figure out how to best preserve them. National Park Service (NPS) frontline interpreters often tell the public that past managers "were doing the best they knew how." This sentiment glosses over the myriad challenges that today's historic preservationists face, all while doing the best they know how. Climate change throws new curveballs, which practitioners have started to research over the last decade or so (Brimblecombe et al. 2011). Climate data suggests summer monsoon storms in the southwestern US have already become more intense (Demaria et al. 2019; Kunkel et al. 2013). The frequency of these heavy storms is likely to increase across the region even while the climate is becoming hotter and drier (Easterling et al. 2017; Vose et al 2017). Likewise, the frequency of Category 4 or greater hurricanes in the northeast Pacific is projected to increase over threefold, meaning the storms resulting from this remnant moisture could occur at times not typically associated with rainfall in the Sonoran Desert (Knutson et al. 2015). Anecdotal evidence from the American Southwest, shared among historic preservationists and cultural resource managers, warns of major collapses, loss, and failures from earthen architecture. Reportedly, this is due to multiday rainstorms, often with periods of high-intensity rainfall, even among prolonged droughts.

The project presented in this paper (see also Hart et al. 2021 for a discussion of this compared with further rain simulations) grew out of the concern for earthen architecture managed by the NPS throughout the southwestern US. Architectural resources managed by the NPS are myriad in both site type and location, and thus weather patterns. They are also often degraded. The NPS manages these architectural remains in their current state, meaning that many are not full height, nor do they always have caps or shelter coats. Any further material loss of these walls is considered major.

The catalysts for this research were previous projects at Tumacácori National Historical Park (TUMA), where masonry adobe church and mission remains from the fifteenth and sixteenth centuries still stand (some intact, some not). Between 2010 and 2018, TUMA had four major collapses or failures at the main site: January 2010 (3.79 in. rain/four days), July 2010 (3.52 in. rain/four days), September 2015 (3.61 in. rain/three days), and February 2018 (1.97 in. rain/two days) (data on file with NPS Southern Arizona Office) (fig. 1). These storms were respectively equivalent to rain events of 10, 5–10, 10–25, and 1–2 years (Bonnin et al. 2011). The rain intensity during these storm events ranged from gentle sprinkles to



FIGURE 1 Major collapse of the west wall of the church at Tumacácori National Historical Park following a two-day storm event in February 2018. Photo: NPS.

short periods of nearly 4 in. per hour. As the Sonoran Desert is unique in having a bimodal annual rainfall, traditional knowledge leads us to understand that major collapses should happen in the winter, during longer, gentle rain events. However, two of the four collapses at TUMA happened in months traditionally associated with monsoon activity, tying in with anecdotal evidence previously mentioned.

Tumacácori is part of the NPS Southern Arizona Group, where two employees are trained in the use of Surphaser (LiDAR, 3D scanning) equipment. The service and equipment are in high demand due to the scanner's precise and accurate modeling and measurements. Thus, as originally planned, this project had two independent research questions focused on honing management of earthen architecture at southwestern NPS sites:

- What is baseline material loss from rainfall for unamended adobe during multiple climate change scenarios?
- How often, and following what type of storm, is the cost of mobilization of the Surphaser and team—and the time necessary for post-processing of data—a positive return on investment?

Using a grant from the National Center for Preservation Technology and Training (NCPTT), we thus set out to systematically test material loss as affected by rain intensity. This took the shape of twenty unamended masonry adobe test walls situated in Tucson, Arizona. Studying bare adobe without

preservation interventions allowed us to investigate its vulnerability to precipitation intensity, providing substantial baseline data for understanding the efficacy of preservation treatments in future research.

Test walls were subjected to a rain simulator. Rain simulators are generally used on soil slopes, and this experiment followed hydrologic research procedures for application. The rain simulator was calibrated to three levels of weather events from historic TUMA weather data: a 1-year storm, a 25-year storm, and a 100-year storm. Five walls were sprayed at each level, leaving five walls in a control group with no simulated rain. Due to low risk of rainfall coupled with high winds, walls were kept uncovered during the run of the experiment, except when they were "tented" during the 30-minute application period to reduce ambient weather effects. This ensured uniform conditions during each simulated rain event and accurate application rates. Isolation of the rain intensity factor was specifically important to allow the collection of baseline data solely regarding anticipated increase in hundred-year events. While a systems approach might seem ideal, it is near logistically impossible to adequately replicate that many variables for rigorous research. Our method intentionally sets aside other variables such as wind or the freeze-thaw cycle, to provide historic preservationists a starting point with, arguably, the most destructive variable in climate change predictions. After treatment the walls were exposed to ambient conditions. All twenty walls were scanned with a terrestrial laser scanner (LiDAR) before and after the treatments.

Context

The twenty test walls were constructed by historic preservationists, archaeologists, masons, and volunteers during a historic preservation training workshop. Knowing that the walls would ultimately be used in the climate change study, project managers designed the walls to specifications logistically needed for use with the US Department of Agriculture (USDA) rain simulator. They thus measured 1 m high, approximately 0.81 m wide, and 0.41 m deep. Each block was approximately 0.41 × 0.25 m (16 × 10 in.), with walls consisting of nine courses. While newly constructed, of limited size, and lacking the complexity and history of extant sites, these twenty test walls provide a unique opportunity for rigorous experimentation.

Sand and clay-rich soil were purchased locally in Tucson and were mixed in a cement mixer at a 2:1 ratio (sand:soil), which produced a material mimicking the bricks at Los Santos Ángeles de Guevavi, a mission that is administratively part of TUMA, with very little intact architecture. The mortar was made with the same ingredients; however, the soil was passed through a ¼ in. screen and the sand:soil ratio was changed to meet the consistency needs in relation to the ambient weather.

Interior wall moisture was measured with embedded volumetric water content sensors (METER Group EC-5), which have a range of 0–1 $cm^3 \cdot cm^{-3}$ and an accuracy of ±0.02 $cm^3 \cdot cm^{-3}$. We were able to say with certainty that the walls were "dry" before the rain simulations began.

Rainfall treatments were based on precipitation frequencies for TUMA estimated by the National Oceanic and Atmospheric Administration (NOAA). This dataset uses historic weather data from multiple stations to estimate average occurrence in a year of rain events with different durations and amounts (Bonnin et al. 2011). We chose treatments simulating rain events that occur at TUMA on average once a year, once every 25 years, and once every 100 years. It led us to the following treatments:

- Control = no rain
- 1-year event = 3.6 cm (1.42 in.)/hr
- 25-year event = 8.4 cm (3.34 in.)/hr
- 100-year event = 10.6 cm (4.18 in.)/hr

We considered the 1-year event to be representative of historic and normal weather at TUMA, while the 100-year event is more akin to the rare high-intensity storm events that we expect to increase in frequency due to climate change in the Southwest. Simulations ran for thirty minutes.

Baseline Run

To further mitigate any biases in choice or construction, we randomly assigned treatment levels to walls. Our team scanned the walls in 3D space before and after treatments (Epochs 1 and 2), using a Surphaser Model, a tripod-mounted hemispherical Class 1 laser scanner that records precise point coordinates. The margin of error for these measurements is ≤1 mm for distances within a 15 m radius of the scanner (Surphaser 2016).

A partnership with the USDA Agriculture Research Service provided equipment and researchers experienced in erosion studies. They used a portable single nozzle, Meyer and Harmon–type oscillating arm rainfall simulator (Meyer and Harmon 1979). This simulator consists of an oscillating nozzle situated at the top height of a metal tripod, positioned 3 m above ground surface in each treatment (fig. 2). The metal tripod is covered in tarps to control for wind (fig. 3). The nozzle choice helps determine droplet size, while the mechanics are connected to a computer that monitors the oscillation



FIGURE 2 USDA Agriculture Research Service rain simulator positioned over an adobe test wall with windscreen. Photo: NPS.

rate. The application of the treatment levels went smoothly, except for Wall P wherein the rain simulator malfunctioned and sprayed rain continuously rather than intermittently at its assigned treatment level.

Three specific measurements were agreed upon as reasonable metrics to quantify material loss: overall material loss, maximum cavity depth, and affected surface area. Overall material loss is presented in percent volume loss per wall. Maximum cavity depth is the greatest negative distance between any point on the first LiDAR scan (Epoch 1) and its corresponding scan point on the second scan (Epoch 2). As the scans create a 3D model of each wall, this can be thought of as a distance or line that is parallel to the plane of the ground. Affected surface area is total surface area wherein there was a difference (≥2 mm) with that point in space between Epochs 1 and 2 (fig. 4). While somewhat hard to describe textually, this is the most comparable metric to traditional field documentation of loss.



FIGURE 3 USDA Agriculture Research Service rain simulator positioned over an adobe test wall concealed by a windscreen and connected to a water reservoir. Untreated test walls appear in foreground. Photo: NPS.

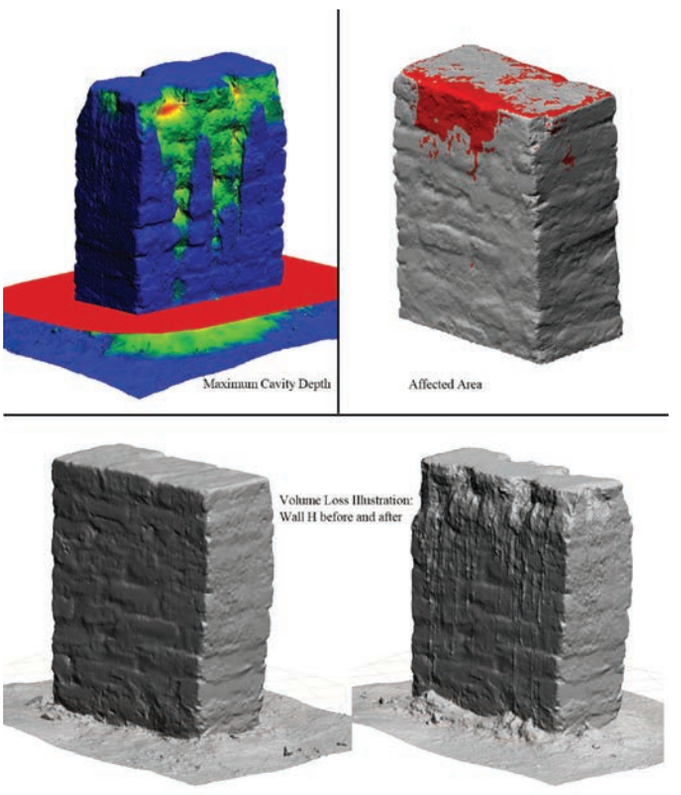


FIGURE 4 Images from 3D LiDAR scans, showing, clockwise from top left: cavity depth, affected surface area, and material loss. Color gradient (with red being the highest) visually shows quantifiable depth. Illustration: NPS.

Results

Results from the LiDAR scans showed significant loss results for all three metrics (with Wall P removed due to the programing error). The relationship between rain intensity and both percentage material loss and affected surface area is parabolic, with R^2 values of 0.93 and 0.98 (figs. 5, 6). Maximum cavity depth also had high R^2 value, 0.96 (fig. 7). At a very basic level, though, our team was surprised to find between 4 and 7% (average 5.6%) volume loss in a 30-minute, 100-year storm, indicating a substantial amount of damage to bare adobe in response to a single, short storm. Likewise, the 100-year storm affected an average of 0.88 m^2 of the walls' surface area and caused cavities 9.2 cm deep (fig. 8).

Maximum cavity depth did not show a parabolic relationship with rain intensity; instead, the trend line leveled off. In fact, post hoc tests revealed that the maximum cavity depth results in the 25-year event treatment were not significantly different from either the 1-year or 100-year event treatments. This is likely due to erosion processes, whereby ponding on the top of the walls leads to runoff over the sides, causing initial rilling, especially at mortar joints. Continued runoff expands the cavity laterally while cavity depth also increases, but at a likely declining rate. However, this metric is the most

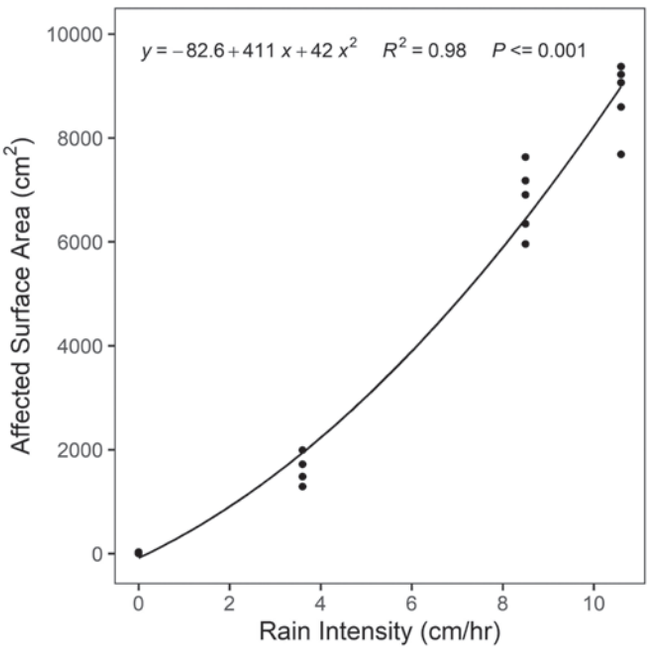


FIGURE 6 Regression of affected surface area of the adobe test walls with rain intensity. Image: NPS.

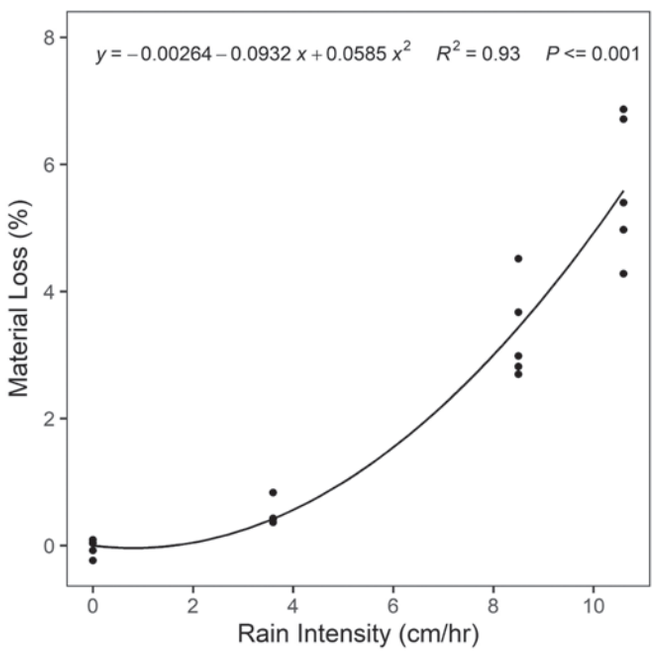


FIGURE 5 Regression of percent material loss of the adobe test walls with rain intensity. Image: NPS.

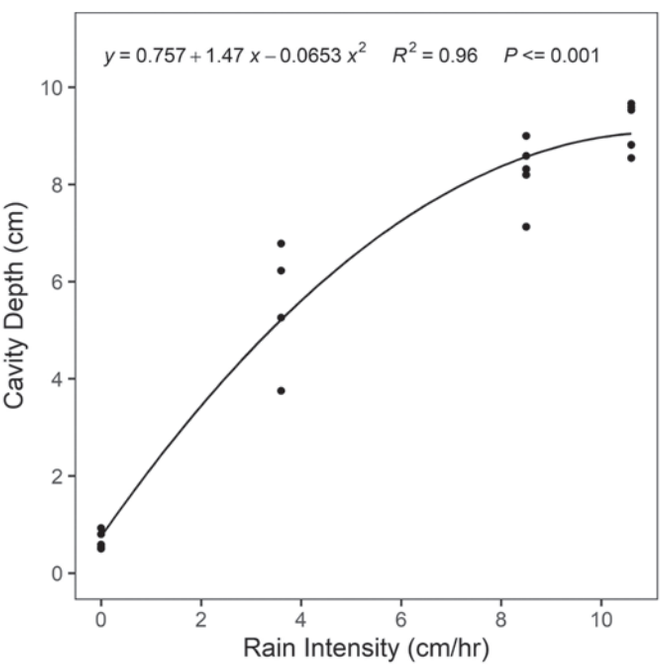


FIGURE 7 Regression of maximum cavity depth of the adobe test walls with rain intensity. Image: NPS.



FIGURE 8 Wall I with damage (4.97% loss), resulting from a 30-minute simulation of a 100-year intensity storm. Photo: NPS.

problematic of the three when using LiDAR scanning, as it is possible that the linear nature of the lasers could get caught/reflected on small, extruding parts of the wall within any cavity. Even so, the results for maximum cavity depth aligned with the other metrics and on-the-ground observations. Further, this amount of damage was accomplished with no or minimal infiltration of moisture into the adobe bricks' interior.

Conclusion

The data herein gives stark answers to the first research question regarding baseline material loss (see fig. 8). Significant material loss can happen in short, intense storms. Moisture from the rain simulations did not reach the interior of the adobe bricks, where the water content and water potential sensors were embedded (12 cm from the outside edge of the brick/wall) during the simulations, and thus during the time that the damage to walls occurred. Further study of the moisture infiltration data, its relationship with multiday storms, and effects on baseline material loss is needed. More study is needed on the hydrologic processes of the surface rill and cavity formation, as well as on storm intensities between 1- and 25-year storms.

Even without those studies, we know the cultural resource manager must now anticipate damaging rainfall in both summer and winter scenarios. Immediate management choices could include increasing cyclical maintenance of sites, including additions of unamended soil caps to vulnerable walls. This data could also precipitate long-term review of management plans and strategies. To that end, next steps will expand testing to various treatments and amended shelter coats, looking at durability and return on investment with climate change possibilities in mind. Regarding the feasibility of mobilization for our team, the LiDAR equipment, and post-processing, there was not a clear "tipping point" where damage occurs that makes use of such a precise technology necessary. With further data from testing, we hope to use trend lines to create general guidelines.

Finally, local rainfall data is very helpful in linking storm events to earthen architecture damage. Many NPS units have nearby weather stations that provide daily rainfall depth, however, sub-daily rainfall data, for example from instantaneous rain gauges, would provide more information on storm duration and intensity, which we found to be a driving factor in the amount of subsequent damage. This more precise weather data could help us correlate specific rain events across the region with damage and evaluate the tangible impacts of climate change. While there are always new and further research directions, this pilot study has provided more than enough baseline data. Increasing intensity in storms leads to significant material loss in unamended earthen architecture. Management of cultural resources in the American Southwest will need to change along with the weather patterns.

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PART 13

Seismic Risk / Riesgo sísmico

Edificios de tierra dentro de centros históricos en contextos con fragilidad sísmico-ambiental: Vulnerabilidad, conservación y reconstrucción— un enfoque práctico y participativo entre Europa y Latinoamérica

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Resumen: *El centro histórico es un organismo complejo y frágil, un patrimonio material y tangible capaz de representar un punto de referencia histórico, social e identitario para la comunidad. En este marco teórico se plantea la importancia de la sensibilización y participación de la ciudadanía en la conservación de los edificios históricos tradicionales dentro de los contextos urbanos, sobre todo en los afectados por las catástrofes naturales, donde a la necesidad material de la reconstrucción se añade la exigencia de fomentar la cohesión social y la identidad. El objetivo de este trabajo es recoger las experiencias de las asociaciones ciudadanas italianas y chilenas constituidas para tutelar, restaurar y reconstruir los edificios en tierra, gracias a la acción directa y conjunta, teórica y práctica de la ciudadanía. Tales experiencias nacen de la toma de conciencia del riesgo de pérdida de un patrimonio y de una tradición constructiva antigua, ante eventos catastróficos o simplemente frente al abandono, la incuria y el olvido. La metodología se basa en el estudio de casos con entrevistas a los miembros y fundadores de las asociaciones. Los resultados de la investigación surgen del análisis de experiencias registradas en realidades distantes y distintas, que enfrentan los mismos tipos de criticidades. De dicho estudio, cabe concluir que los resultados son esperanzadores. Resulta que muchas asociaciones, en los diferentes contextos geográficos, han desarrollado actividades exitosas en la investigación, así como en la práctica. Distintas perspectivas y experiencias siempre conducen a resultados más complejos, con múltiples variables y, por lo tanto, más exhaustivos.*

Abstract: *The historic center is a complex and fragile organism, an example of tangible and intangible heritage capable of representing a historical, social, and point of reference for the identity of a community. Within the theoretical framework of this paper, the importance of the public's awareness and participation in the conservation of traditional historic buildings within urban contexts is addressed. This awareness is especially important in those areas affected by natural disasters where, in addition to the material need for reconstruction, we see the need to promote social cohesion and identity. The objective of this work is to collect the experiences from Italian and Chilean citizen associations that were created to protect, restore, and rebuild earthen buildings, thanks to the direct, joint, theoretical, and practical actions of citizens. These are experiences that result from an increased awareness of the risks of heritage loss, as well as of an ancient construction tradition in the face of abandonment, negligence, neglect, or catastrophic events. This paper's methodology is based on information gathered from case studies and from interviews with members and founders of the associations. The results of the research emerge from the analysis of experiences recorded in distant and different realities that face the same types of critical issues. From this study, it can be concluded that the results are encouraging. It turns out that many associations in different geographical contexts have developed successful activities in research as well as in practice. Different perspectives and experiences always lead to more complex, multivariable, and, therefore, more comprehensive results.*

Palabras clave: centros históricos, adobe, terremotos, Chile, Italia, educación, participación

Tutela de los centros históricos: Formación y participación en los hitos normativos internacionales

El concepto de centro histórico que sirve de fundamento en la disertación es amplio y transversal, complejo y multidisciplinar.

El valor de los centros históricos como conjuntos es reconocido a nivel internacional y ocupa un lugar preponderante en el debate global desde hace tiempo. Ha sido objeto de un lento proceso de elaboración desde las posturas románticas de John Ruskin, que Françoise Choay considera pionero en este debate, y las siguientes contribuciones de Camillo Sitte y de Gustavo Giovannoni (Choay 1965), hasta llegar a la redacción de la Carta de Venecia en 1964, que proporcionó reglas teóricas con alcance internacional. Desde entonces el tema de la tutela de los centros históricos se ha difundido en todo el mundo y se ha ido desarrollando, articulándose y enriqueciéndose con el paso del tiempo y bajo empujes diferentes en concordancia con los acontecimientos histórico-culturales de las distintas áreas geográficas.

La vulnerabilidad de estos conjuntos es un hecho evidente desde el nacimiento del concepto mismo de centro histórico que, como fue definido por la *Enciclopedia italiana de ciencias, letras y artes,* surge en los primeros años del siglo XIX, periodo en el que estas áreas "dejan de ser la ciudad toda y, como tal, comienzan a perder la diversidad propia de toda urbe" (Carrión 2005), cuando la revolución industrial impulsó un crecimiento de las ciudades nunca antes visto. Los procesos de transformación siguen desafiando a los urbanistas, arquitectos y conservadores a encontrar el equilibrio dinámico entre tutela y modernización, desarrollando "una política sin fin de agregación de valor" (Carrión 2000).

La vulnerabilidad de estos frágiles y complejos conjuntos es transversal: por un lado, social y cultural y, por otro, material. Construidos con materiales antiguos y técnicas tradicionales, estos conjuntos requieren intervenciones de mantenimiento continuas y respetuosas, y el desarrollo de una "cultura permanente de intervención" (Carrión 2000).

La fragilidad física de los conjuntos históricos se amplifica en los contextos con riesgo sísmico. El sismo puede destruir en pocos minutos el patrimonio material de un centro histórico y poner a prueba su patrimonio inmaterial: la comunidad con sus tradiciones, que con el desarraigo de su territorio y de sus símbolos corre el riesgo de deshacerse (Fried 1966).

Por otro lado, estudios de sociología afirman que frente a desastres, existe una resiliencia de comunidad (Prati y Pietrantoni 2009). Como reacción en los primeros momentos después de una catástrofe, las redes de relaciones, la memoria de los lugares y la cohesión social, de estar bien sostenidas y organizadas, son los elementos inmateriales que se empoderan, se refuerzan (Gist y Lubin 1989) y permiten a la comunidad rescatar el propio patrimonio material, su lugar, su historia y su identidad: sus centros históricos. La comunidad tiene un papel importante no solo en el posdesastre, sino también en la preparación, la prevención y la mitigación de los riesgos (Prati y Pietrantoni 2009).

El tema de la participación informada de la ciudadanía en la tutela de los centros históricos está presente desde el principio del debate sobre la salvaguardia de los conjuntos urbanos. En las Normas de Quito de 1967, por ejemplo, se plantea que "la colaboración espontánea y múltiple de los particulares en los planes de puesta en valor del patrimonio histórico y artístico, es absolutamente imprescindible."

A su vez, en la Recomendación UNESCO de 1976 relativa a la Salvaguardia de los Conjuntos Históricos o Tradicionales se dedica una sección entera, la quinta, a la investigación, enseñanza e información a todos los niveles. Asimismo, la UNESCO subraya en dicho documento lo indispensable que resulta fomentar la formación de artesanos y especialistas en la salvaguardia de conjuntos históricos, además de las propias técnicas artesanales amenazadas por los procesos de industrialización.

La carta de Washington de 1987 para la conservación de ciudades históricas y áreas urbanas históricas da otro paso importante y añade, a la importancia de asegurar la participación informada de los habitantes, el tema de las asociaciones para asegurar la conservación y restauración.

La Recomendación de la UNESCO sobre el paisaje urbano histórico de 2011 recoge novedades y nuevos desafíos como el turismo de masas y el cambio climático. Además, el documento plantea la nueva definición de paisaje urbano histórico, ampliando el concepto de conjunto histórico, hasta comprender la dimensión intangible de estos lugares, las prácticas y los valores sociales, culturales y económicos. También aquí se indica que en la formación y la colaboración entre ciudadanía, profesionales y administraciones se halla la clave para la salvaguardia de estos organismos tan complejos.

El debate sobre la tutela de los conjuntos históricos y el papel de las comunidades sigue activo y en continua evolución.

Construcciones en tierra y riesgo sísmico

Entre las técnicas constructivas tradicionales que caracterizan los conjuntos históricos de las áreas geográficas del continente americano en las costas del Océano Pacífico que están

afectadas por los terremotos y en los países europeos en torno al Mar Mediterráneo, como España, Italia, Francia y Grecia, destaca el uso de los bloques de tierra cruda.

Como todas las construcciones por bloques sin reforzamiento el comportamiento sísmico de los muros de adobe "generalmente se caracteriza por el colapso súbito y dramático" (Tolles, Kimbro y Ginell 2005); a pesar de ello, algunos estudios como los llevados a cabo por la Pontificia Universidad Católica del Perú, observando la respuesta de las construcciones en tierra cruda frente a las solicitaciones sísmicas, reales o reproducidas en laboratorio, han visto que éstas, cuando están bien construidas, respetando determinadas reglas geométricas y utilizando algunas técnicas constructivas mixtas, pueden alcanzar buenas características de respuesta a los sismos, además de las conocidas cualidades que tienen desde el punto de vista ecológico-ambiental y térmico.

Lamentablemente, aún no se ha desarrollado una fuerte y difundida cultura de la protección de las construcciones tradicionales vernáculas en adobe y en muchos países hay una falta de normativa de protección adecuada.

Así pues, muchas veces, sobre todo tras terremotos, estas construcciones de adobe, si bien poco dañadas, han sido demolidas. Cabe también añadir que, adicionalmente, en los centros históricos, el precio del suelo es alto y hay una presión económica que hace considerar la influencia del mercado en el proceso de sustitución de las casas de adobe con nuevas de concreto, para disminuir el ancho de muros, ampliar los espacios y tener más rentabilidad.

Debido a todo ello se está produciendo un proceso gradual de desconocimiento y olvido de las técnicas tradicionales y de las buenas prácticas de la construcción con tierra.

Pese a esto, se está formando una resistencia a estas tendencias a cerrar los ojos frente a la pérdida de este patrimonio en adobe, que entraña una tradición antigua y un conocimiento artesanal.

Chile ha promulgado hace poco una normativa específica para las intervenciones de construcciones en tierra, como respuesta al terremoto del 2010: la Norma Técnica NTM 002 y la NCh 3332 del 2013. Para su elaboración, la inspiración fue la norma peruana, donde la actual "NTE E 080 del 2000 procede de una versión anterior de 1977" (Cid, Mazarrón y Cañas 2011).

Italia todavía no tiene una normativa nacional específica, sino que hay normas genéricas como la L.42/2004 para la protección del patrimonio cultural y paisajístico en sentido amplio; algunas regiones se han dotado de una legislación particular, y hay algunas propuestas de ley a nivel nacional, impulsadas por las asociaciones que se ocupan de la tutela de las construcciones en tierra.

Hitos oficiales importantes en este camino se deben a UNESCO, ICOMOS e ICCROM, que desde los años 70, junto con la Pontificia Universidad Católica del Perú y el Getty Conservation Institute, organizan simposios internacionales, cursos y talleres sobre la conservación del adobe para fomentar el debate entre los investigadores y los profesionales.

Entre ellos cabe destacar the Adobe Preservation Working Session, US/ICOMOS–ICCROM 1977, Santa Fe, Nuevo México; el Simposio internacional y curso taller sobre conservación de adobe, Lima, Perú, 1983; y la Carta del Patrimonio Vernáculo Construido, ratificada en México por la XII Asamblea General de ICOMOS de 1999.

Experiencias y asociaciones ciudadanas entre Europa y Latinoamérica

Paralelamente al camino internacional oficial de UNESCO e ICOMOS, se están desarrollando, en el ámbito académico, estudios científicos sobre los materiales y las técnicas tradicionales que, a través del conocimiento empírico y de un acercamiento crítico constructivo después de cada evento sísmico, actualizan y perfeccionan estudios importantes para comprender y superar los errores de las intervenciones dañinas hechas en el pasado con materiales y estructuras incompatibles (Binda y Cardani 2019).

En diferentes lugares del mundo, se están desarrollando también interesantes experiencias nacidas de la ciudadanía para la protección y la reconstrucción del patrimonio en tierra. A continuación, se analizarán aquellas experiencias asociativas nacidas en países con riesgo sísmico como Italia y Chile, como respuesta de la ciudadanía a eventos catastróficos, con el objetivo de proteger el patrimonio en adobe, su cultura y tradición constructiva. Estas experiencias comparten, además de los principios de la participación e inclusión, una vocación educativa, no solo teórica cultural sino también práctica.

Procesos de patrimonialización comunitaria

Escuela Taller de Artes y Oficios Fermín Vivaceta, barrio Yungay, Santiago de Chile

El terremoto del 27 de febrero de 2010 provocó una destrucción importante del patrimonio arquitectónico de Chile y, en Santiago, afectó particularmente al barrio Yungay, un barrio patrimonial del centro que, gracias al trabajo de una comunidad de vecinos organizados en un comité muy activo, fue declarado Zona Típica (categoría de protección de un conjunto, de acuerdo con la Ley de Monumentos Nacionales de Chile) y por lo tanto protegido de la urbanización violenta que afectó a otras áreas de la ciudad.



FIGURA 1 Módulo del prototipo de vivienda con materiales reclamados en Chanco, ejecutado por Reclaiming Heritage e.V. Fotografía: Miguel Delso/ Reclaiming Heritage e.V.

Tras el terremoto, el comité "Vecinos por la Defensa del Barrio Yungay" (Biblioteca CF+S 2012) logró enfrentar los primeros momentos de la emergencia con la ayuda de muchos voluntarios. Gracias a su acción, en el barrio no se llevó a cabo ninguna demolición total, cosa que, lamentablemente, sí ocurrió en muchos otros lugares de Chile, donde fueron derribados bienes patrimoniales dañados, sin una evaluación atenta a la posibilidad e importancia de optar por su recuperación.

Poco después, el comité de vecinos del barrio dio vida a la Escuela Taller de Artes y Oficios Fermín Vivaceta, que tiene como objetivo formar mano de obra especializada para la restauración de inmuebles patrimoniales, a través del rescate de oficios tradicionales (Uribe 2014) como la carpintería en madera y la yesería, además de la recuperación de técnicas de construcción en tierra como el adobe, la quincha y la tapia.

El barrio Yungay y su organización constituyen todo un ejemplo de cómo enfrentar la catástrofe, demostrando lo eficaz que puede resultar la respuesta comunitaria frente a los terremotos.

Reclaiming Heritage y el Museo de la Reconstrucción en Chanco, Chile

Reclaiming Heritage (http://www.reclaimingheritage.org) es una fundación con un equipo internacional, con sede en Berlín, que trabaja en la exploración de las posibilidades de utilizar materiales de construcción tradicionales recuperados para reconstrucciones tras catástrofes. La fundación nació en el ámbito académico con una vocación educativa, de experimentación, y un enfoque sensible y práctico de la reconstrucción.

Tras el terremoto del 2010 en Chile, Reclaiming Heritage desarrolló algunos proyectos interesantes en Chanco (D'Alençon 2011), una pequeña comuna en la Región del Maule (Sur de Chile), declarada Zona Típica debido a la armonía del conjunto y a los rasgos patrimoniales de sus construcciones



FIGURA 2 Talleres con la comunidad, desarrollados durante el trabajo de Reclaiming Heritage e.V. en Chanco. Fotografía: Carmen Gómez/Reclaiming Heritage e.V.

vernáculas, muchas en adobe. El proyecto piloto fue la realización de un prototipo con materiales recuperados de un edificio gravemente dañado (fig. 1). Además, se creó el Museo de la Reconstrucción tras la recuperación de una casona patrimonial en adobe que fue la ocasión para hacer talleres prácticos sobre las técnicas constructivas tradicionales con tierra.

Por un lado, dichas actividades obtienen el resultado práctico y tangible de recuperar un edificio patrimonial (fig. 2); por otro lado, contrarrestan el riesgo de olvido de las técnicas tradicionales de construcción en tierra, fomentando al mismo tiempo la participación ciudadana, la cohesión social y la identidad (Franco 2015), factores tan importantes para superar el trauma de la pérdida tras una catástrofe (Prati y Pietrantoni 2009).

Eco aldea autoconstruida de Pescomaggiore

Tras el terremoto del 2009 en Pescomaggiore, un pequeño conjunto histórico entre las montañas del Centro de Italia que resultó gravemente afectado por el sismo, nació una experiencia interesante de autoconstrucción con técnicas tradicionales y materiales naturales (ver http://www.pescomaggiore.org/progetto-eva/).

La voluntad de reacción de los ciudadanos encontró la experiencia de un equipo de arquitectura (B.A.G.) y de un grupo de voluntarios que llegaron de todas partes para ayudar en la emergencia y para aprender las técnicas de autoconstrucción (fig. 3).

Las nuevas construcciones ecológicas y eco compatibles, realizadas con estructura de madera, muros en paja y revoques en tierra, nacieron fuera del pueblo afectado, como viviendas para permitir a los habitantes quedarse en su lugar de origen, con la idea, una vez reconstruido el centro histórico, de convertirlas en lugares para la colectividad.

Esta experiencia es un ejemplo de cómo encauzar positivamente las energías reactivas que surgen tras una catástrofe: la energía de una ciudadanía afectada por la pérdida, la energía de un equipo de profesionales apasionado y competente, y la vitalidad de una humanidad sensible y empática que, ante una emergencia, quiere ayudar.

Los resultados del trabajo conjunto de estas energías son múltiples. Por un lado, está la formación del uso de técnicas constructivas y la utilización de materiales tradicionales y naturales; la obra de construcción fue un taller continuo de aprendizaje y transferencia de conocimientos. Por otro lado, está el resultado social y psicológico de una comunidad afectada, pero bien respaldada para que autoconstruya su presente y su futuro en su misma tierra.



FIGURA 3 Construcción de uno de los edificios de *Eco Villaggio Autocostruito* (E.V.A.) en Pescomaggiore. Fotografía: Paolo Robazza.



FIGURA 4 Uno de los edificios de *Eco Villaggio Autocostruito* (E.V.A.) en Pescomaggiore. Fotografía: Paolo Robazza.

Finalmente, está el resultado práctico de la realización de construcciones eco compatibles y antisísmicas que, a corto plazo, responden a una necesidad habitacional y, a largo plazo, pueden contribuir al fortalecimiento de la identidad de la comunidad, como símbolos de una memoria colectiva de resiliencia y de vínculo con su propia tierra, pueblo e historia (fig. 4).

Conclusiones

Los centros históricos son ecosistemas frágiles y complejos, sobre todo en áreas con vulnerabilidades materiales e inmateriales; lugares con el riesgo de ser afectados por un desastre o por el abandono, por el descuido o por las acciones del mercado inmobiliario.

Se hace necesaria, por lo tanto, una política pública enfocada a la conservación del patrimonio histórico y paisajístico vernáculos y tradicionales, a través de normativas específicas actualizadas y eficientes, que tengan en cuenta la importancia del conocimiento de los materiales y de las técnicas tradicionales.

El camino de las experiencias recogidas en este artículo nos indica que una exitosa mitigación de las vulnerabilidades físicas pasa por la mitigación de las vulnerabilidades sociales y culturales, que a su vez requiere el fomento de la educación y de la cohesión social (Prati y Pietrantoni 2009).

Estas experiencias dan cuenta de que una respuesta posible está en la formación, en la participación ciudadana y en la práctica del oficio de la construcción en tierra.

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Post-Earthquake Restoration Measures and Documentation of the Royal *Phodrang*s in Upper Mustang, Nepal

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Abstract: *The former kingdom of Mustang in Nepal is dotted with early Buddhist cave temples, ancient monasteries, fortresses, and centuries-old* phodrang*s, or palaces—predominantly built using the rammed earth technique, sun-dried bricks, and timber—that form an extraordinary Buddhist cultural landscape along one of the oldest trade routes through the Himalayas. During the 2015 earthquake, sadly, the main icon of the medieval earthen-walled capital Lo Manthang, the four-story, fifteenth-century Tashi Gephel Phodrang, was badly damaged, as were many other traditional buildings in Mustang. This paper focuses on the different immediate response measures that have been taken to safeguard this exceptional heritage. A preliminary assessment of the damage was carried out with the support of HimalAsia Foundation, assisting the local communities to stabilize vulnerable structures. Furthermore, the documentation and development of a database was initiated, particularly of the five damaged ancient* phodrang*s of the former* gyalpo *(king) of Mustang. Moreover, HimalAsia assisted the* gyalpo *to conduct emergency repair at the Tashi Gephel Phodrang. Further, practical training workshops were organized to reintroduce the rammed earth technique and improve methods of retrofitting houses, as the local building traditions, including maintenance and conservation management, are being slowly forgotten. A new motorway, moreover, led to an increased use of cement for building hotels, since Mustang is a significant tourist destination. Special building codes therefore need to be enforced to preserve this extraordinary heritage.*

Resumen: *El antiguo reino de Mustang, en Nepal, está salpicado de los primeros templos budistas en cuevas, antiguos monasterios, fortalezas y palacios centenarios, construidos predominantemente con la técnica de tierra apisonada, con adobes y madera que forman un extraordinario paisaje cultural budista a lo largo de una de las rutas comerciales más antiguas del Himalaya. Lamentablemente, durante el terremoto de 2015, el Palacio Tashi Gephel (*phodrang*) de cuatro pisos, del siglo XV, ícono principal de Lo Manthang, la capital medieval amurallada, sufrió graves daños, al igual que muchos otros edificios tradicionales en Mustang. El presente trabajo se centra en las diferentes medidas tomadas como respuesta inmediata para salvaguardar este excepcional patrimonio. Con el apoyo de la Fundación HimalAsia, se llevó a cabo una evaluación preliminar de los daños, lo que ayudó a las comunidades locales a estabilizar las estructuras vulnerables. Adicionalmente, se inició la documentación y el desarrollo de una base de datos, especialmente de los cinco* phodrangs *dañados del antiguo rey (*gyalpo*) de Mustang. HimalAsia también ayudó al* gyalpo *a realizar reparaciones de emergencia en el Palacio Tashi Gephel. Como parte de estas acciones, se organizaron talleres prácticos de capacitación para reintroducir la técnica de tierra apisonada y métodos mejorados de remodelación de casas a medida, según las tradiciones locales de construcción, incluidos la gestión, el mantenimiento y la conservación, que están siendo olvidadas poco a poco. Aún más, dado que Mustang es un destino turístico significativo, la construcción de una nueva carretera ha permitido incrementar el uso de cemento para la construcción de hoteles. En ese sentido, es necesario reforzar códigos especiales de construcción que preserven este extraordinario patrimonio.*

Keywords: earthquake response, rammed earth technique, ancient palaces, documentation methods, training courses

Introduction

The former kingdom of Mustang in northwest Nepal adjoining the Tibetan Autonomous Region, at present understood as Upper Mustang, is dotted with early Buddhist cave temples, ancient monasteries, fortresses, centuries-old *phodrang*s (or *gyalkhang*; palaces), and traditional buildings along one of the oldest trade and pilgrimage routes leading through the Himalayas (von der Heide 2010). These are predominantly built using the rammed earth technique as well as sun-dried mud bricks made from local earth, stone aggregate, and timber, thereby forming an extraordinary Buddhist cultural landscape in the trans-Himalayan region. The Nepalese government opened this area in 1992, and Upper Mustang has developed over the years into a significant tourist destination.

Mustang became a spiritual and culturally important area from the eleventh century CE onward, undergoing continuous religious and cultural development that culminated in the formation of an independent kingdom in the fifteenth century, with close ties to West Tibet and places along the Silk Road. It was an independent state from 1440 until it was unified into the Kingdom of Nepal in the late eighteenth century and was known historically as the Kingdom of Lo or Mustang (Dhungel 2002). Even though Mustang was then administratively within Nepal's territory, it maintained its cultural independence, being influenced up to today mainly by Tibetan culture. In 2008, when Nepal was declared a federal democratic republic, monarchical rule ended also in Mustang. Nevertheless, the former *gyalpo* (or *gyalchung*; king) and his family are still highly revered, and the institution of the monarchy is seen as part of the cultural identity of the Lopa people living there.

Many heritage sites and traditional buildings in Mustang were destroyed during the 2015 earthquake in Nepal, including the four-story, fifteenth-century phodrang, the main icon of the medieval earthen-walled capital of the former kingdom, Lo Manthang. Four other phodrangs of the former kings in the surrounding villages, each an impressive example of a unique vernacular architecture that arose in the fourteenth and fifteenth centuries, were also damaged.

This paper will focus on the different measures that were taken after the earthquake (and after unforeseen excessive rainfall) as immediate responses to safeguard these exceptional earthen vestiges.

The Earthquake and Its Aftermath: Assessment and Protection of Sites in Lo Manthang

The author and the parliamentary representative of Mustang visited the area in the immediate aftermath of the devastating 2015 earthquake and carried out a preliminary assessment of the affected buildings and monuments in consultation with local stakeholders. As a further step, the author and the team from the HimalAsia Foundation assisted and supported the local communities in Lo and surrounding villages, salvaging fragments of damaged temples, stabilizing vulnerable structures, and securing artifacts at temporary storage areas. The importance of reusing the remaining architectural elements was discussed. This was especially the case in the community inhabiting the Medieval Earthen Walled City of Lo Manthang, inasmuch as it is a site on the UNESCO Nepal Tentative List for future World Heritage nominations.

Out of 153 households in Lo Manthang (altitude: 3800 m), ten sustained serious damage and many others suffered cracks in the rammed earth or dried brick walls. Lo is famous for its 6 m high rammed earth wall around the densely inhabited area (800–950 inhabitants), which fortunately only suffered minor damage. The famous Jhampa Lhakhang and Thubchen Lhakhang monasteries, both constructed in the fifteenth century and restored recently (by the American Himalayan Foundation), also remained intact.

Emergency Repair at the Royal Palaces

Sadly, the largest complex of Lo Manthang, the famous fifteenth-century Tashi Gephel Phodrang of the former *gyalpo*s of Mustang, unique in the architectural design of its four stories and an additional underground structure and the first building to be constructed (1440) in the former capital by King Ame Pal (Dhungel 2002), was about to collapse and needed to be urgently rebuilt, at least in part. Its external walls, constructed with the traditional rammed earth technique, as well as the interior partition walls made with molded and sun-dried mud bricks, suffered major structural damage that manifested in huge horizontal and vertical cracks. Additionally, the roof was in need of renovation (fig. 1).

The palace was a center of secular power, and its massive structure (7.5 m above the plinth, measuring some 45 m from east to west and 30 m north to south), in front of the main northern entrance to the fortified city, is surrounded by vernacular houses. Larger than the surrounding monasteries, the palace is a reminder of the importance that has been given to the Lopa *gyalpo*s in the past (fig. 2). They are still regarded by the local population as symbols for their unique culture, attracting many tourists. The king had been requested by different restoration organizations to have his palace restored for many years, but he always gave preference to the temples and chortens of Lo, since, as he argued, "they belong to the

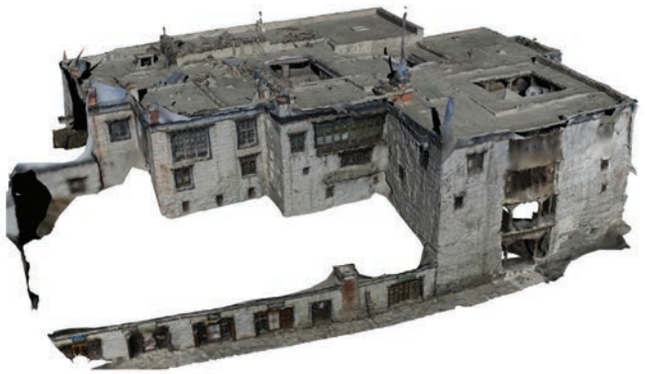


FIGURE 1 Agisoft PhotoScan result of the Tashi Gephel Phodrang, Lo Manthang. Illustration: Matthias Kolbe, HimalAsia, 2017.

Lopa people and need to be taken care of first" (pers. comm., Gyalpo Jigme Singhi Palbar Bista).

The other medieval phodrangs of the former rulers were also badly damaged: the summer palace in Thingkar in northern Lo, the phodrangs in the villages of Ghemi and Dhagmar in the southern part of Upper Mustang, and the Samdup Gephel Gyalkhang in Tsarang, the latter built in the fourteenth century, even before the palace in Lo Manthang.

Of utmost importance, therefore, was the prompt repair and stabilization of the deteriorating outer and inner wall structures and roof areas of the royal phodrangs, since these are iconic buildings that represent unique medieval monumental architecture. In cooperation with the royal family and local construction specialists, and with the financial support of the Gerda Henkel Foundation, the HimalAsia team was able to conduct necessary repair work, particularly at the main Tashi Gephel Phodrang and partly at the Thingkar Phodrang. Unfortunately, the Dhagmar, Ghemi, and Tsarang Phodrangs, which have long been in a bad state of conservation, are still in urgent need of repair.

As an initial step in order to stop the worsening of damage at the Tashi Gephel Phodrang, the most damaged portions of the outer and inner walls were torn down and rebuilt, while cracked walls that still could be preserved were repaired (fig. 3). Additionally, certain areas of the roof were renewed and set at a sloped angle to prevent water from leaking inside, since the building, like the other four phodrangs, does not have a proper drainage system. In order to avoid further damage to the exterior walls, all the phodrangs are in need of such a system for rainwater, since intensive rainfall is becoming more common now. Due to excessive precipitation, for example, the northwestern section of the Tashi Gephel Phodrang has had water seeping into the foundation walls.

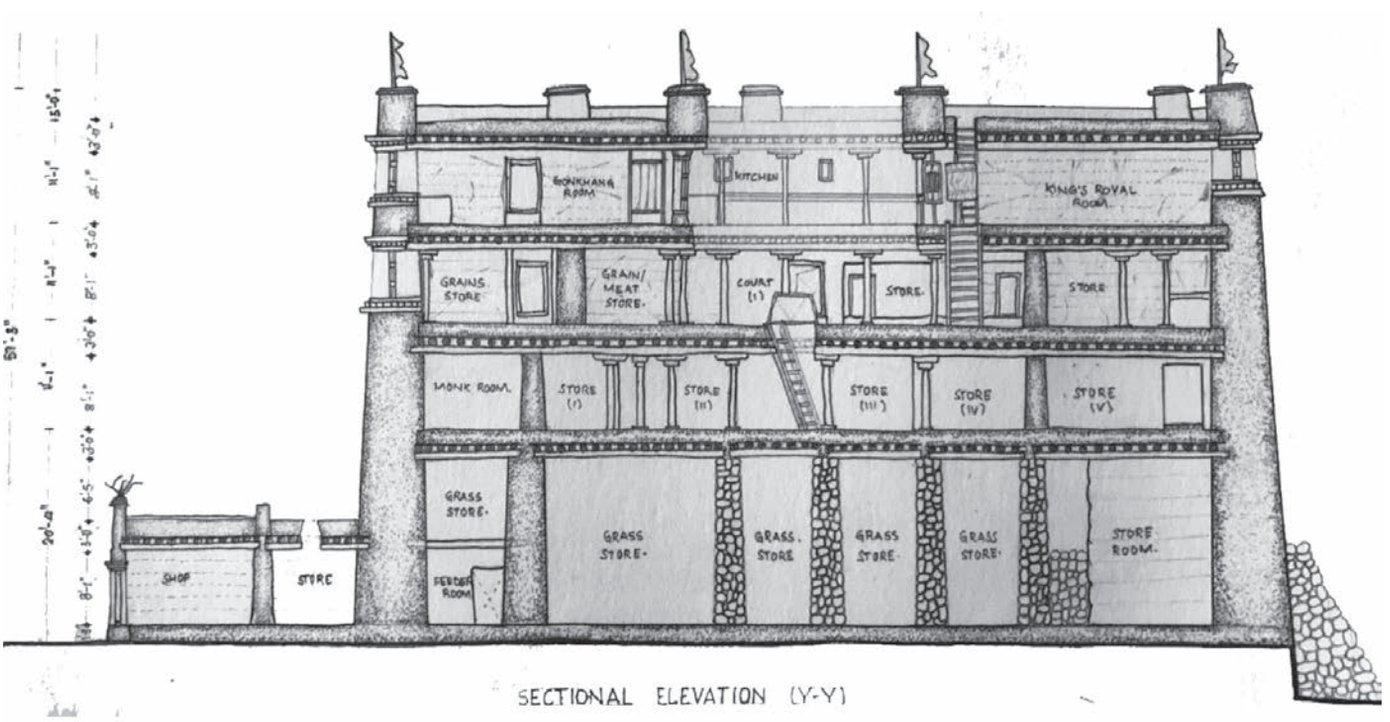


FIGURE 2 Schematic section, Tashi Gephel Phodrang. Illustration: Bipul Rawal, HimalAsia, 2021.



FIGURE 3 Repair of rammed earth wall at the entrance of the Tashi Gephel Phodrang. Photo: Susanne von der Heide, HimalAsia, 2018.

It was therefore decided, together with the local workers, to repair the damaged foundation with a special composition of mud and quicklime mortar (in a lime:mud ratio of 1:3 after testing different blends), instead of the traditionally used mud mortar. This treatment has been never used here before, but the results are convincing and are now used by Lopa people to repair their own houses.

Threatened Traditional Architecture

Traditional buildings in Upper Mustang are made of robust rammed earth or mud brick walls, featuring flat roofs with low parapets and facades with a few openings for windows. Sustainable materials are used for construction, such as timber, stone, sun-dried mud bricks, and compacted earth inside wooden frames that are rammed with a local *durmus*, a kind of hammer, to produce solid walls. In Upper Mustang sun-dried mud bricks (known in the local Tibetan Lopa dialect as *poub*) are generally preferred when constructing traditional houses since they are associated with both quicker and easier building and are cheaper than rammed earth. But building with mud bricks without employing retrofitting methods is not earthquake resistant. *Gyang* or *gyangka*, as the rammed earth technique is locally known, is far stronger than mud bricks and is employed mainly for larger structures, as for the medieval wall surrounding Lo Manthang and the outer walls of monasteries, palaces, and larger houses, whereas mud bricks are normally used for the partitions inside these buildings. To keep these structures intact, proper maintenance needs to be carried out regularly, especially in such a seismically active area as the Himalayas, and is becoming difficult now due to several factors. Three major problems threatening the unique architecture of Upper Mustang have been identified:

- Since the opening for tourism and the construction of a corridor road through Mustang after 1992, the out-migration of especially the younger generation has increased. Lopa children are mostly taught at boarding schools outside of their homeland these days, and therefore knowledge transfer of their traditional cultural values no longer takes place. To find locals who still have the skills and knowledge necessary for construction and maintenance of their traditional vernacular architecture is therefore quite difficult now. Often costly construction workers from outside of Mustang need to be hired;
- The changing weather patterns in the last decade resulting from climate change with heavy snow and rainfall frequently damage the foundations, exterior walls, and roof constructions (which need to be slanted and retrofitted to prevent water from seeping inside) of traditional buildings. More innovative strategies and upgrading techniques need to be introduced to help these structures adapt to climate change;
- Seismic damage needs to be mitigated by introducing different retrofitting methods that avoid the increasing use of cement. Six years after the earthquake there are already several examples of buildings in Upper Mustang where cement is employed (fig. 4), due to the fact that people unfortunately think it is safer than other materials.

In close consultation with Nepalese cultural heritage professionals, HimalAsia organized several practical training workshops on earthen building techniques in Lo to introduce improved building methods, such as retrofitting mud



FIGURE 4 A new cement gate for the Choede Monastery that breaks through the ancient medieval rammed earth wall of Lo Manthang. Photo: Susanne von der Heide, HimalAsia, 2018.

brick buildings with lintel bands to reduce earthquake damage. These practical workshops were well attended, mostly by younger Lopa who had returned to Mustang to engage in the fast-developing tourism business (fig. 5). Likewise, practical wintertime training sessions in Bhaktapur, Kathmandu Valley, for carpenters from Mustang were meant to improve their construction and building techniques.

Documentation of the Phodrangs and the Development of a Database

In 2017, the condition of the five phodrangs worsened due to unforeseen excessive precipitation in Mustang caused by drastic local climate change. Because proper documentation (including the development of a database for the unique medieval palace architecture in Mustang) had not yet been conducted, it was decided together with the royal family that this, along with the general repair and maintenance work, was one of the prerequisites for safeguarding and preserving this extraordinary heritage. In cooperation with the Deutsches Archäologisches Institut (DAI) in Berlin and the Lumbini Buddhist University in Nepal, and with financial support from the Gerda Henkel Foundation, HimalAsia initiated a campaign in 2018 to document the five severely damaged medieval phodrangs in Mustang. This project included Nepalese and German experts, local specialists, and students.



FIGURE 5 Lopa people participating in a workshop on rammed earth construction. Photo: Susanne von der Heide, HimalAsia, 2018.

An overall damage assessment was done, including building measurements and damage mapping of the outer walls, roofs, and diverse interior rooms of the phodrangs. Room logs were created, explaining the specific use of each space. Moreover, an architectural construction survey was conducted regarding building usage and earlier renovation for different phodrangs. Further, hand-drawn measurements were carried out with the help of triangulation, tape, lasers (figs. 6, 7), and three-dimensional, coordinate system photography. To date, 3D models have been developed with Agisoft PhotoScan of the phodrangs in Lo, Thingkar, and Ghemi (fig. 8). The Structure from Motion (SfM) technique was used to document the roof structures and the west, north, and east exterior sides of the phodrang in Lo. Manual measurements and drawings were preferred over tachometry at Lo, as most of the chambers in the lower floors were difficult to access. Nevertheless, tachometry surveys were carried out in the larger spaces of the building, such as in the courtyards. The



FIGURE 6 The DAI and HimalAsia teams working at the Thingkar Phodrang. Photo: Susanne von der Heide, HimalAsia, 2018.

use of drones (UAV) is unfortunately forbidden in this area because of the proximity to the Tibetan-Chinese border.

The application of the above-mentioned appropriate techniques has been a necessary working method for properly documenting the phodrangs. It will be helpful when preparing digital monument records for an archive that will be established in a museum within the main palace building in Lo. The archive, including 3D models, will be accessible to the public.

The documentation of this specific medieval palace architecture is the first step in understanding the spatial structure and construction of these phodrangs, as well as building and maintenance measures that have been applied in the interest of heritage conservation. Such an understanding of the current state of the royal buildings provided by the documentation and the data collected is a necessary precondition for further renovation, restoration, and preservation of these exceptional monuments.

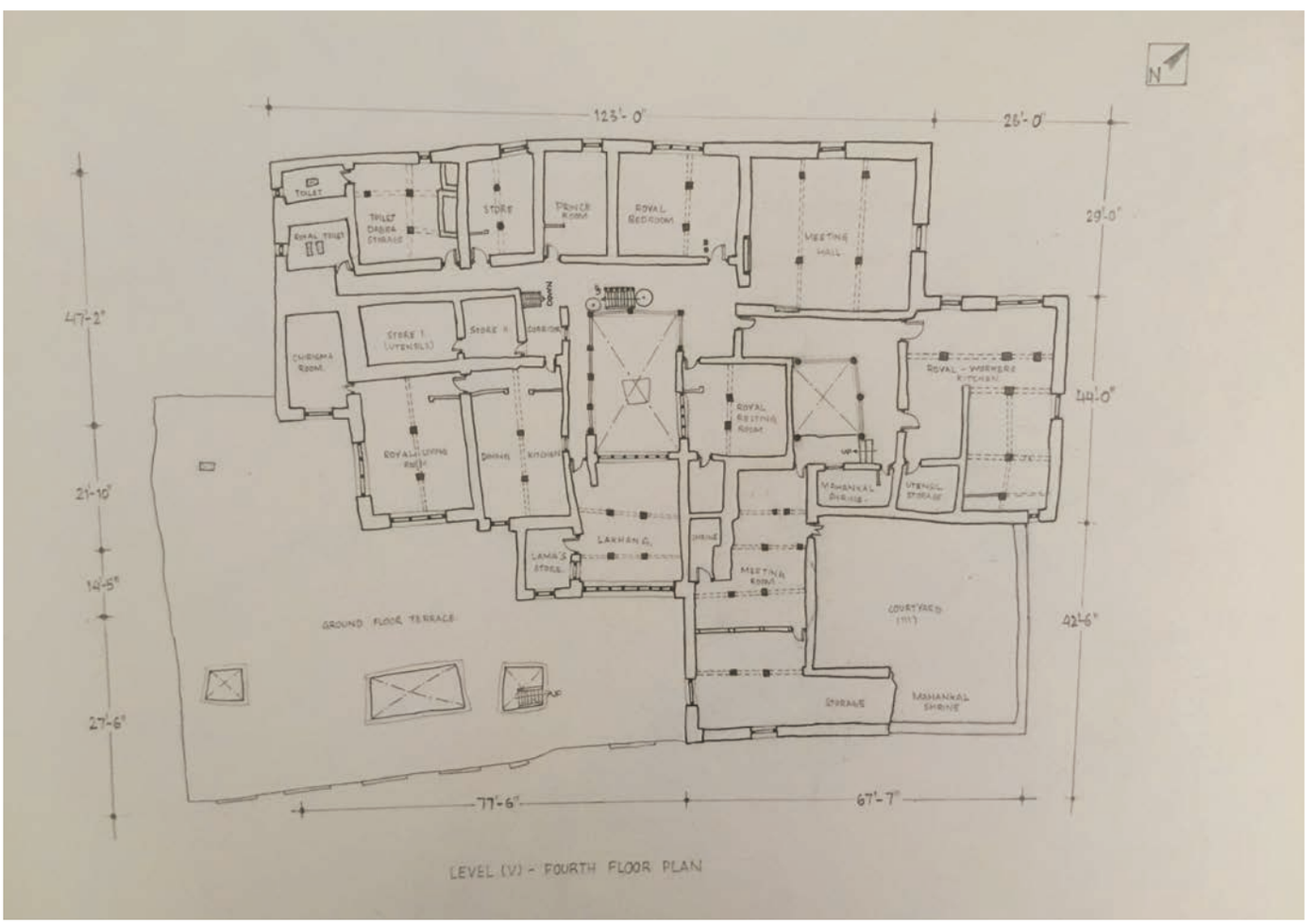


FIGURE 7 Plan of the Tashi Gephel Phodrang, fourth floor. Illustration: Rija Joshi, HimalAsia, 2020.

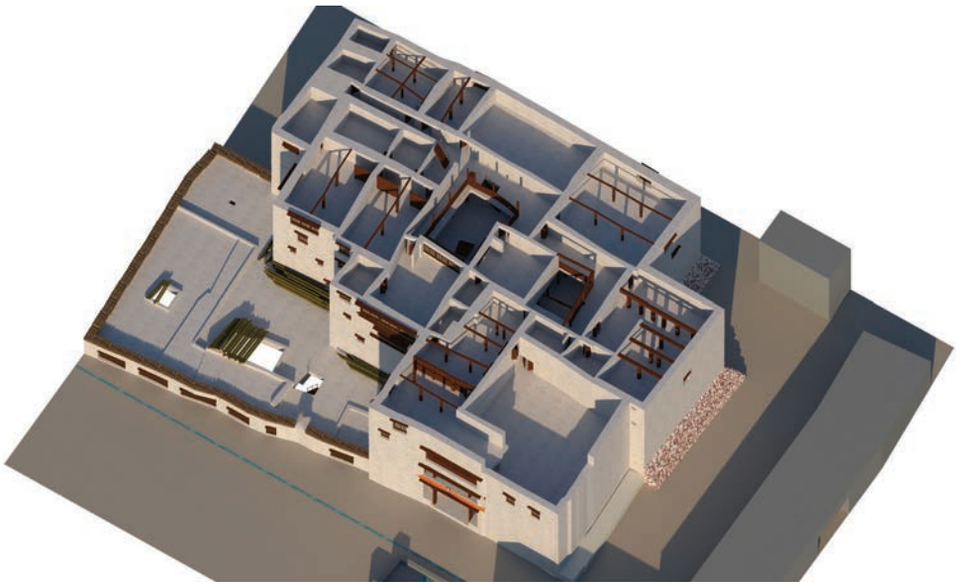


FIGURE 8 Model of the Tashi Gephel Phodrang, with fourth floor. Illustration: Bipul Rawal, HimalAsia, 2020.

Conclusion

Outmigration, seismic activity, consequences of climate change, and increased tourism are key challenges for protecting the extraordinary traditional earthen architectural heritage of Upper Mustang, one of the most sacred landscapes in the Himalayas (Bista and von der Heide 1997). Eventually, the Lopa will change their animal husbandry and agriculturally based community lifestyle to a more commercially oriented society that will concentrate on tourism as their main income source. Promoting Mustang as a high-end tourist destination, on the principle of sustainability as seen in Bhutan, could be one way to preserve their cultural identity.

The role of the former royal family and their interactions with heritage in this context is of great importance, since they are still regarded by most of the Lopa people as custodians of their cultural values. The phodrangs are symbols of the Lopa's cultural identity and, furthermore, are also major attractions for tourists. To restore, renovate, and document the Tashi Gephel Phodrang in the former capital Lo is, therefore, of great significance for most of the Lopa, and the wish of the former king to convert a portion of the building into a museum with an archive open to the public is highly welcomed. The planned conversion of the Ghemi Phodrang into a standard hotel is also regarded as a model of how an ancient traditional building can be put to a new use.[1]

Learning and monitoring integrated adaptation strategies to combat the impacts of climate change on high-altitude places like Mustang are essential for people's well-being as well as for cultural heritage preservation. Substantial financial backing and skills-based training are imperative for future restoration and renovation projects in this region. Special building codes must be drafted and enforced, and incentives should be created for private and public stakeholders to retrofit, rather than destroy, their traditional buildings in order to protect this extraordinary heritage.

Note

1 The former king set an example when the village of Samzong had to be relocated because of a water shortage. He provided a suitable area with fertile land next to a river near Lo Manthang for the resettlement of the village and, with the financial support of a Swiss NGO, three-room buildings made of traditional mud brick were constructed and distributed by lottery to the eighteen households of Samzong.

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Building Culture and Seismic Assessment of a Rammed Earth Village in the Chicamocha Canyon, Colombia

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Abstract: *The municipality of Cepitá is located in the central eastern area of Colombia, within the outstanding landscape of the Chicamocha Canyon. The building tradition of Cepitá is based on the use of* tapia pisada *(rammed earth), which is actually used for almost all the buildings that form the urban fabric. The urban, architectural, and construction features maintain the morphological characters of the Spanish colonial heritage. This paper describes the results of research on the building culture and the seismic vulnerability of the municipality of Cepitá conducted collaboratively by the Department of Architecture at the University of Florence and the School of Engineering at Universidad Industrial de Santander. The first part of the paper identifies and classifies traditional building techniques and processes that use earth and wood as materials, according to construction models of colonial origin. Codifying the building practices of this area, which are becoming obsolete in the collective imagination with the recent introduction of modern materials, attests to the wisdom of the master builders refined over centuries and represents the availability of technical support for the conservation and maintenance of the existing heritage. In the second part of the paper, a quick and essential assessment method for the analysis of seismic vulnerability is illustrated and applied on three buildings selected as case studies.*

Resumen: *La municipalidad de Cepitá se encuentra en el área centroriental de Colombia, dentro del paisaje excepcional del Cañón del Chicamocha. La tradición constructiva del área de Cepitá se basa en el uso de tierra apisonada* (tapia pisada) *que prevalece en casi todos los edificios que conforman el tejido urbano. Las características urbanas, arquitectónicas y de construcción, mantienen el carácter morfológico del patrimonio colonial español. En este artículo, se describen los resultados de una investigación sobre la cultura constructiva y la vulnerabilidad sísmica del municipio de Cepitá, que se llevó a cabo con la colaboración del Departamento de Arquitectura de la Universidad de Florencia y la Escuela de Ingeniería de la Universidad Industrial de Santander. En la primera parte del artículo, se identifican y clasifican las técnicas y los procesos de construcción tradicionales, en los que se utiliza la tierra y la madera como materia prima, de acuerdo con los modelos de construcción de origen colonial. La codificación de las prácticas de construcción de esta zona, que progresivamente se vuelven obsoletas en el imaginario colectivo con la reciente introducción de materiales modernos, evidencia la sabiduría de los maestros de obras, perfeccionada a lo largo de los siglos según los recursos locales, y puede resultar un notable apoyo técnico para la conservación y el mantenimiento del patrimonio existente. En la segunda parte del artículo, se ilustra un método de evaluación rápido y esencial de la vulnerabilidad sísmica y se aplica a tres edificios seleccionados como casos de estudio.*

Keywords: rammed earth, Colombia, seismic assessment, building culture

Introduction

In Colombia, the construction techniques based on earth as a building material are highly influenced by the type of locally available material and the expression conferred by local cultures on their buildings. Two aspects that have greatly affected the improvement of certain construction techniques are heavy rainfall and the seismic activity of this country (Marulanda Fraume 2018). We can find important typological and constructive differences when observing earthen architecture in the different regions of the country. In the highlands, for example, buildings are mainly built with adobe. In Antioquia, the Medellín region, and along the banks of the main rivers, the Magdalena and the Cauca, use of wattle and daub is predominant. In the Department of Santander, on the other hand, we find almost exclusively *tapia pisada* (rammed earth).

Our research took place in the Santander region, more specifically in the Chicamocha Canyon. The Chicamocha Canyon, the second largest in the world, is a gorge carved by the river of the same name in the territory of the Departments of Boyacà and Santander. The canyon is located near the Mesa de Los Santos, an upland area where the largest number of seismic events in the country is recorded (Marulanda Fraume 2018), and it reaches its maximum depth near the municipality of Cepitá. It is certainly the place of greatest scenic interest in the Department of Santander and one of the most fascinating natural places in the country, so much so that its cultural landscape is on the UNESCO World Heritage Tentative List.

In the heart of the gorge is Cepitá, a small town founded in 1751 and made up of buildings constructed using the *tapia pisada* technique. The town is located in a very isolated area, far from other urban centers. The closest city, Bucaramanga, is about two and a half hours from the town and is reached by the only highway (built in 1987 and still half unpaved) (fig. 1). The small urban center of Cepitá rises in a limited flat area, near the Chicamocha River and its tributary, the Perchiquez stream. Cepitá is organized according to the typical checkerboard layout of colonial settlements, with most of the buildings still maintaining the original architectural characteristics. Our field-based diagnostic investigation has highlighted a fair state of preservation of the earthen buildings (fig. 2), although the municipality of Cepitá lacks any heritage protection strategy (Baratta Adolfo, Magarò, and Quintana Ramirez 2018; FOREC 2015).

Description of the Research Objectives

The first objective of our research consisted of cataloging all the urban buildings. This was carried out by mapping the area's rammed earth architecture, which highlighted the state of conservation, the degree of authenticity, and the recurrent damage seen on individual buildings (fig. 3).

We then carried out an in-depth diagnosis on a number of relevant buildings, inventorying and classifying the local construction systems and processes, with the ultimate aim of transmitting the intangible knowledge and values of the area's earthen heritage. The results from this study allowed us to pursue the third and final objective of our investigation, which was to determine the degree of seismic vulnerability of some buildings using a fast methodology based on the evaluation of fourteen relevant parameters for earthen buildings (Cruz Hernandez and Cortès Puentes 2002).



FIGURE 1 View of Cepitá in the Chicamocha Canyon, next to the Chicamocha River and its tributary, the Perchiquez stream. All photos and renderings: Fabio Paparazzo and Giovanni Pianigiani.



FIGURE 2 View of the traditional urban fabric of Chicamocha.

The survey was carried out by choosing three buildings, different from each other in terms of construction period, internal distribution, and location in the lot, but with some common features that allowed us to document their overall similarities.

The material and dimensional survey was carried out in the field and reached a level of detail suitable for the type of analysis mentioned above, while the graphic representation for each building analyzed supported the evaluation of the quantitative parameters (Paparazzo and Pianigiani 2020).



FIGURE 3 Survey of the state of preservation and the main changes to the rammed earth buildings of Cepitá.

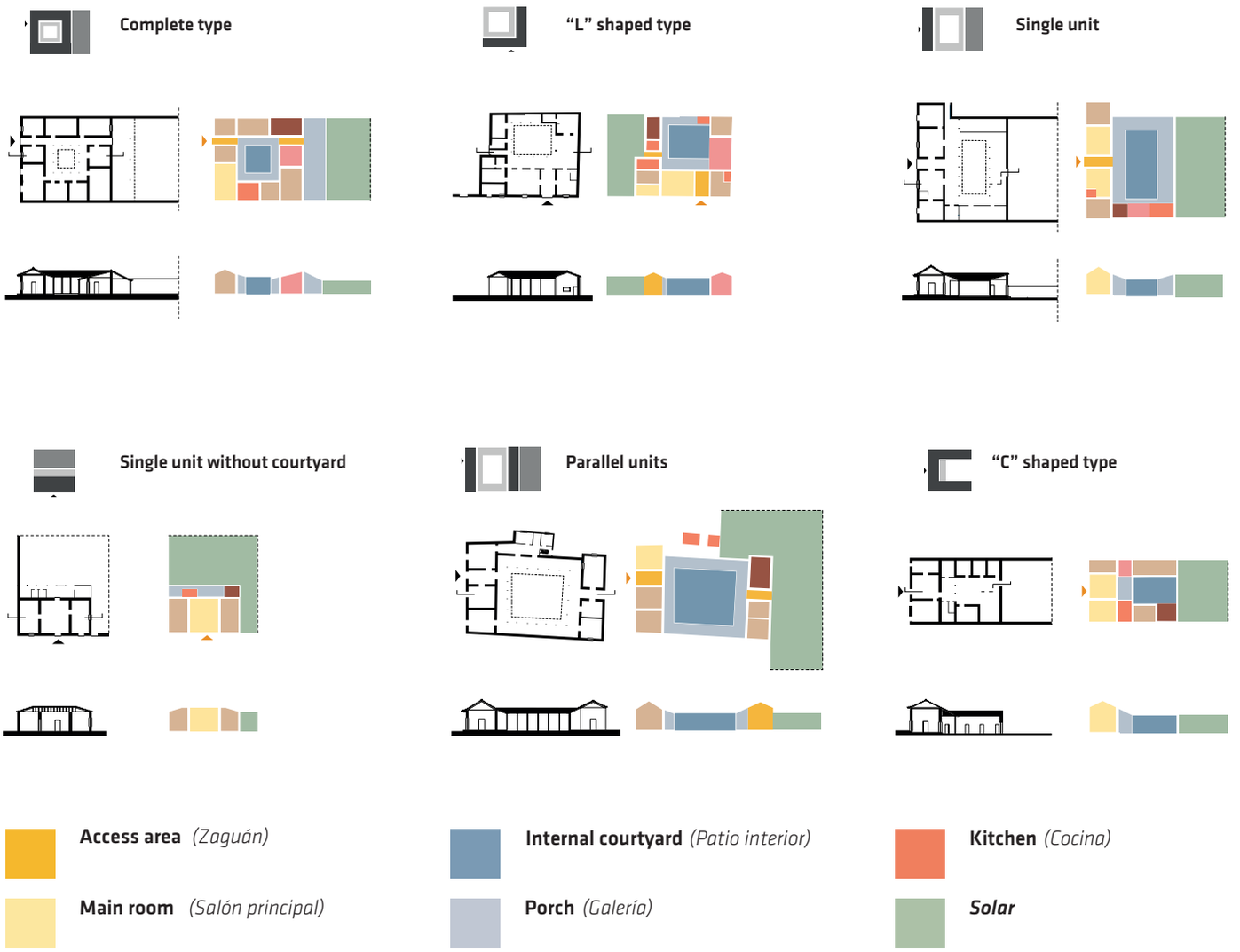


FIGURE 4 Schematic of the main courtyard house types in Cepità. The plan of the houses is generally square or rectangular and the indoor spaces are distributed on one or two sides of the patio.

Constructive Culture in Cepitá

Buildings in the Chicamocha Canyon area are mainly single story and are organized according to the layout of the patio house, an effective morphological model from a structural and functional point of view in relation to the socioproductive context characterized by a rural economy. The plans of the houses are generally square or rectangular, with interior spaces distributed on one or two sides of the patio (fig. 4). The *galería* (portico), where the inhabitants spend most of their time in the hottest hours, almost always surrounds the patio on all four sides and is supported by wooden pillars, forming a shade filter. There are often shrubs or aromatic plants growing on the patio (fig. 5). Another outdoor space of the house



FIGURE 5 View of an internal courtyard.

is the *solar*. Located in the area farthest from the road, these frequently include a stable, a stone sink also used as a tub, and sometimes a well.

The load-bearing structures of almost all the traditional buildings are made of *tapia pisada*. It is possible to observe sporadic uses of adobe bricks, usually for the construction of gables in buildings with pitched roofs, while *bahareque* (a technique that involves the application of earth on a support of wattle) can be observed in the partition walls.

The use of *tapia pisada* involves the construction of a monolithic system with boxlike functioning that works well in compression (fig. 6). The building materials are available nearby and the technique does not require the use of heavy vehicles or complex equipment. In fact, building construction takes place by confining the earth in special formworks and pressing it, layer by layer, with the aid of a *pisón* (pestle).

The *tapial* (wooden formwork) is composed of two boards with a length that varies between 100 and 120 cm and a

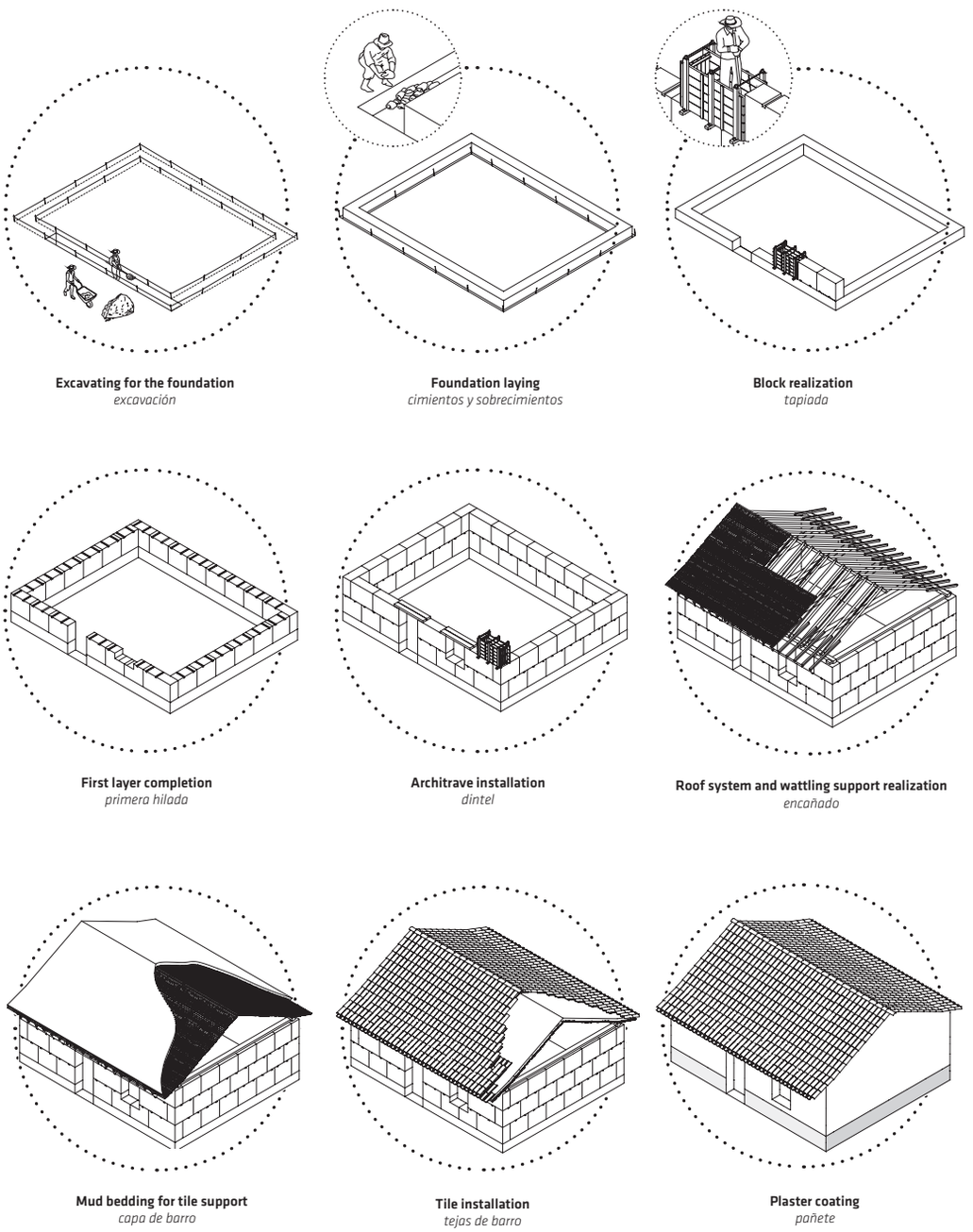


FIGURE 6 Illustration of the process for the construction of a rammed earth building.

height that can vary between 50 and 100 cm.[1] The box closing system must be rigid to avoid displacements during the earth pressing procedure, and for this reason the device is assembled with great accuracy during each phase. The box consists of wooden boards that support the walls of the formworks with jute ropes that stretch across the upper ends, integrating the structure and thus allowing it to resist the lateral thrusts generated by the pressing action.

As in all earthen architecture, particular attention is paid to both the construction of the roofing system and the attachment to the ground. The stone foundation plinth is continuous and must be at a depth that allows it to rest on fairly solid ground that is beyond the organic surface layers (Higuera Reyes 2007). Furthermore, it is essential that the foundation rises above the ground level by at least 30–50 cm in order to create an external base whose function is to prevent rising damp from capillarity and the deterioration phenomena derived from contact with surface water (fig. 7).

The first course of rammed earth is set above the foundation. Its height, which can vary between 50 and 90 cm, is defined by the height of the formwork. Once the *tapiada* (first block) is completed, the formwork is dismantled and reset and the layers of rammed earth are created by proceeding horizontally around the perimeter of the *hilada* (entire building) before proceeding with the next layer. An important precaution during the juxtaposition of the layers consists in the offset of the joints that derive from the head closure of the formwork. The openings always have a wooden lintel, of a length

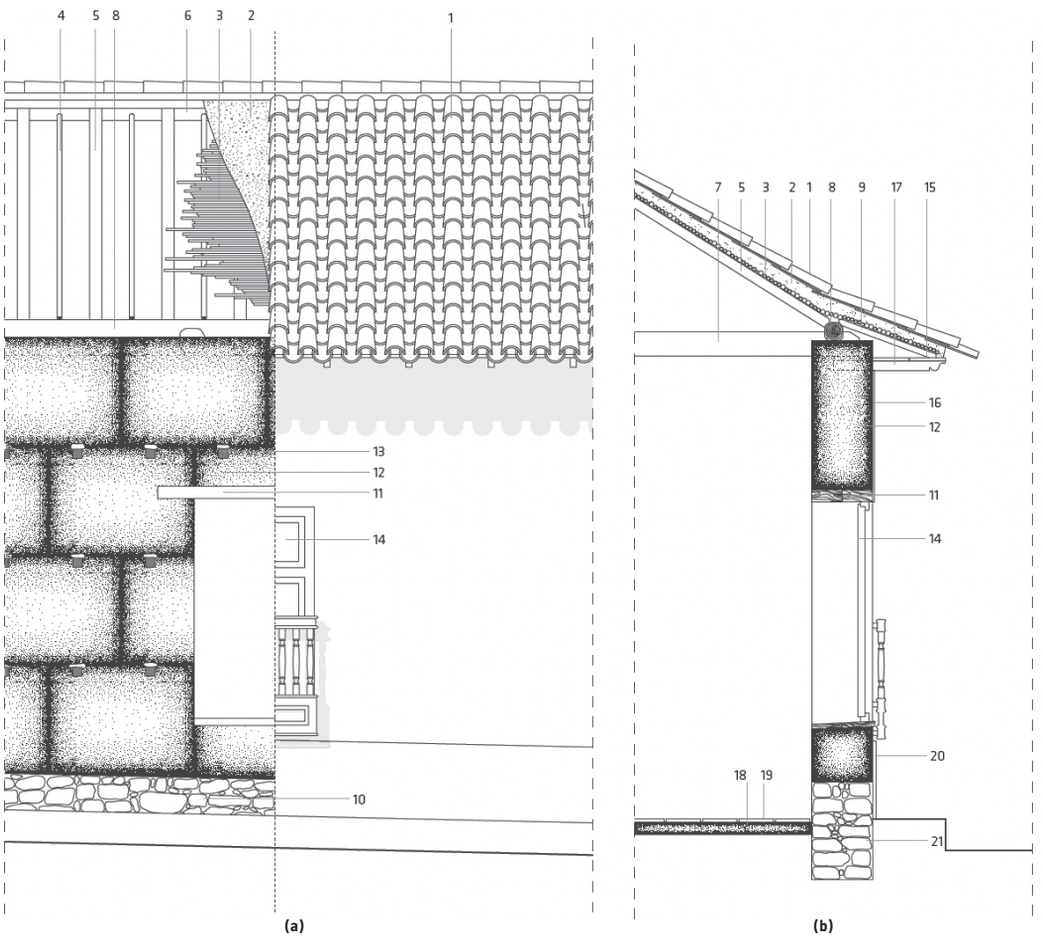


FIGURE 7 (a) Facade and (b) cross section of the surveyed "Manosalvado" building.

1. Covering roof with clay tiles on top (*tejas de barro*)
2. Earth bedding layer
3. Wattle - diameter of the canes: 2–3 cm (*encañado*)
4. Main wattle (3–4 cm)
5. Rafter; 5–7 cm x 6–9 cm (*par*)
6. Ridge board-5–7 cm x 6–9 cm *(Hilera)*
7. Main joist (*viga tirante*)
8. Wall plate (*viga solera*)
9. Eaves rafter -(5–7 cm)
10. Stone basement (*sobrecimiento*)
11. Architrave
12. Rammed earth wall 90 cm x 120 cm
13. Putlog holes left in the masonry by the scaffolding
14. Wooden shutter
15. Wooden soffit
16. Plaster layer made by a mix of excrement, lime, and ox blood (2–3 cm)
17. Joist overhang (5 x 8cm)
18. Earth basement
19. Floor made from clay tiles (*tablón de barro/baldosa de barro cocido)*
- tiles size: 33 cm x 33 cm
20. Plaster layer for the basement protection (3–4 cm)
21. Stone foundations (*cimiento*)

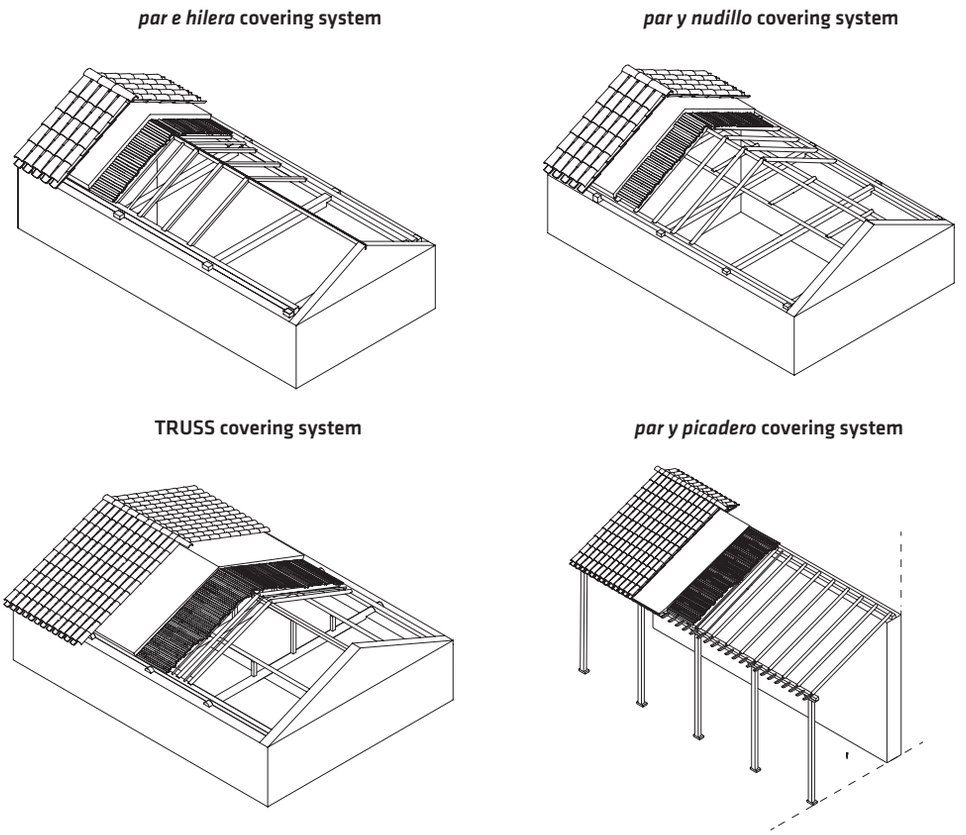


FIGURE 8 Axonometric views of the main types of roofs.

such that it fits into the portions of the adjacent wall by at least 25 cm, and respect a minimum distance from the corners of the buildings.

The rammed earth masonry is then covered with a layer of earth-based plaster. The increasingly frequent use of plasters based on materials that do not allow the wall to breathe (such as cement mortars) can generate degradation phenomena by blocking the moisture inside the wall (Baratta Adolfo, Magarò, and Quintana Ramirez 2018).

Care should be taken so that roofs and horizontal components do not push in one direction or, at the least, the forces generated by the static typology adopted must be countered. For example, the *par e hilera* roof structure is the most common in the village and is characterized by strong horizontal thrusts that are contrasted by a chain in order to ensure stability (fig. 8). This structure represents the simplest solution and is achieved by juxtaposing pairs of oblique joists and interposing a horizontal axis, called *hilera*, that gives transversal stability to the entire structure. Another type of roof structure, called *par y nudillo*, provides *nudillo* (horizontal rafters) that are interposed between each pair of *pares* (rafters) at about one third of their length, thus contributing to the reduction of their becoming bent.

In small buildings, the so-called *par y picadero* typology is used: it is made up of *pares* that rest on the *picadero* (edge beam). In the case of double pitch, a longitudinal wall is located in the center of the room to allow the support of the edge beam. When the width of the compartment reaches large dimensions, a *de cerchas* structure is used: the beams of the main structure are parallel to the longest side of the space and can be connected by struts to a horizontal beam with a rectangular or circular section. The secondary frame consists of a series of oblique rafters arranged orthogonally to the main structure according to a maximum slope ranging between 20 and 35%, with a center distance between 50 and 80 cm. The rafters rest at the top on the ridge beam and, at the perimeter walls, on a wooden edge beam that is embedded either with the transverse beams or on a double layer of bricks.

After the load-bearing roof structure is constructed, the wattle is settled and the canes are placed and tied together by main larger canes. A layer of earthen mortar is then laid on the wattle, serving as a bedding layer for the brick tiles.

Assessment of Seismic Vulnerability

The assessment of seismic risk in a given area depends on the interaction of three factors: danger, exposure, and vulnerability. Unlike danger and exposure, vulnerability is closely linked to the construction and qualitative characteristics of the individual artifacts, requiring a specific analysis of the materials, the techniques used, and the morphology of the building. In the case of Cepitá, the methodology used for assessing the seismic vulnerability of earthen buildings is based on the vulnerability index method. The method was presented in 2002 by Professor Ricardo Cruz Hernandez of Universidad Industrial de Santander (Cruz Hernandez and Cortès Puentes 2002). It can be classified as qualitative, as it carries out a classification of buildings by observing their physical characteristics, using only simple structural calculations established by the vulnerability index method. It is inspired by another method proposed in Italy in 1984 by Benedetti and Petrini and subsequently taken up by the National Earthquake Defense Group (Benedetti and Petrini 1984; GNDT 1993).

This assessment method (Cruz Hernandez and Cortès Puentes 2002) evaluates a building's vulnerability index according to fourteen parameters (table 1) and is considered to represent the predisposition of a masonry building to suffer damage during a seismic event. Each parameter is associated with a weight coefficient ranging from 0.15 to 1.0. These parameters are rated on a scale from A to D, where A represents the maximum score. The building's vulnerability index is obtained by adding the score of the individual parameters multiplied by the corresponding coefficients. This score, which can range between 0 and 430, will highlight the vulnerability of the building in relation to the priority of intervention.

This type of risk survey belongs to a category of so-called expeditious assessment methods that are less expensive and quicker to execute. They are particularly convenient when the goal is to extend the risk assessment to a series of buildings in order to establish priorities by understanding which building(s) might require urgent intervention (Colombini 2014).

A decisive factor in the final score is the planimetric configuration of the building and structures where regular, simple shapes maintain lower values and, therefore, better responses in the event of an earthquake.

The first parameter concerns the "walls distribution" and evaluates the maximum distance between the orthogonal and load-bearing walls and the structural density, both of which can be calculated according to the measurements of the rooms and the thickness of the walls in plan. Earthen buildings (and more generally, masonry buildings) are characterized by an important presence of load-bearing walls, a peculiarity due to the fact that masonry techniques are mainly based on the resistant capacity due to the structure's own weight.

Parameter two relates to the quality and organization of the resistant system. It evaluates the effectiveness of the connections between the various structural elements, highlighting their importance to ensure a good distribution of loads within the structure. For example, the presence and effectiveness of the connections between orthogonal walls are evaluated.

Parameter five, which evaluates the position of the building and its foundation / soil consistency, has an important influence on the result of a building's vulnerability. The Colombian NSR-98 is a metric that divides types of soil into four different classes. The most favorable condition is when the ground on which the building stands is completely level with conditions worsening as the slope increases. The foundations analyzed during the surveys highlight a good execution, especially with regard to the stone elements chosen and the depths of their foundation layers.

Parameter ten is the relationship between full and empty and can be obtained by calculating the percentage of openings in the walls and verifying the distribution along the extension

Table 1 Parameters for Evaluating a Building's Vulnerability Index

Parameters for Evaluating a Building's Vulnerability Index		A	B	C	D	Wt
1	Bearing walls distribution	0	10	20	50	0.3
2	Type of structure and structural connections	0	10	20	50	1.0
3	Quality of the structure	0	10	20	50	0.25
4	Capacity-Demand Index	0	10	20	50	1.0
5	Position of the building and foundation systems	0	10	20	50	0.65
6	Layout of the structure in plan	0	10	20	50	0.35
7	Horizontal elements	0	10	20	50	1.0
8	Roof	0	10	20	50	1.0
9	Layout of the structure in elevation	0	10	20	50	1.0
10	Relationship between solids and voids	0	10	20	50	0.4
11	Current status	0	10	20	50	1.0
12	Non-structural elements	0	10	20	50	0.25
13	Age	0	10	20	50	0.15
14	Adjacent buildings	0	10	20	50	0.25

of a given wall. A critical point can arise when new gates are inserted into walls that weaken the structural response of the wall, a very frequent occurrence in Cepitá.

In order to effectively assess the qualitative parameters, which refer to the method of execution and the quality of the elements that make up the buildings, it is necessary to evaluate the data collected in the field and compare those with the existing literature or professional experience.

Our in-depth analysis of roof types allowed us to evaluate the relative parameters in relation to their static performance, forming an opinion on this basis as well as on the quality of the elements used in construction. We found, generally, that the choice of the roof type is suitable for the dimensions to be covered, while the individual components are more critical.

Injuries and damage due to narrow proximities between adjacent buildings are a very common problem in earthen buildings. When an earthquake occurs, each building vibrates in accordance with its own dynamic characteristics, and, consequently, two adjacent buildings can give rise to the destructive phenomenon of hammering. In such circumstances, the relative position of the horizontal structures of adjacent buildings becomes relevant. When, for example, the floors of two neighboring buildings are at different heights, one of the two can hit the supporting structure of the other during the seismic event. For this reason, it is always important to evaluate the distance between buildings during parameter calculations so as to be able to take into consideration the possibility of a negative mutual influence in the event of an earthquake.

Conclusion

The vulnerability indices of the cases analyzed in our study classify all buildings as "not very vulnerable" or as "moderately vulnerable."

The parameters relating to the position of a building, its horizontal structures, and the configuration in elevation are decisive, as they refer to characteristics common to almost all the buildings in the Chicamocha Canyon area. The factors that determine these results need to be found in the construction and quality standards for the dwellings, such as the beneficial practice of building single-story houses with good clamping of the load-bearing walls. Furthermore, the roof structures are made in such a way as to contribute to the boxlike system of the buildings, where horizontal beams are well clamped to the edge beams and the oblique beams have good-quality joints.

The result of this research work consists, first, in the systematization of knowledge relating to the construction techniques and procedures through which the earthen buildings were constructed in the area of the Chicamocha Canyon. The documentation demonstrates that the examples studied do not represent isolated cases but form part of a local building culture. However, any action of protection or seismic improvement must be inserted within a universe in which there are constructive rules, with strengths and weaknesses, which must be respected and/or improved in a manner compatible with the existing one (Bollini 2013; Mileto and López-Manzares 2017).

Earthen architecture represents a real wealth for the inhabitants of Cepità, who, in addition to having an unlimited availability of the material, have always appreciated the intrinsic qualities deriving from their healthful interior environments and climatic comfort. However, the dispersion of traditional construction knowledge and the contextual lack of skilled labor have led to the progressive abandonment of this material, supplanted by the increasingly widespread use of concrete, considered to be more noble and durable. Throughout the region there are numerous buildings in a state of advanced decay or total abandonment. There are also repairs, additions, or buildings with techniques and materials that are not compatible with the earth, creating an incorrect perception of quality of such heritage. As a consequence of this adverse phenomenon, the heritage of earthen architecture risks disappearing due to the tendency to demolish and rebuild with modern materials rather than intervening with renovations and consolidations that are aimed at enhancing the heritage.

The need to protect these buildings is, therefore, very clear. This includes applying a methodology that is compliant with alternatives for anti-seismic improvement, consolidation, and/or maintenance in order to increase the levels of safety and comfort on the basis of local knowledge. Finally, we hope that the diffusion of this knowledge and the values of this precious construction technique will be developed so that a progressive recognition of Cepitá's architecture is encouraged by both the community and the local administrations, and that the practices of safeguarding, maintenance, and restoration are promoted.

Note

1 Measurements taken by the authors during inspections of the construction sites of Barichara (Colombia).

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Information Needs for a Deep Learning System for the Assessment and Restoration of Earthen Heritage Structures: Case Study of the 2017 Puebla, Mexico, Earthquakes

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Abstract: *Heritage structures present great value to a nation's history and national pride and can be a source of economic development through tourism. The preservation and restoration of such structures is a continuous effort and requires recording and tracking data that describes the current state of each structure and the needs for restoration work. Of particular interest to this paper are earthen heritage structures, which are subject to damage in different forms due to earthquake events of varying magnitude, intensity, focal depth, and so on. Data collection may include description of the structures, earthquake events, and damage. The volume of such datasets may be large and can benefit from tools to examine all the data records and provide advice for further action. Machine learning can provide insight into large datasets and extract patterns that can be difficult to obtain solely through analysis. Machine learning requires a large volume of data, with annotation and organization to enable the learning process to extract desired patterns. This paper identifies the types of information needed for machine learning systems in this area and some organizational schemes to make the data easily accessible to these systems.*

Resumen: *Las estructuras patrimoniales constituyen un gran valor para la historia y el orgullo nacional de un país, y pueden ser una fuente de desarrollo económico por medio del turismo. La conservación y restauración de estas estructuras requiere de acciones continuas, y del registro y seguimiento de los datos que describen el estado actual de cada una de ellas, además de los trabajos de restauración que se necesitan. En este artículo, las estructuras patrimoniales de tierra son de especial interés, ya que están sujetas a diferentes fuentes de daños, como terremotos de distintas magnitudes, intensidades, profundidades focales, etc. Los datos por recopilar pueden incluir la descripción de las estructuras, los terremotos y los daños. El volumen de datos suele ser grande, por lo que puede ser de utilidad contar con herramientas que analicen todos los registros de datos y ofrezcan asesoramiento para las acciones posteriores. El aprendizaje automático puede brindar información sobre grandes conjuntos de datos y extraer patrones difíciles de obtener solamente por medio del análisis. Asimismo, el aprendizaje automático requiere de un gran volumen de datos, con comentarios y organización para que el proceso de aprendizaje pueda extraer los patrones deseados. En este artículo, se identifican los tipos de información que se necesitan para los sistemas de aprendizaje automático en este ámbito y algunos esquemas organizativos para que estos sistemas puedan acceder con facilidad a los datos.*

Keywords: heritage structures, earthen buildings, historic churches, earthquake damage, machine learning, deep learning, pattern recognition

Introduction

Over the past many decades, precious religious heritage structures (e.g., churches, cathedrals, mosques, and temples) have suffered unprecedented damage and collapse during catastrophic earthquakes around the globe, especially in South America, Europe, and the Mediterranean, among other areas. For example, historic churches in Mexico, Peru, and Ecuador have been found to have suffered extensive damage and losses from the frequent, devastating earthquakes that have struck these areas over the past 100 years. Preservation and restoration of such historic churches is extremely critical in developing countries like Mexico and Peru, as the residents rely on the power of prayer and assembly to cope with the economic, psychological, and traumatic consequences of earthquake devastation and the short- and long-term impacts on their lives. The church governing bodies, news media, local and provincial governments, professional practitioners, universities, NGOs, and researchers have, over the decades, documented the observed damage suffered by the beautiful and historic churches during previous earthquakes. The huge amount of observed church damage data that has been accumulated is found to be scattered over a multitude of agencies, organizations, and jurisdictions.

Earthen Heritage Buildings in Seismic Areas

The cultural value of heritage buildings represents an important aspect of a nation's identity and must be preserved through the study of damage patterns caused by earthquakes. Such a study offers support for the restoration of damaged buildings and the retrofitting of other, similar buildings to withstand future earthquakes.

Extensive knowledge of and experience with earthen structures in seismic areas have been found to exist in many parts of the world, including Iran, India, Afghanistan, the Mediterranean region, Peru, Mexico, Colombia, China, and Europe. Some of the major international efforts to document and help improve the seismic safety of earthen structures in seismic zones are as follows:

- International Workshop on Earthen Buildings in Seismic Areas, Albuquerque, New Mexico, 1981 (May and Cuny 1981). This first historic workshop was an important source for the state of the art of earthen buildings in seismic areas around the world at that time. It serves as an important deep source of knowledge and data about the performance, behavior, restoration, and conservation of earthen architectural heritage in seismic areas;
- Getty Seismic Adobe Project, Getty Conservation Institute. Initiated in 1990, this initiative has been a major undertaking aimed at documenting, restoring, and preserving precious earthen architectural heritage in seismic areas around the world (Hardy, Cancino, and Ostergren 2009; Getty Conservation Institute 2006);
- Earthen architectural heritage of Peru. The earthen architecture of Peru, its evolution, and an outstanding assessment of the damage suffered by historic earthen buildings during the 2007 Pisco, Peru, earthquake has been presented by Cancino (2009). Especially notable is the innovative *quincha* dome construction developed for the Church of San Francisco in Lima. Another interesting observation from surveys of adobe buildings during earthquakes is that adobe buildings on softer soils suffered greater damage compared to those founded on firm soils. The typical modes of failure of earthen structures observed during recent earthquakes in Peru have been analyzed and presented elsewhere (Lourenço et al. 2018);
- GEER Reconnaissance Project. A comprehensive reconnaissance of the September 2017 Puebla earthquakes has been carried out and documented by Mayoral, Hutchinson, and Franke (2017). This comprehensive report also includes data about the damages suffered by historic churches during the September 2017 Puebla earthquakes, obtained using advanced survey technologies such as terrestrial and aerial surveys (UAV, LiDAR, etc.).

Historic Churches Damaged by the 2017 Puebla Earthquakes

The performance and behavior of historic churches that were severely damaged by the catastrophic Puebla earthquakes of September 7 and 19, 2017, have been presented by Peña, Chávez, and Garcia (2020), Preciado et al. (2020), and Diaz et al. (2021), among others.

- Description of observed damage (partial or total collapse) suffered by the historic churches—bell towers, roofs, buttresses, walls, and arches—has been presented by Pena, Chávez, and Garcia (2020) and Chavez et al. (2021);



FIGURE 1 Vaulted roof damage at Iglesia del Carmen, Atlixco, Puebla. Photo: © Dr. Maria Margarita Segarra Lagunes.

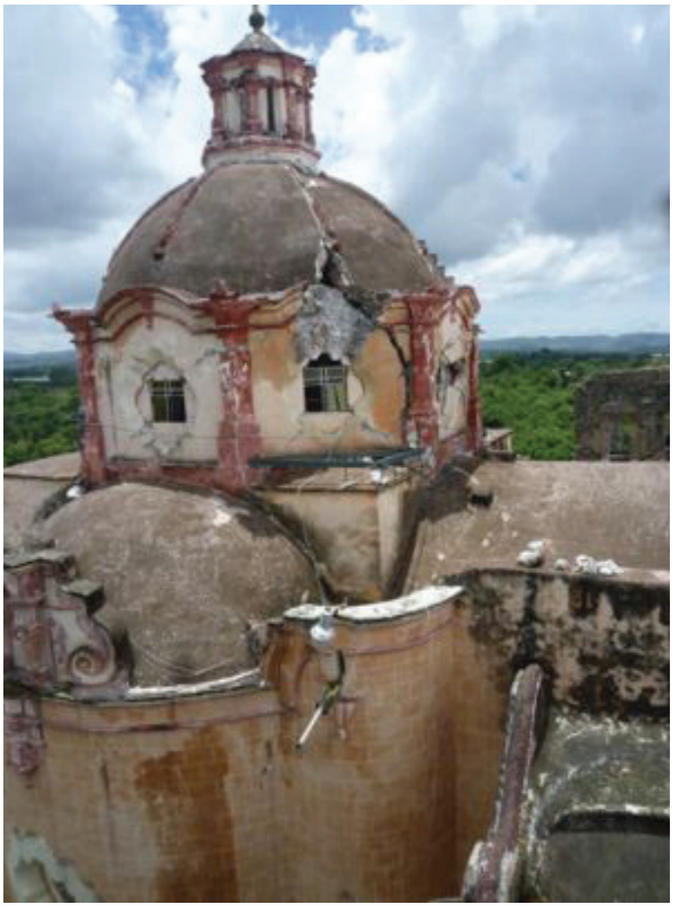


FIGURE 2 Heavy damage to the main dome of the Immaculada Concepcion, Zacualpan de Amilpas. Photo: © Dr. Maria Margarita Segarra Lagunes.

- A systematic post-earthquake investigation of historic churches and bell towers that were damaged by the September 19, 2017, Puebla earthquake (Mw = 7.1) has been presented by Preciado et al. (2020). Thousands of historic buildings were damaged during this earthquake and the aftershocks that followed. It is noteworthy that partial or total collapse of bell towers, facades, arches, vaults, and domes in historic churches were observed during this catastrophic earthquake;
- An excellent assessment of the seismic damage suffered by historic churches during the September 2017 Puebla, Mexico, earthquake has been presented by Diaz et al. (2021). Highlights of this investigation include the following:
  - Typical characteristics of the colonial churches;
  - Typologies of the churches examined;
  - Recurring damage patterns;
  - Seismic damage assessment;
  - Seismic damage mechanisms documented and analyzed;
- A comprehensive and systematic documentation of the historic churches damaged by the September 2017 Puebla earthquake has been presented by the Secretaría de Cultura, Mexico (Goldberg Mayo 2018).

Some of the observed serious damage to historic churches during the September 2017 Puebla earthquakes is presented in figures 1 and 2 (Lagunes 2020) and figure 3.

Machine Learning Needs

Advances made in the field of machine learning present the opportunity to extract patterns from large sets of data and

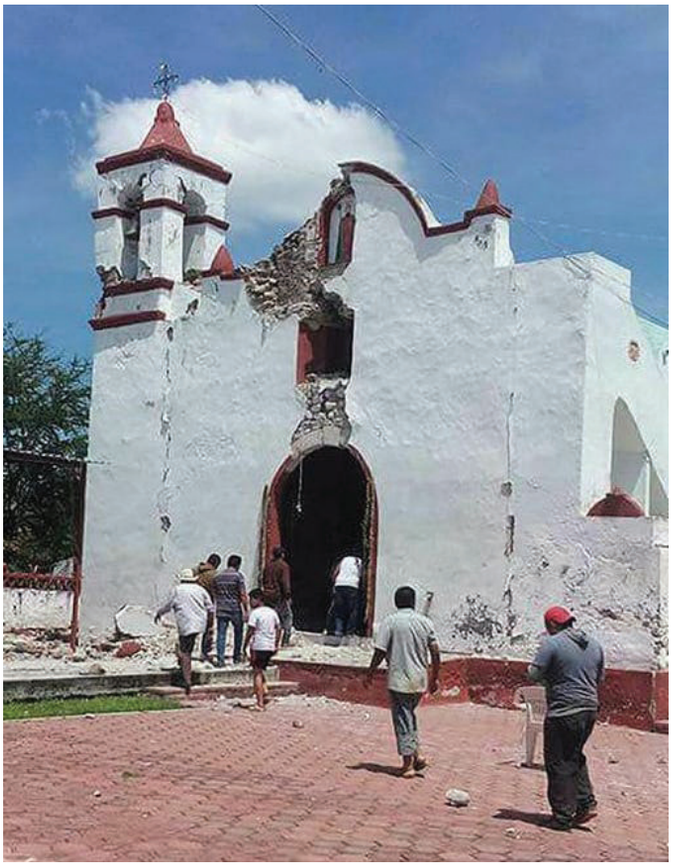


FIGURE 3 Bell tower and facade damage at Santo Tomás de Tetelilla, Jonacatepec, Morelos. Source: www.colonialmexico.blogspot.com/2017/09.

provide insight into relationships between data items. Figure 4 presents a simple process for building a machine learning system. The collected data must describe both the earthquake event and the damage caused by this earthquake in sufficient detail to allow for the recognition of patterns across data items. The crucial step in building a deep learning system is the construction of a model of the data that captures the essential features of the events and objects being recognized. Data collected from multiple sources presents a challenge in constructing a model that is consistent with all data records. There is a need to cleanse the data, normalize it, and remove any inconsistencies. Cleansing refers to removing useless data from the datasets. Useless data may be incorrect data, incomplete records, duplicate records, or contradicting records from multiple sources. Normalizing data refers to formatting data from multiple sources into a uniform model, eliminating naming ambiguities, and standardizing units of measurement. Efforts to build deep learning systems for earthquake damage data include Patterson et al. (2018) and Behrouzi and Pantoja (2018).

This paper focuses on damage data of historical structures for churches. The data exists in the form of pictures, tabulations, and textual descriptions in natural language. There may also be video footage from surveying sites of damage. All forms of data are related. For example, pictures are often described in textual form and related to tabulated damage classification measurements. A learning system requires a model of features, represented by the datasets, that it can process to extract sufficient patterns to recognize a number of categories of damage in new data records, e.g., new images.

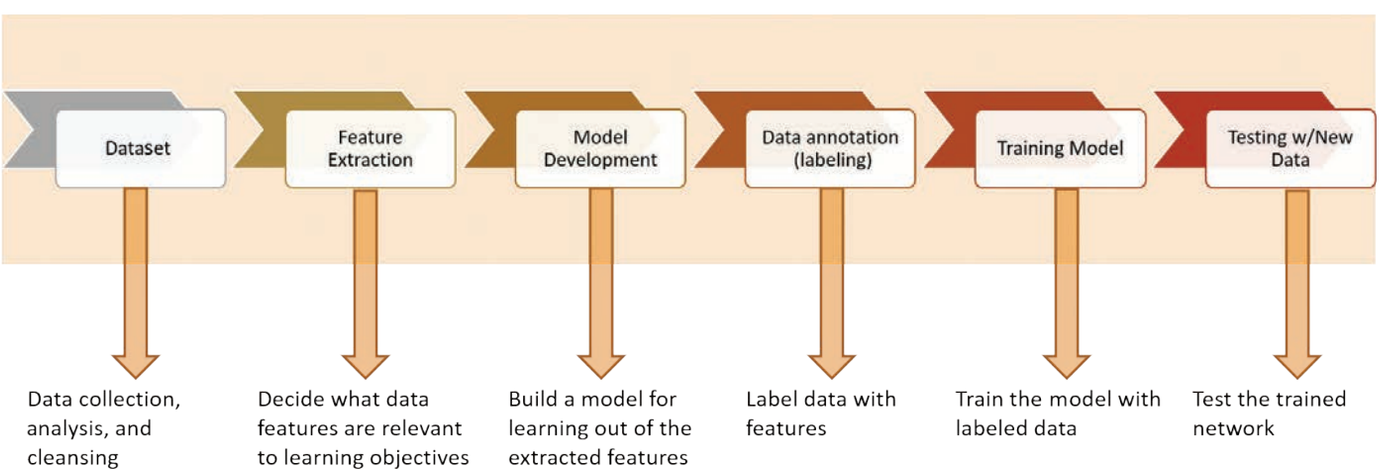


FIGURE 4 A simplified process for machine learning. Rendering: Satwant Rihal.

Platform and Tools

The system proposed in Rihal and Assal (2012) provides an integrated platform to collect earthquake data from multiple sources and feed it into a general-purpose ontology that represents all aspects of collected data, from ground motion to structural performance data to damage data (fig. 5). The platform offers mapping capabilities to generate required submodels out of the stored model information. Such a system can facilitate the work of preprocessing new data records and can accelerate modeling for a learning system. The platform identifies the types of collected data into two main categories: earthquake event data (earthquake characteristics, ground motion data) and observed damage data (building types and configurations, patterns of structural damage). This platform was adapted in Rihal and Assal (2016) in and their later work to provide more targeted representation for specific purposes.

Information Sources

Selected sources include the plans for prevention of seismic risks of earthen buildings initiated by the International Scientific Committee on Earthen Architectural Heritage (ISCEAH) (Achenza et al. 2021) and documentation of post-earthquake damage assessment of cultural heritage including earthen heritage as reported by Tandon (2017), Toki and Pahari (2012), and the Global Facility for Disaster Reduction and Recovery (GFDRR) (2011), among others.

The information published about the 2017 Puebla, Mexico, earthquakes and their aftermath includes images of damaged structures showing many types of damage to structural elements as well as ornamental facade elements. Analysis of the damage data suggests that patterns of damage can be identified from images such as these, as well as those from similar events. The recording of damage data should focus on collecting more information about the type and age of the structure, any previous damage to the structure that may have compromised its integrity, and any restoration or repair work that may have been performed on it. This information, along with standard earthquake event data such as the epicenter, magnitude, and shaking intensity (MMI), can be used to build the deep learning model. Combining earthquake data with damage data in a learning model will allow the system to recognize patterns of damage to many types of earthen structures

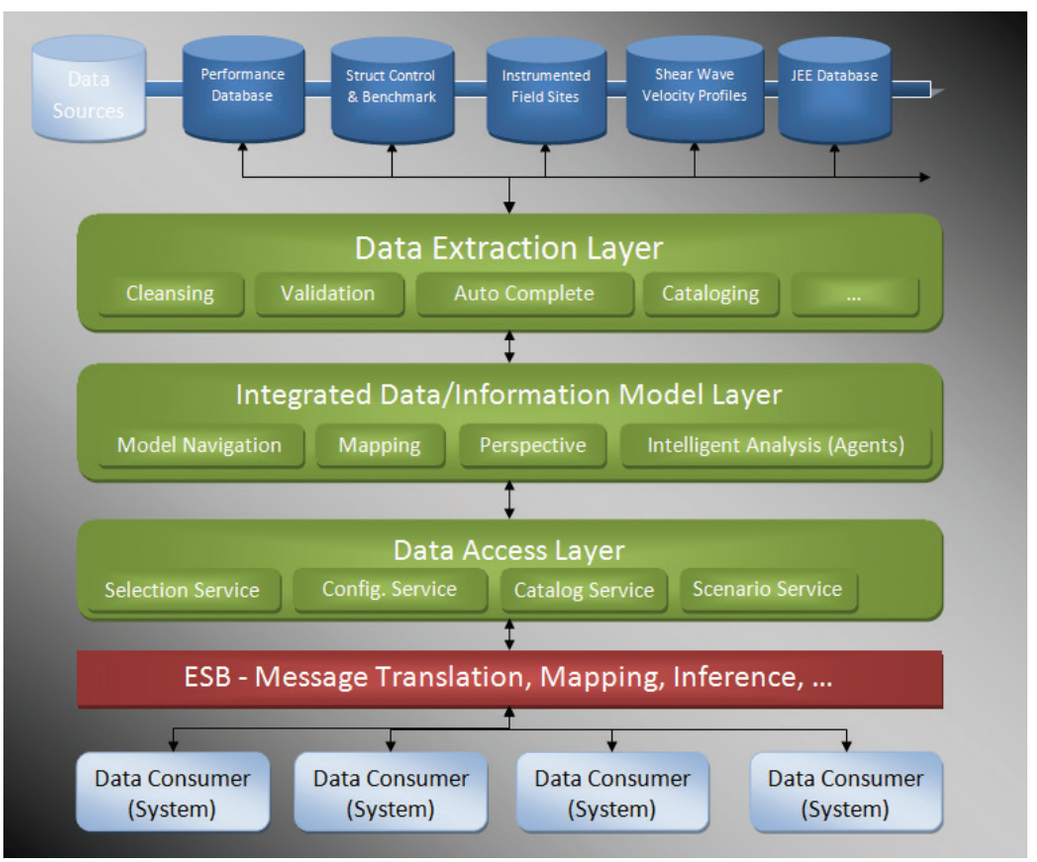


FIGURE 5 System architecture for the integrated framework for seismic design and assessment. Rendering: Rihal and Assal 2012.

and predict the possible damage under different earthquake scenarios. It is important to collect as much data as possible from earthquake events where similar structures suffered the types of damage that we are concerned with.

Information Types

The significant types of damage and structural distress can be categorized as follows:

- Foundation settlement, ground failure;
- Structural cracking (due to seismic response displacements/distortions, inadequate shear, tensile strength, etc.);
- Collapsed structural elements (e.g., bell towers, vaults, and domes or dome toppings);
- Separation of structural elements (joint failure).

All the collected data can be used to develop an ontology to describe the organization of data and the different types of relationships that may exist between data items. The ontology can be stored in the above-mentioned system and be used to generate many models for deep learning purposes. Some of the tools described in Rihal and Assal's analysis (2012) can be developed to automate the model extraction from the ontology. For example, a learning system that requires images of structural distress can perform a targeted query to the ontology and have the tools to formulate a model from the stored information.

Conclusion

Preservation and restoration of earthen heritage structures requires the identification, and often the anticipation, of the types of damage that may result from an earthquake. The large number of such structures can benefit from tools to automate the analysis and identification of damage from pictures, videos, and other means of data collection. This can be achieved through a platform for building systems of machine learning with the support of a set of data analysis tools.

Machine learning can provide great support to the study of the effects of earthquake events on existing structures. The type and extent of damage can be learned and categorized based on the structure type, architectural form and configuration, site information and earthquake characteristics, and ground motion data. Identifying the types of information needed to build a deep learning system helps guide data collectors to the important data items and the relationships between them to provide the opportunity to build meaningful models for the learning systems. The use of standardized platforms, such as the one presented in this paper and its associated tools, will allow systems developers to focus on building the learning models for the desired learning objectives.

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PART 14

Traditional Materials / Materiales tradicionales

New Findings on Vernacular Construction Methods in Adobe Windmills: A Case Study of *Āsbād*s in Nashtifan Village, Khaf, Iran

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Abstract: *Nashtifan, one of the ancient cities of Iran, is located in central Khorasan Province, 40 km southwest of Khaf City. The* āsbād*s (windmills) in this city are a type of Indigenous industrial architecture built entirely with eco-friendly local materials. Utilizing the clean energy of the winds in Sistan that occur 120 days a year, these architectural structures turn wheat into flour and have produced bread for the people of this region since the Kharazmshahi-Timurid period. This study identifies the methods of building local adobe structures that have been forgotten over time. New findings were achieved using field study methods and by interviewing senior architects in the area involving the construction of* āsbād*s. The construction of a typical* āsbād *unit was investigated. Accordingly, details related to site selection, assembly of integrated architectural components (each unit separately), foundation construction, adobe processing, wall-mounting steps, roof covering, millstone, wind wheel, and girder installation were elaborated.*

Resumen: *Nashtifan, una de las ciudades antiguas de Irán, se encuentra en la provincia central de Jorasán, a 40 kilómetros al sudoeste de la ciudad de Khaf. Los molinos de viento de esta ciudad son una clase de arquitectura indígena-industrial, construida en su totalidad con materiales locales y respetuosos de la naturaleza. Gracias a la energía de los vientos de Sistán, que soplan 120 días al año, estas estructuras arquitectónicas convierten el trigo en harina y permitieron la producción de pan para la población de la región desde el período timúrida. En este estudio, se identifican los métodos de construcción de estructuras locales de adobe que han sido olvidados con el paso tiempo. Se ha llegado a nuevos descubrimientos gracias a métodos de estudio de campo y entrevistas a arquitectos con experiencia en la temática de la construcción de los* asbads *(molinos de viento). Se investigó acerca de la construcción de una unidad de un* asbad*, lo que incluyó la selección de su emplazamiento, el conjunto de componentes arquitectónicos integrados (cada unidad por separado), la construcción de los cimientos, el proceso de elaboración del adobe, los pasos para construir los muros, el revestimiento de los techos y la rueda de molino, así como la instalación de las vigas.*

Keywords: earthen architecture, vernacular architecture, *āsbād* (traditional windmill), Nashtifan, construction technique, mud brick, adobe

Introduction

The *āsbāds*[1] in Nashtifan village belong to a type of vernacular windmill in eastern Khorasan (Khaf, Iran).[2] With its location along the Silk Road and Spice Routes, this village was an important geohistorical destination in the past. Although attributed to the Safavid period (ca. 1501–1736), they possibly date back to the reign of Khwarazmians, Timurids, and Muzaffarids (ca. 1100–1500).[3] Surprisingly, the thirty-four āsbād units have maintained a relatively stable structure since they were built. Therefore, based on their continued architectural authenticity, all features, elements, and details remain definitively genuine. Due to the presence of caretakers, three of the āsbād units still have a traditional flour-milling capacity. Hence, these structures could be seen as characteristic architectural and technological examples that represent an important stage in human history.

No information has been provided regarding their construction methods in previous studies and historical documents.[4] Using field research, in situ documentation, and oral interviews with the last generation of windmill caretakers in Nashtifan, this paper has attempted to understand their construction methods, materials, and homogeneity within their surroundings. Overall, these windmills are complex structures with precise geometries. Constructed from earthen materials, wooden elements, and grinding stones, they are excellent architectural models of earthen flour-milling factories[5] in eastern Iran (especially Khaf). Perhaps similar structures in this region are yet to be identified.

Site Selection

Nashtifan's topography has a gradual slope toward its center, is flat in the northern regions, and includes pine gardens on its southern side. The ground level at the āsbāds is higher than the southern urban fabric. This typological geography leads to the generation of strong wind currents toward the southern districts and gardens.

A complex of more or less similar āsbād units is located at the highest location of northern regions near the Shemiran district, which was then at the outskirts of this historic town near the ancient route to other cities in the eastern Khorasan. Although located near the historic graveyard (Khaksar 2019),[6] this region once was a military ridge outside the city gates. And, due to its accessibility to trade routes while also having a vast plateau without architectural or natural barriers, it easily facilitated powerful gusts of wind. Given the importance of such historic graveyards and the economic progress brought by the construction of the āsbāds, the site selection also signified further urban development over time (fig. 1).[7]

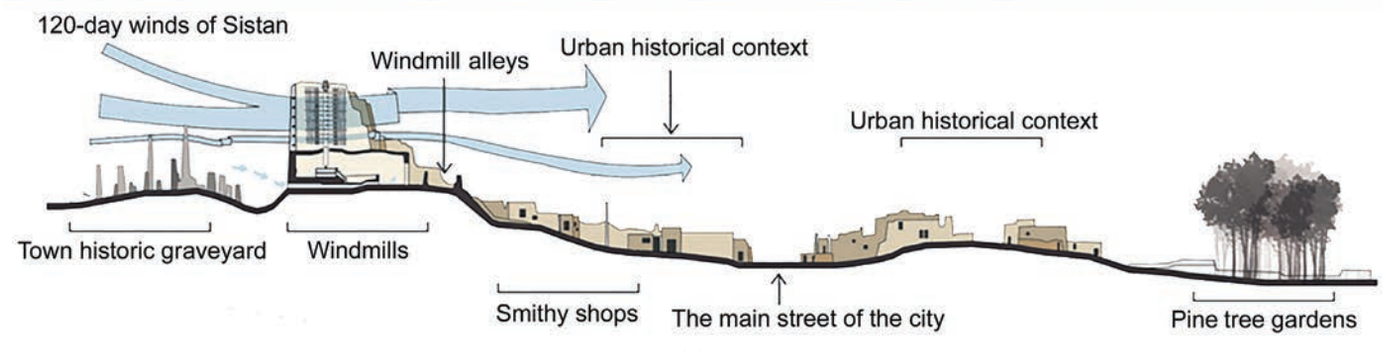


FIGURE 1 (a) Topographic landscape section and (b) photo showing the location of windmills in Nashtifan in relation to other constructions in the village and adjacent natural features. Rendering and photo: Anis Darvishi and Bita Ghahremani.

Structural Construction of the Āsbāds: Foundation, Load-Bearing Walls, and Covers

Results of fieldwork studies indicate that architects and local craftspeople employed earthen materials and local natural resources, including deposits of calcium, clay, and *teros* soil, to build the āsbāds. Each was built as a separate unit of an integrated whole whose structures function homogeneously and have been proven to be remarkably resilient to earthquakes and other natural disasters.[8]

Local architects laid an integrated (composite) foundation for āsbāds following the natural form of the earth's surface, according to geographical location, climatic conditions, and other technical aspects such as soil resistivity, mechanics, type, and structural load. Consequently, the underlying foundations of eleven āsbād units (out of thirty-three extant structures) were dug by hand and the rest were positioned near the surface of the ground corresponding to the physical features of the site.

The *shāh-pey*[9] load-bearing walls were built layer by layer ($30 \times 30 \times 7$ cm^3) with adobe bricks and *kāh-gel*[10] on the strongest parts of the foundation. This construction method remained integrated up to the height of the *par-khāneh*[11] walls. These walls were made in the form of stairs (or corbiesteps) to facilitate the elevation of the *khar-pol*[12] to the top of the load-bearing walls.

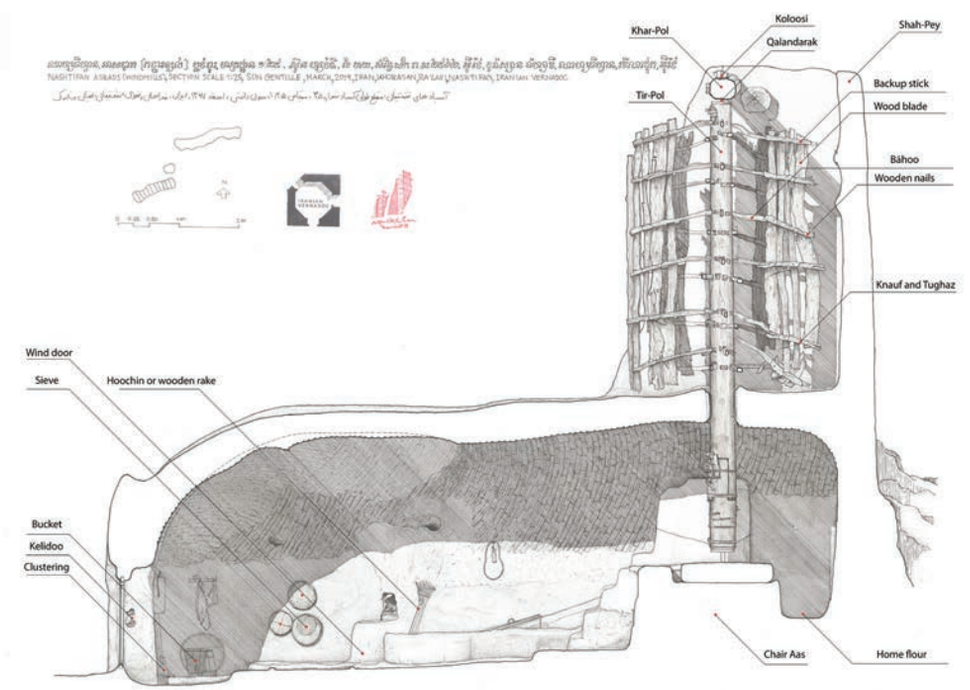
The construction of these structural elements and the flour-processing chamber required a sticky yet flexible mortar like thatch, which could very well correspond to locally accessible materials such as adobe and clay bricks. This architectural style was very common in places with enough clay soil and little rain (Khazaeli and Motarjem 2021). After the construction of the walls, the roofs were built in the form of dome vaults. The structure was then covered with thatch (15–25 cm on top for insulation, 3–4 cm for the walls) (fig. 2).

Adobe Brickmaking: Compounds and Resistance

Most buildings in the Iranian deserts are made of adobe. In addition to these structures being located in hot and dry



(a)



(b)

FIGURE 2 Overall view of āsbāds in Nashtifan: (a) *par-khāneh* and its main *kongerehs* (corbiesteps) in 1971 before the restoration of windmills. Photo: Mahmoud Baghideh; and (b) section of a typical āsbād in Nashtifan. Rendering: Sun Gentille.

climatic conditions, raw clay has been economical because of its widespread availability. Moreover, the technical specifications of mud made it a very efficient and intelligent material choice for such structures (ICOM-Iran 2020). Depending on the type of available soil in this region, 30–50% is composed of clay. The remaining components consist of gravel stones, sand, and silt, none of which plays any role in the adhesion of soil particles in the production of raw adobe bricks (Khazaeli and Motarjem 2021). The architects used to supply the required soil for the construction of āsbāds by digging in the nearby pine tree[13] gardens. Subsequently, local craftspeople used their regional knowledge to assess soil quality for adobe bricks, interior coatings, and the walls behind the āsbāds.

After transporting the soil to the brick preparation area, the required amount of soil was combined with the remaining straw from the harvested wheat and water from the adjacent underground water channels, locally known as *qanāt*. An experiment on the clay brick deposition and coating materials in Nashtifan village was designed in 2016 to analyze the soil gradation under laboratory conditions and to verify technical know-how (Darvishi 2016).[14] Soil with a higher clay percentage is more suitable for brickmaking and roof insulation, whereas soil with higher amount of silt is more suitable for the interior coating of the windmill chamber, locally known as *ās-khāneh*[15] (fig. 3).

The preparation of a large number of raw bricks normally requires excessive water. The *khesht-māl*[16] used to facilitate this process in two natural pools (referred to as *talkh* in the local dialect) was located in the downstream area of āsbāds.

Qanāt water was gradually mixed with the dry soil and straw into a small *ākhoreh*[17] (circular puddle) made by raising the pile's edge. The mud was then foot-treaded for five to six days to become completely paste-like and flexible. After the mud was processed,[18] the *khesht-māl* would place and fit the formed mud lumps within wooden frames or clay molds. These mud lumps would be beaten inside the molds and their entire surface would be smoothed with water.[19] In this way, both sides of the raw bricks could be usable during the construction process. Lastly, the bricks would be arranged vertically on the smooth ground to dry. Bricks would be turned every day to allow their surfaces to dry completely and evenly and to prevent warps and cracks (figs. 4, 5).

Commonly the brickmaker sampled some of the dried bricks. If their corners were dry and brittle to an extent they



FIGURE 3 Selection of suitable soil in the pine orchard and production of clay by masters. Photo: Anis Darvishi.



(a)



(b)

FIGURE 4 Clay production: (a) the stages of combining suitable soil with straw, *ākhoreh*, and mud beaten by *khesht-māl* masters, and arranging bricks to dry in mid-summer. Photo: Anis Darvishi; and (b) *khesht-māl* master, or brickmaker, beating mud in wooden frames, known as clay molds. Photo: Mahmoud Baghideh.



FIGURE 5 Worker thatching the roof with *kāh-gel* at an appropriate roof slope. Photo: Alireza Khaksar.

turned to powder merely by touch, this indicated that there was too much sand in the compound. Therefore, more clay soil had to be added to the mixture. Surface cracks indicated a high percentage of clay, which could be balanced by adding more sand. To test flexural strength (transverse rupture strength), several contemporary fired bricks were vertically stacked and the raw brick was placed across the stacks at their edges. If the raw brick did not break when someone stepped on it, it had adequate flexural strength. Occasionally, the adobe brick was placed in the flowing water of the aqueduct to thoroughly examine its crusting. In this way, the strength of the raw brick samples' ability to withstand the beating, along with the density of its constituents, could be evaluated while it was damaged.

Finally, the roof was thatched every year for maintenance after the winter rains (with more clay than straw or silt). The thatch was troweled and rolled so that the roof would be insulated with a slope between three and five degrees. Notably, the processing and application techniques have always played an important role in the survival of the living earthen heritage.[20]

Construction of Moving Elements (Windwheel and Stones) for Flour Milling in Āsbāds

The most important functional elements in mills are the two grinding stones (locally known as *ās*), which grind grains by rotating against each other. Complex professional and technical skills were required to select, mine, and carve the proper types of stone (fig. 6). The stone mine, or, according to locals,

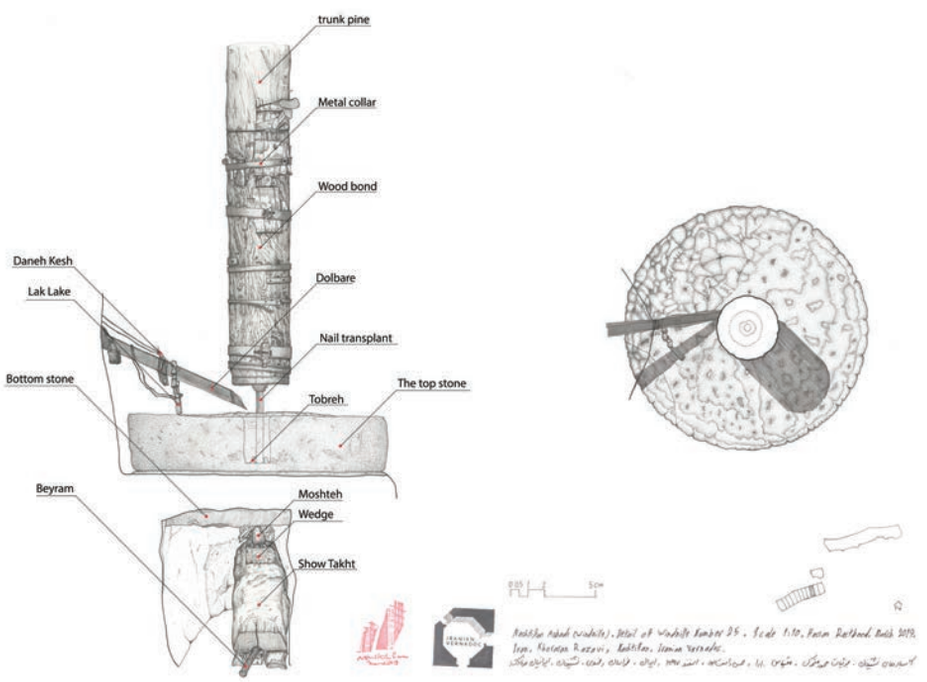


FIGURE 6 Section and plan of the grinding system. Rendering: Hasan Rastbood.

the *kārkhāneh-ye sang* (stone factory), had two types of salty and sweet conglomerate rocks and was located on Mount Sina-Kooh,[21] 6 km west of Nashtifan village. Salty rocks had higher resistance, so they were useful in building the bottom grinding stone, whereas sweet rocks were cut for the top. After cutting, the grinding stones were transported to the construction site by strong animals like cows or mules while *āsiyabān*s (windmill caretakers) performed sacred rituals accompanied by *dhikr* and local instruments.

Nashtifan village has fertile pine tree gardens that have long been used for wood supply. Wood selection has always been a key aspect in the construction of the main or secondary beams and columns for local structures. After investigating the gardens, the local carpenters would select and cut trees of a suitable trunk thickness (a diameter of at least 40 cm) whose wood had few knots and a uniform texture. Among different types of wood, mulberry, jujube, or apricot trees have optimal tensile and compressive strength and are excellent for structural elements like a *bāhoo* (*bāzoo*)[22] or *koloosi*. Similarly, the *charkh-bād* (windwheel), positioned in the center of the *par-khāneh* (āsbād's first floor), is significant for transmitting the wind power to the millstones. The main structural components of *par-khāneh* from the top to the entrance of *ās-khāneh* include *khar-pol*, *koloosi*, *qalandarak* (bearing element and its hollowed handle), *bast* (fastener), *tir-pol*,[23] *bāhoo*, *parreh* (blade), support buttress, and wooden pegs.

In Nashtifan village, the 120-day period of Sistan[24] wind currents begins in early May and runs to mid-October, simultaneous with harvest time. During this period, there are strong or weak wind currents throughout the entire day and, therefore, the āsbāds were busy producing flour all the time (Chevalier and Gheerbrant 1996). During the flour production phase, a thresher was used to separate the wheat from the straw and husks. Then, the pebbles and other impurities were cleansed by wind or a sieve, and the wheat was poured into a *par-kho* (container). As the wind blew and the grinding stones rotated, the wheat was poured from the *par-kho* to the millstone to be ground into flour.

Conservation and Monitoring of the Earthen Āsbād Structures

Unlike some historic masonry constructions (in Iran and globally) that were built by very skilled architects, the earthen structures in the villages of Iran, and in particular in this region, were typically constructed by local people who worked simultaneously in these windmills and gradually learned the required construction and repair techniques. Although their structural design might seem primitive compared to massive masonry buildings, these buildings have a spontaneity to their architectural formation, where the local earthen craftsmanship remains mingled with local lifestyles and needs.

Conservation activities have been carried out in the historic āsbād complex of Nashtifan in different phases (fig. 7). At first, practical measures were taken by local millers and caretakers and these consisted of regular (weekly or monthly) monitoring that included checking the adobe parts, wooden elements, and both *ās* stones, as these elements are prone to severe damage caused by strong environmental factors (i.e., wind and rain). The components needed to remain functional, as they were in constant use within historic flour production factories that provided a basic food ingredient for the entire Khaf region and surrounding cities. Over time, repair know-how was gradually passed on from generation to generation (father to son) until modern flour mills with electric or diesel machines were introduced. Due to the lack of necessity to continue the traditional flour milling, the āsbāds fell out of favor to a point where only a few reached out to the *āsiyābān*s, and the buildings were sometimes completely abandoned for a while. Infrequently, someone would go to the two or three mills belonging to those who preserved their ancestors' traditions, to prepare the flour they needed.

The Iranian Cultural Heritage Organization (ICHO) registered this significant historic complex on the List of Iranian National Heritage in 2001. At the time, the shift toward tourist-centered heritage practices resulted in large-scale strategies for the conservation and restoration of earthen architecture in Iran. Therefore, after evaluating the budget required for the conservation of these earthen windmills,



FIGURE 7 Restoration activities to rehabilitate the damaged parts of āsbāds. Photo: Mahmoud Baghideh.

practical measures were planned as short-term conservation phases. The need to gradually implement the reconstruction and consolidation plans that were prepared for their structural components and wood and stone elements has been emphasized.

Since the discussions to designate this historical complex as a UNESCO World Heritage Site began, the Nashtifan Research Center was established in a historic house near the āsbāds to provide opportunities for study, administration, and the gradual implementation of conservation plans. After the 4th International Vernacular Documentation Camp in Nashtifan (VERNADOC 2019), detailed technical plans were prepared, and gradually in situ documentation and methodical analysis of historic data were implemented (figs. 8a, b).

In addition to the reports on conservation activities (Khaksar 2019, 2020) for the Nashtifan Research Center during the two-year research opportunity, a database was established to collect, classify, and analyze existing literature and new technical information. These activities were in line with the efforts to identify and understand the intrinsic values of this ancient windmill complex as a characteristic example of a wider range of architectural styles in Nashtifan and similar regions.

According to our field studies, all existing āsbāds in this region are authentic, original, and intact, as they belong to an architectural style with special features in their formal structure, spatial arrangements, and functional elements. However, this construction method is not limited to the Nashtifan village and can also be traced to nearby towns. Due to the lack of historical literature and documents, the last generation of windmill caretakers in Nashtifan provided an opportunity for us to acquire a better understanding of vernacular construction technologies and to integrate it with current scientific methods.



(a)



(b)

FIGURE 8 Photo documentation of the windmills in Nashtifan during the VERNADOC camp in March 2019: (a) experts during the documentation. Photo: Ali Malekabbasi; and (b) participation of local children in the ongoing activities. Photo: Ali Malekabbasi.

Conclusion

Representative of ecological culture, the architecture of āsbād structures in Nashtifan exhibits a direct and strong interaction between humans and their environment. This article attempted to fill some of the gaps in introducing the historical status and ongoing use of āsbāds by documenting data regarding their construction methods. Also highlighted were some key points regarding the main scientific and conservation approaches in the past two decades, as well as the current maintenance plan. Particularly, the series of research activities concerning this historic complex provided a clearer understanding of various cultural, historical, and spiritual values in this region and emphasized the importance of documenting construction techniques and relevant existing data, as well as the preservation of these structures. Furthermore, the use of authentic techniques and materials compatible with adobe materials and local knowledge was emphasized.

Although earthen structures similar to these āsbāds make up approximately 80% of architectural remains in the Khaf region, these structures have rarely been thoroughly studied. Today, with limited professional training on such

structures, a lack of knowledge transfer from generation to generation in the region, and a lack of proper documentation for their respective cultures, some authentic construction techniques either are now forgotten or will imminently be so. Therefore, in this article, we attempted to reintegrate the accessible vernacular windmill construction know-how and document the results of our interviews with the last generation of *āsiyābān*s—some of whom passed away during the COVID-19 pandemic—in a methodical way.

The preserved knowledge will be useful in training new specialists and local caretakers to plan maintenance schedules and prepare accurate reports (daily, weekly, monthly, and annually). It is also important to monitor and record all structural behaviors during different seasons or after seismic events and to monitor elemental strength against atmospheric factors and humidity. Moreover, by designing new laboratory experiments on brickmaking and regional soil quality, we could incorporate local knowledge to produce higher-quality raw earth bricks, mortars, and other modes of adobe and masonry materials needed for a variety of architectural elements. For instance, efforts could include designing a proper drainage system after pathology studies on the downpour traces, processing high-quality thatch and thatching techniques for the walls and roofs, investigating tourist attractions and visits, and designing educational programs for people (children, adults, locals, tourists, students, and specialists) to increase awareness regarding the cultural significance of āsbāds as representative of vernacular ecological culture concerning the history of this region. Such educational efforts would facilitate plans and prospects that benefit local, national, and international cooperation.

It should be noted that flour, having been a main food ingredient, is produced by the convergence of human intelligence and local spiritual beliefs with technology. Mixing this combination with hard work, consequently, makes flour symbolic of the gradual ascesis that leads to purification, highlighting the hidden cultural and spiritual values that should not be forgotten. These values should first be thoroughly understood before their use in cultural education by deepening our existing knowledge to create a sustainable and dynamic conservation approach that could be expanded toward the protection of the natural landscape of Nashtifan, and by zoning the "windscape" (plateau and mountains) against urban developments or ore mining.

Almost a decade after these studies, in addition to preparing conservation and consolidation plans for this complex, it is also hoped that expert maintenance of āsbāds by local participation would provide firm grounds for designating this invaluable historic complex as a World Heritage Site, which would lead to greater attention as well as continued conservation activities to revitalize all existing āsbād structures in this region.

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Notes

1 *Ās* and *bād* ("mill" or "grind" and "wind," respectively); this word refers to a windmill structure.

2 Khaf is both a region and a city, and Khorasan (*Khurāsān* in the local dialect) is an eastern province and a historic geographical region in present-day Iran.

3 Āsbāds are attributed to the Safavid period on the Iranian National Heritage List. However, according to previous studies, the Great Mosque and cistern date back to the Timurid era (Roemer 1986, 214), thus supporting the current hypothesis.

4 The āsbāds of Sistan have been mentioned in the story of Yazdgerd III (624–651 CE), who was killed by an āsbād caretaker (locally called *āsiyābān*) in Marv (Pigulevskaia 1993, 295–98), implying that these types of windmills have a historical background of well over a thousand years, at the very least.

5 According to the locals, *kārkhāneh-ye ārd-sāzi* (flour-milling factory).

6 Fieldwork, architectural research, and documentation of tombstones provided interesting evidence for their precedence over these windmills, contradicting the local beliefs or suggestions of previous studies. Therefore, these āsbāds would have been built after the graveyard of this ancient city.

7 During the Safavid period, new settlements, blacksmiths, and carpentry shops were settled in their proximity, a place that was later called *bazah-asiabou*, which in the local dialect of Khaf City means the district of *āsiyābān*s (windmill caretakers).

8 According to our studies, several massive earthquakes occurred in the Khaf region between 1337 (ca. 737 AH in Jizad, Khaf) and 2019 (5.8 magnitude). Therefore, having the experience of previous earthquakes, local architects constructed the earthen structural components of these windmills with specific technical aspects (precise geometry, on solid foundations and/or with hand-dug, thick-walled structures) that would make them either resilient during a massive earthquake or suffer minor damage.

9 *Shāh* and *pey* ("king" or "chief" and "foundation," respectively); this word locally refers to the main load-bearing walls.

10 *Kāh* and *gel* ("straw" and "mud," respectively); this word refers to thatch or cob.

11 *Par* and *khāneh* ("feather" and "house or chamber," respectively). *Par* usually refers to the lightweight upper story in the structure of āsbāds; in the construction of āsbāds, it is one of several wood pieces, with a dimension of $400 \times 15 \times 1.5$ cm^3.

12 *Khar* and *pol* ("main" or "strong" and "bridge," respectively); this word refers to a column 30–50 cm in diameter and 4–5.5 m in length that is connected to a horizontal beam whose two ends are placed horizontally on the sides of the walls. In the windmill, this element is connected to the mill's central axis and prevents side thrust in the movement conversion. In the middle of the *khar-pol*, there is a *koloosi* (hole) upon which the vertical axis of the *charkh* (wheel) and *par* connect to the horizontal *khar-pol*. Moreover, a wooden element facilitates the axis rotation inside this *koloosi*.

13 Called *gonjeshk* (sparrow) or *benoosh* trees.

14 For this purpose, two soil types were sampled from the adjacent gardens and kept in two glass containers (⅓ of the volume, each). Subsequently, each container was filled with water and mixed with a shaker for 20 minutes. Then, both containers were kept still until the soil particles fully settled. This process was repeated once. After a few hours, the soil in each container appeared to aggregate in three layers. After the height of each layer was measured, its gradation was understood. One of the samples had higher amounts of clay while the other contained more silt.

15 *Ās* and *khāneh* ("mill" or "grind" and "house" or "chamber," respectively).

16 *Khesht-māl* in Farsi; *khesht* (raw brick, clay) and *māl* (to knead or rub).

17 *Ā(b)* (water) and *khoreh* (drink), normally used to refer to a circular watering basin made of mixing soil and straw to form a shape like an elevated watering basin or trough on the ground.

18 *Amal amadan* (to become activated), similar to kneading bread dough after adding water to yeast and flour, leaving the dough for a time to be activated.

19 *Āb* (water) and *māl* (to knead or rub).

20 The buildings have not been severely affected or damaged by natural or human factors since they were built. The fact that these āsbāds in Nashtifan village were not neglected and were continuously maintained during the rainy or working seasons prevented partial or total destruction.

21 Also called *Kooh-e Sino*, where the grinding stones would be extracted from an area near the summit and later from the slopes; a practice that is almost a thousand years old.

22 Meaning "arms," these are wooden elements that are connected to several *par* pieces from one side.

23 *Tir* (column) and *pol* (bridge).

24 Sistan is a historic geographical region in present-day southeastern Iran and southern Afghanistan; hence, these wind currents move in a south–north direction.

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Earth and Vegetable Fibers for Roofs: Characterization of Local Practices, Techniques, and Materials from Communities in Northern Argentina

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Abstract: *A number of research endeavors have shown the existence of a diversity of techniques for earthen roofing. However, these techniques have not been considered in any depth in the literature. The same situation applies to the conservation of these techniques; there is a lack of analysis of pathologies, best strategies for their remediation, and recommended actions for their maintenance. This becomes problematic as damage to a building's roof engenders different pathologies in other parts of the building. This paper focuses on the characterization and analysis of two techniques used on roofs in different communities of northern Argentina and nearby regions:* torteado *or* torta de barro *and* guayado*. The first consists of a series of continuous layers of soil in a plastic state with different stabilizers, and the second is based on the use of straw embedded in mud in a viscous state. Both techniques have had and continue to have a high presence in the region and have been subject to multiple transformations due to erroneous conservation strategies. This paper analyzes the materials used, procedures for their execution, possibilities and weaknesses they present, and potential pathologies that may arise in relation to these techniques. The material presented arises from documentation carried out in recent years in the region as part of broader research, which has allowed participatory observation of roofing practices in different communities and is complemented by laboratory information derived from studies on the raw materials.*

Resumen: *Distintas investigaciones han mostrado la existencia de una diversidad de técnicas para el techado con tierra. Sin embargo, estas técnicas no han sido particularmente consideradas en la literatura. Esta misma situación se observa en su conservación, en la cual se evidencia cierta carencia de análisis sobre las patologías, las mejores estrategias para su remediación, y las acciones recomendadas para su mantenimiento. Esto se vuelve problemático en tanto los daños en las cubiertas encadenan diferentes patologías en otras partes de los edificios. Este artículo se concentrará en la caracterización y análisis de dos técnicas utilizadas en los techos en distintas comunidades del norte argentino: el* torteado *y el* guayado*. Mientras que la primera consiste en una serie de capas continuas de tierra en estado plástico con distintos estabilizantes, la segunda se basa en el uso de paja embebida en barro en un estado viscoso. Ambas técnicas han tenido y tienen una alta presencia en los edificios de valor patrimonial y han estado sujetas a múltiples transformaciones producto de estrategias erróneas para su conservación. Como parte de este trabajo se analizarán los materiales empleados, los procedimientos para su ejecución, las posibilidades y debilidades que presentan, y sus potenciales patologías. El material presentado surge del registro realizado en la región, que ha permitido distintas instancias de observación en diferentes comunidades. Esto se complementará con la información de laboratorio surgida de los estudios sobre las materias primas.*

Keywords: Andean area, roofs, local communities

Introduction

Within the field of research on earthen building cultures, techniques used for roof manufacture have been among the least studied and, in fact, are usually absent from the main studies (Tomasi 2013). Earthen roofs constitute a relevant field of inquiry for conservation, both for their material significance and for strictly technical issues. Indeed, the lack of proper maintenance can trigger degradations that affect buildings in integral terms, including potential structural damage (Tomasi and Barada 2020b). The heterogeneous Andean area is one of the regions where earthen and vegetable fiber roofs have a high presence in earthen heritage.

The objective of this presentation is to approach the integral characteristics of the roofing solutions used in the highlands of northern Argentina, concentrating on two specific techniques known as *torta de barro* or *torteado* and *guayado* (fig. 1). Along with their characterization, degradation mechanisms and practices linked to their periodic maintenance will be observed. Transformations during the twentieth century in earthen heritage, resulting from the actions of different state agencies, will also be described. Finally, some conservation alternatives will be proposed from the possibilities of local building cultures.

In methodological terms, this paper is based on a comprehensive approach that considers regional fieldwork carried out in recent years involving different case studies, which have included both the survey and the development of intervention projects (Tomasi and Barada 2021b). The analysis of historical documentation and the study of raw materials in the laboratory is also explored (Tomasi and Barada 2020a).

The study area corresponds to a heterogeneous space that integrates the altiplano, together with a group of high-altitude valleys such as the Quebrada de Humahuaca, which was included on the World Heritage List in 2003. Although the analysis concentrates on what is now Argentina, the area was historically (and to a certain extent still is) integrated into a wider region that includes the current territories of Chile, Bolivia, and Peru. Within this framework, there are multiple continuities and intersections in the practices of the communities in the region, including constructive technologies. The techniques that will be analyzed present similarities with others executed in this broad area (Tomasi 2013). In environmental terms, the area includes altitudes ranging between 2000 and 5000 m above sea level, with a semi-arid climate and a large thermal amplitude. Rainfall is concentrated during the summer months (December to March) and tends to be limited but torrential.

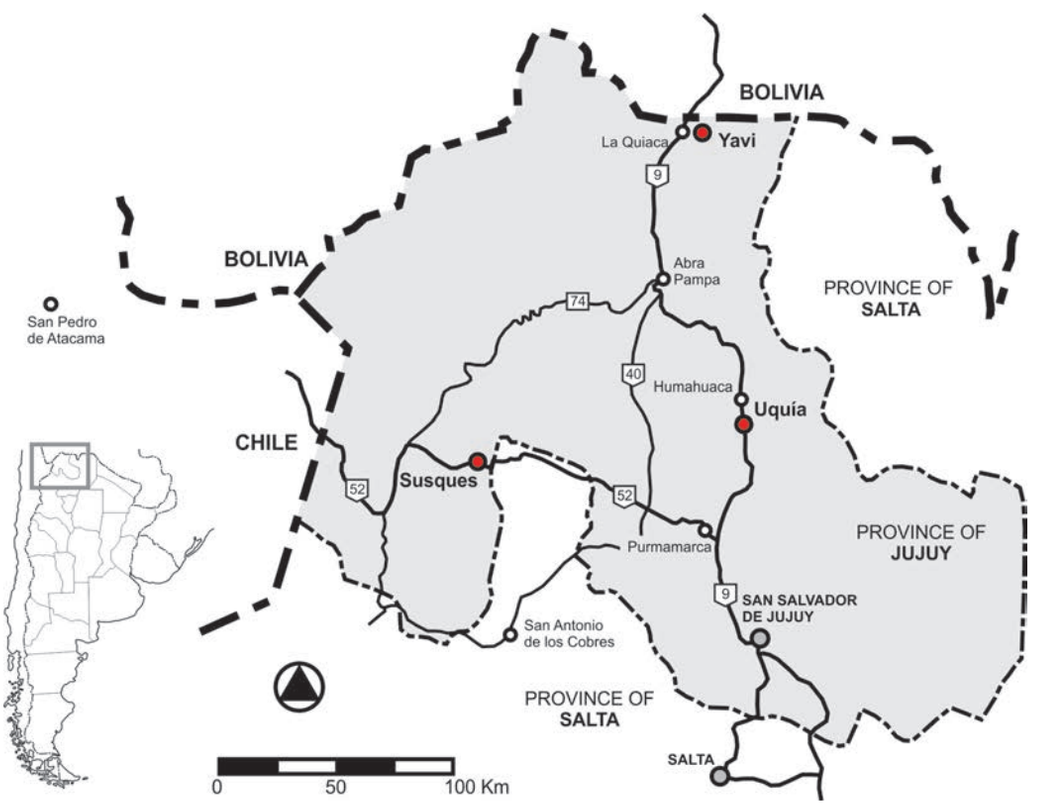


FIGURE 1 Location of the study area and localities used in the fieldwork conducted in northern Argentina. All figures courtesy of the author.

Roofing Techniques

Earth construction is an integral part of building cultures that, from their dynamic condition, are part of habitat production in a large part of the Andean area, including the highlands in northern Argentina (Tomasi et al. 2020). These building cultures are modeled as such from a set of practices, on domestic and community scales, which are inseparable from other fields of social life and are shaped around various techniques that have adobe as the predominant material (Tomasi and Barada 2020a). Historically, roofs have had gabled configurations with A-trusses that support a surface of reeds, branches, or straw onto which two possible techniques are usually executed: *guayado* and *torta de barro* (Tomasi 2013). The use of these techniques has been practiced in the region over a long period of time, with documented use in the colonial period, between the sixteenth and nineteenth centuries, although they probably have antecedents in pre-Hispanic times.

Guayado technique consists of layers of straw, partially embedded in a mud of viscous consistency (Rotondaro 1984; Delfino 2001; Tomasi 2013). The straw is laid in bundles, forming continuous horizontal strips that overlap vertically from the eaves toward the ridge, over a first layer of cut straw called *cijne* (fig. 2). In this application, the end of the straw that is coated with mud is hidden under the upper layer, while the other ends (the thinnest of the fibers) remain visible and compose the final finish of the roof (fig. 3). The mud has a waterproofing role and also maintains the adherence between the straw fibers to give continuity to the roof. The soil, having extremely fine granulometry and a high clay percentage, is mixed in large pits until it reaches the right consistency (Tomasi 2013).



FIGURE 3 View of the *guayado* on the roof of the Church of Susques.

Torta de barro, literally "mud cake," consists of the continuous execution of layers of mud in a plastic state, with a consistency similar to that required for the production of adobes, until a thickness of about 10 cm is reached (although this final thickness varies in different places) (Rotondaro and Rabey 1988; Tomasi 2013) (fig. 4). Normally, *torta de barro* is executed

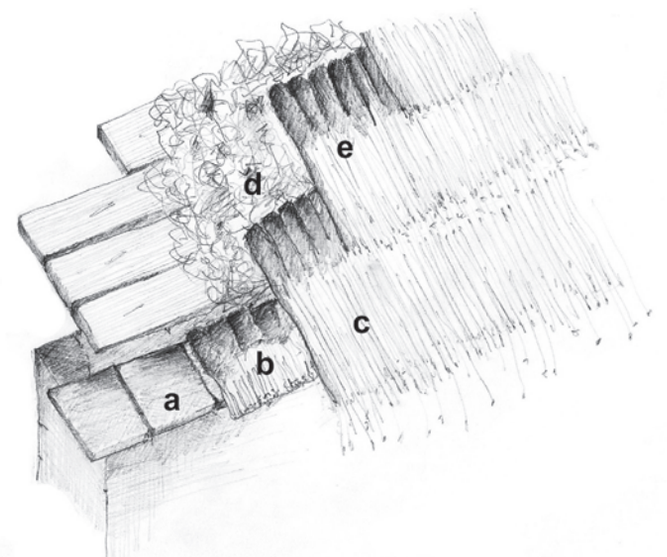


FIGURE 2 Diagram of a *guayado* with its different layers: (a) stone eaves, (b) first eaves of straw with roots facing outward, (c) top eaves of straw, (d) base layer of *cijne*, loose straw for leveling, and (e) overlapping layers of bunches of straw soaked in mud.

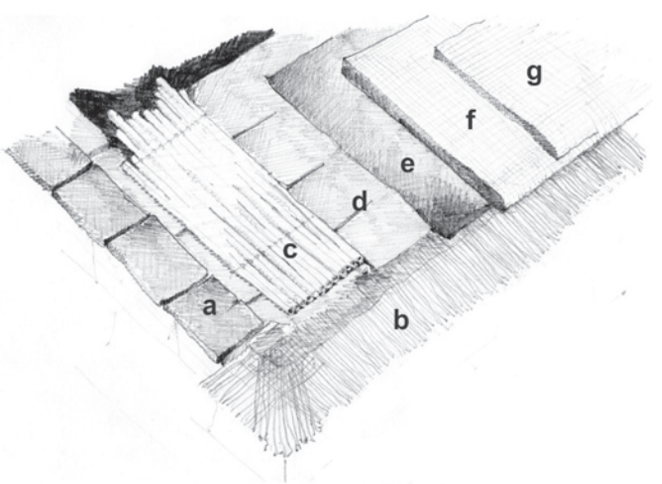


FIGURE 4 Scheme of the *torta de barro* with its different elements: (a) stone eaves, (b) straw eaves, (c) tied reed base, (d) cardboard layer, (e) plastic layer, (f) base mud layer, and (g) mud wear layer. Elements (d) and (e) correspond to recent changes in construction technique.



FIGURE 5 View of the *torta de barro* on a house in Susques.

in two or more successive layers: a base layer, which has the greatest thickness, and a wear layer, which is usually 2–3 cm (fig. 5). This soil has a more balanced granulometry than that used for *guayado*, again similar to what is required for adobes. Various stabilizers are incorporated to influence the behavior of the torta, particularly vegetable fibers, although animal fat or ashes are also often used (Tomasi 2013).

Both techniques provide adequate waterproofing insulation for the environmental conditions in which they are used, combining runoff with partial absorption of excess water that is then released into the environment. At the same time, due to their composition, the methods allow for the evaporation of humidity inside the rooms, reducing the possibility of biodeterioration and other associated pathologies. The region's rainfall pattern is characterized by occasional rains during the summer months, which are not sustained over a long period of time. The earthen roofs do not become saturated with water because they are subject to daily cycles of humidity and drying. As these roofs have a high percentage of vegetable fibers, particularly *guayado*, they are extremely flexible and respond adequately to the expansion and contraction associated with the thermal amplitude.

Guayado and *torta de barro* roofs require periodic maintenance, as their constant exposure to environmental agents, particularly rain and wind, precipitates erosion, reducing their waterproofing capacity. In extreme situations, their degradation can lead to significant leaks that cause damage first to the wooden roof structures and then to the walls (Tomasi and Barada 2020b). Proper roof preservation prevents a series of important damages.

Procedures for periodic maintenance may include either punctual material addition or the replacement of the entire roof. In the case of *torta de barro*, it is possible to periodically repair the top layer without affecting the base layer. Similarly, for *guayado*, the work may involve the addition of a new layer of straw and mud as reinforcement. However, these partial repairs can lead to an increase in the amount of material and thus an additional load on the roofs. For this reason, in larger cycles, it is necessary to completely renew the roof covering.

Institutional Transformations

Prejudice and ignorance have historically conditioned interventions on earthen heritage, at least in the Argentine context, where this heritage had a high presence within the National Historic Monument (NHM) declarations (Herr and Rolón 2018). Indeed, since the beginning of systematic and institutionalized conservation practice in the first decades of the twentieth century, recurrent conservation actions tended to change the materials of the NHMs in different parts of the country (Tomasi and Barada 2021a). These actions implied the alteration of techniques and the incorporation of foreign procedures and materials, particularly cement and concrete, within different elements of the earthen constructions. This prejudicial view, which has been registered in different countries worldwide, creates new damages instead of contributing to the consolidation of buildings (Tomasi and Barada 2020b).

While many of the alterations were concentrated on adobe walls, earthen roofs—both *torta de barro* and *guayado*—were particularly affected, and these transformations were guided by two different, but related, objectives: on the one hand, to increase the durability of roofs and, on the other, to reduce the presence of certain materials associated with being backward and not durable in relevant historic buildings. This has led to two types of actions by conservation agencies and professionals. First, the alteration of procedures and materials while maintaining certain features of the techniques and, second, the integral replacement of roof materials with the introduction of other, foreign construction systems. While partial alterations were particularly linked to *torta de barro*, integral replacements constituted the main action for *guayado*.

Buildings maintained the *guayado* roofs in a few cases, such as the Church of Susques in the Puna de Atacama, while the technique was replaced in others. The Church of San Francisco de Yavi, near the current border with Bolivia and declared an NHM in 1941, is a representative case of these processes (Herr and Rolón 2018). The original roof, reputed to have been



FIGURE 6 Tiled roof on the Church of San Francisco de Yavi.



FIGURE 7 Alterations in the *torta de barro* on the Church of Santa Cruz in Uquía.

made of *guayado*, was replaced by a metallic one around 1912, before its declaration. After its formalization as an NHM, it was restored and a roof of *torta de barro*, not of the original *guayado*, was installed. Due to the technical problems that arose decades later, the roof was again transformed and this time the ceramic tiles that can be seen today were added (fig. 6).

The Church of the Santa Cruz and San Francisco de Paula, in Uquía, Quebrada de Humahuaca, is another representative case of these processes that are related to the alteration of *torta de barro*. Since its declaration as an NHM, also in 1941, this colonial chapel underwent several interventions that involved profound changes such as the incorporation of a reinforced concrete structure (Tomasi and Barada 2020b). The original *torta de barro* roof was modified to include various materials said to extend its durability and reduce the need for maintenance, but instead resulted in completely distorting the technique. At the beginning of the twenty-first century, this technique was altered by incorporating a cement mortar base, metal mesh, plastic textile coating, and liquid membrane (fig. 7) (Tomasi and Barada 2021a). In addition to the conceptual and technical alteration of the construction system that affected the roof's authenticity, the incompatibility of the materials generated leaks that seriously affected the building.

These types of conservation actions on historic architecture have had their correlation in current domestic buildings, where the transformation of techniques or the replacement with other materials such as sheet metal roofing is also recorded. Although the use of both *torta de barro* and *guayado* in domestic architecture has been reduced in recent decades, new materials have implied a broadening of the repertoire of available techniques, but not a total abandonment of historical procedures.

Temporalities and Challenges

These actions and material transformations of earthen heritage, particularly their roofs, are inscribed in certain social representations on materials and techniques, and in some conceptions linked to temporality. Institutional and institutionalized representations become involved and are in tension with local points of view regarding conservation temporality. In fact, in Andean communities, the repair of roofs made of *torta de barro* and *guayado* were constituted as technical actions associated with a social relevance around the construction and strengthening of certain collective bonds (Tomasi 2013). In this framework, the transformations in the materials and techniques used in the roofs have implications that intersect with the social sphere in an integral way (Tomasi and Barada 2021b).

In any case, there is a need to construct a view and practice of conservation that overcomes the dichotomy between the institutional and the community in order to recognize the broader intersections within the framework of new and changing social realities. The increased durability of roof construction techniques is not only an expectation of state agencies linked to conservation. On the contrary, it also emerges as a demand and a need from the local communities themselves, as their insertion within other social dynamics for which the

collective availability of time for periodic interventions is not the same as it was historically.

The challenge is to develop conservation actions that allow the sustainability of practices, within their temporalities while responding to the new conditions within the social dynamics. This may involve actions in relation to the conservation management of this heritage, and interventions around the specific behavior of materials and their longevity. In relation to management, the intervention of public and private institutions has tended to overlap and replace local dynamics instead of being integrated with and contributing to the sustainability of practices. It is necessary to develop an approach that is based on local ways of organization.

At the same time, it is possible to work around the procedures, improving their capacities and durability and exploring the density of the building cultures themselves, with actions that align with the existing techniques and the know-how of local communities. For example, in a recent intervention at the Church of the Santa Cruz in Uquía, the recovery of *torta de barro* was carried out by incorporating lime in the wear layer as a way to improve its resistance to erosion without affecting its properties (Tomasi and Barada 2021a). The use of lime, in fact, was recorded in this building not for *torta de barro* but for the mortars in the foundations and plasters. It is necessary to recognize other temporalities in conservation, where meanings linked to authenticity may imply the total replacement of roofing materials while still affirming the social practices related to their production.

Conclusion

Throughout this article we have sought to show how roofs are a relevant topic for the field of earthen heritage conservation, in both technical and social terms and based on the methods used in different communities in the province of Jujuy in northern Argentina. These techniques, *torta de barro* and *guayado*, imply the use of certain materials and technical gestures that allow for the generation of an adequate waterproof insulation. Both require periodic maintenance that, historically, communities have developed within the framework of rituality associated with the strengthening of certain collective bonds and a particular temporality.

As we have stated, due to the prejudices associated with earthen construction, institutionalized conservation actions on National Historic Monuments have tended to alter the characteristics of techniques like these with construction systems that are unrelated to the materiality of buildings, not only affecting authenticity but also causing various pathologies in the buildings. The challenge is to achieve a conservation of earthen roofs with practices consistent with local building cultures.

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Arga as a Building Material: Its Properties and Application Technique

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Abstract: *Tibetan traditional architecture uses materials that are suitable for the harsh local climate, which has wide temperature variations between winter and summer, day and night, as well as dry winters contrasting with a summer monsoon. In central areas of the Tibetan plateau in China's Tibet Autonomous Region (TAR), a natural material called* arga *is used to waterproof flat roofs. Little is known about its composition and whether it has intrinsic waterproofing qualities or whether it attains these qualities through the technique of its application. This study introduces* arga *as a building material—the chemical and mineralogical types of different samples—and the application technique as practiced in the Lhasa region. It is based on the author's fieldwork in the Lhasa and Tibetan regions with master artisans and builders who are experts in working with this material, as well as on her work reviving the* arga *technique in Lhasa.*

Resumen: *En la arquitectura tradicional tibetana, se utilizan materiales adecuados para el clima local hostil, que presenta variaciones de temperatura muy amplias entre el invierno y el verano, el día y la noche, la sequedad del invierno y la humedad del monzón del verano. En los territorios centrales de la meseta tibetana que se encuentran en la Región Autónoma del Tíbet (TAR) de China, para impermeabilizar los techos planos se utiliza un material natural denominado "*arga.*" Se sabe poco sobre su composición y también se desconoce si posee cualidades intrínsecas de impermeabilidad o si éstas se obtienen por medio de su técnica de aplicación. Hay poca bibliografía disponible sobre lo que es realmente este material y lo que da a los techos de* arga *sus cualidades de impermeabilidad. En este estudio, se presenta al* arga *como un material de construcción (los tipos químicos y mineralógicos de las distintas muestras) y la técnica de aplicación que se practica en la región de Lhasa. La información incluida se basa en el trabajo de campo de la autora en las regiones de Lhasa y el Tíbet con los maestros artesanos y los expertos en la construcción con este material, así como el trabajo de recuperación de la técnica del* arga *en Lhasa.*

Keywords: *arga*, conservation, building material, traditional building technique, natural waterproof materials, Tibetan architecture

Introduction

Traditional houses on the Tibetan plateau and arid regions of the Himalayas have flat roofs and are built with stone, adobe, rammed earth, soil, and locally sourced wood. In central Tibet, there is a material with insulation properties that is applied to roofs and floors for waterproofing. In Tibetan, this material is called *arga*. According to artisans and experts, "Arga is neither stone nor soil."

It is unknown when arga was first used or, particularly, when it started to be widely used as a roofing and flooring material. It was used extensively in Lhasa, in monasteries and temples as well as in residential buildings until the mid-twentieth century. It was applied to roofs and parapets and also used in interior rooms and galleries to inhibit dust and give the floor a shiny coat, especially when polished. The condition of the floors varied according to the level of maintenance, the importance of the room, and the economic status of the owner.

I had the opportunity to hear and witness many stories about the strength and qualities of arga. One house in Lhasa that we were preparing to restore had a ground-floor room that had remained locked for many years. We found that insects had eaten the wooden pillar and bracket, leaving the ceiling unsupported. Directly above was the living room of the current tenant with an arga floor, the strength and "concrete-like" qualities of which had prevented it from collapse. Regarding its waterproofing qualities, a well-applied arga not only protects the roof from water leakage but also prevents water infiltration in the walls. It also has good insulating properties.

Composition of Arga

If arga is neither stone nor soil, what is it? Between 1996 and 2010, we collected arga samples from different quarries in central Tibet, Amdo (Qinghai), and Kham (Sichuan) (fig. 1). These samples were analyzed using physical and chemical tests:[1] the study concluded that arga is not a specific stone but a combination of different types of stone composed of calcium carbonate and silicate inclusions (table 1). The samples used in roofing share similar properties, primarily that their silicate content ranges between 7 and 30%. These silicates include quartz, mica, feldspars (microcline and orthoclase), and clays. The clays were identified as montmorillonite with small amounts of kaolinite and illite. Small amounts of other clays may also be present.

"Good" arga also tends to be the hardest according to the breakability test. The amount of silicate content indicates that arga should not be considered a marl but, rather,

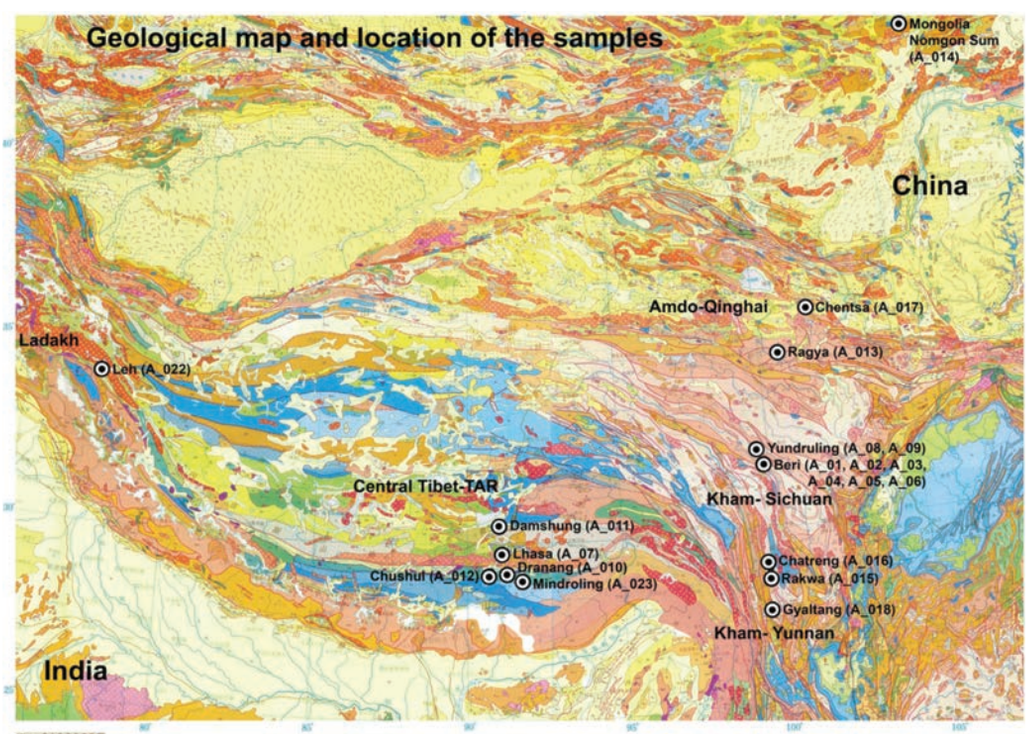


FIGURE 1 The location of the twenty arga samples on a geological map of Asia, 1975. Compiled by Academy of Geological Sciences of China. Beijing: Map Publishing House.

Table 1 Results of Analysis of Arga Samples Using Physical and Chemical Tests

Sample / Properties	CaCO3%	Silicates%	Montmorillonite	Kaolinite	Other clays and silicates	Matrix	Allochems / clasts	Porosity	Dunham classification	Quality
01	59%	41%	+++	+	+	---	---	---	---	---
02	---	0%	---	---	---	---	---	---	---	---
03	73%	27%	+++	+	+	Micrite/ micro spar	Fine quartz	0	Wackestone	++
04	70%	30%	+++	+	+	---	---	---	---	---
05	77%	23%	+++	+	+	---	---	---	---	---
06	79%	21%	+++	+	+	Micrite/ micro spar	Calcite, quartz, iron oxide	4%	Wackestone	++
07	90%	10%	++	+	+	---	---	---	---	+++
08	71%	29%	+++	+	+	Micrite/ micro spar	Fine quartz	0	Wackestone	++
09	68%	32%	++	+	+	---	---	---	---	---
010	77%	23%	+++	+	+	Micrite/ micro spar	Quartz, mica, biotite	0	Wackestone	+++
011	73%	27%	+++	+	+	Micrite/ micro spar	Clastic feldspars, quartz	0	Wackestone	+++
012	80%	20%	+++	+	+	Micrite/ micro spar	Oncoids	6%	Wackestone	+++
013	76%	24%	+++	+	+	Micrite/ micro spar	Fine quartz	---	Lime mudstone	++
014	99%	1%	---	---	+	---	---	---	---	0
015	50%	50%	+	++	+		---	---	---	0
016	89%	11%	+++	+	+	Micrite/ micro spar	Peloids	0	Packstone	++
017	57%	43%	++	+	+	---	---	---	---	0
018	12%	88%	+	+++	+	---	---	---	---	0
022	94%	6%	++	+	+	Micrite/ micro spar	Bioclastic	16%	Framestone	0
023	90%	10%	+++	+	+	Micrite/ micro spar	Ooids, peloids	0	Wackestone	+++

an argillaceous limestone. Based on Dunham's classification of rocks (1962), the depositional texture of arga falls into various types of stones: lime mudstone, wackestone, and packstone.

Thin sections indicate that arga was formed in a non-marine carbonate environment. The crystal structure of the calcium carbonate in arga is calcite, with a fine-grain micrite matrix that is less than 4 μm. Some arga samples have a spar calcite matrix greater than 4 μm. There are also other visible fragments, which include silicates and calcium carbonates in the form of ooids, oncoids, and peloids.

Revival of the Arga Technique

After 1959, private property was nationalized and turned into public housing, and many of the original homeowners were allocated ground-floor rooms. Since then, the houses have been poorly maintained and many problems have appeared. We started conservation work in Lhasa old city in the mid-1990s by taking a social survey of over 100 houses to identify their problems. We found that one of the main problems was leakage from the roof and parapets that led to house damage and collapse. To restore them, we had to learn where to find arga, as well as to locate people who still knew the application techniques and the work songs associated with it. Cement was usually used as a roof sealant in government restoration or reconstruction projects. Later the government construction companies began to organize their own arga teams, and its use was revived for the repair of religious buildings.

Where to Find Arga

The identification of arga for use as a building material requires experience and knowledge. According to Hirako and Dorje (2001), arga is usually found on south-facing mountain slopes that experience strong sun exposure. Its surface, neither flat nor smooth, often contains red or white soil. The mountain should not have rocks or water springs nearby and limited vegetation, usually grass. These criteria are still used in present-day Tibet to search for deposits.

Arga Singers

The workers who lay arga on roofs are called a*r ka bcag mkhan* in Tibetan (fig. 2). The arga master, *zhal dpon*, can be a woman or a man. The technique consists of stamping layers of raw arga for several days until it is well compacted. This requires a group of fifteen to forty people, depending on the roof size.

There are many ways to organize the stamping depending on the project size. In one method, a big group is divided in half and these two groups stand facing each other. The first group starts by stamping and singing in the direction of the opposite group and then returns to its original position. The



FIGURE 2 Arga singers applying the material to the roof of a Tibetan house in Lhasa. They are called arga singers because the application technique is accompanied by constant singing. Photo courtesy of Tibet Heritage Fund.

second group then does the same in the opposite direction while the first group rests, and so on. This is always accompanied by singing. Work songs are an intrinsic part of the process and have been studied by Grothmann (2011).

Arga Tools

The tools used in arga application are very simple and are made on-site by the masons. The tool for stamping arga floors is a flat, round stone with a central hole into which a wooden handle is fixed at waist height. This is called a *'bog rdo* (fig. 3).

A hand-held wooden tool called *lag bcag* is used to stamp the arga into the rounded parapets and roof ends. After stamping, the arga is polished with a *dbur rdo*, a round and smooth river stone. A cleaning cloth, *phyis ras*, is used at the end of the process. Other tools used in the process might include masons' hammers, shovels, buckets, and brooms.

Preparation for Arga Application

To understand arga application, one must understand how the Tibetan flat roof is built. Roofs rest on rafters that are laid on the tops of walls and over a beam-and-pillar structure. Wood board, twigs, and stones are laid on top of the rafters to close the gap between the rafters and to create a support for the mud layer that will go on top (Alexander and De Azevedo 1999). This layer is not completely waterproof and the arga is applied on top of this mud layer (fig. 4).



FIGURE 3 A worker assembling a *'bog rdo,* the main tool for arga application. The tool is made completely by hand. Photo courtesy of Tibet Heritage Fund.

If the roof is newly built, it should rest for a year before arga is applied. In the past, this would be taken into consideration, but today people tend to apply arga directly without waiting, a practice that carries a high risk of cracks due to the simultaneous drying of walls and wood, and therefore potential roof leakage. The arga layer is applied with a slight slope, enough for water to flow to the gutter and away from the roof.

The Roof Layers

To improve the qualities of the roof, a base layer called *mthil zhal* (see fig. 4) should be applied a few weeks after finishing the mud roof using *ar hrog* (big pieces) that are stamped slowly into the dry mud layer and allowed to settle and harden

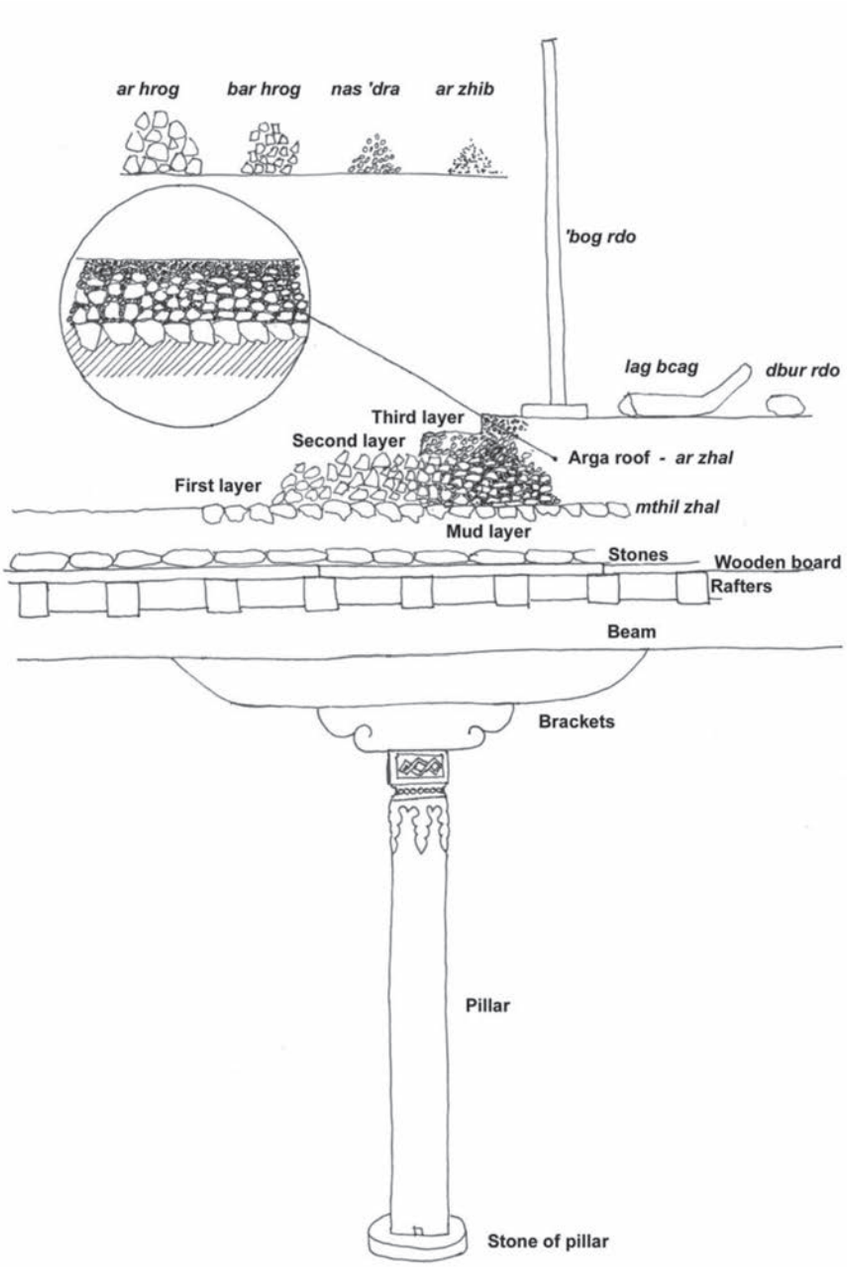


FIGURE 4 Drawing showing the wooden structure of the houses, the different parts of the roof, and the different arga layers. It also shows the tools, the arga sizes with their Tibetan names, and a detail of the finished arga roof. Drawing by P. de Azevedo.

for one year. This hardened layer supports other layers and takes about one day to stamp. If it is not possible to wait for a year, this layer should be applied a few weeks before the other layers, but the effect will not be the same. The thickness of the layers depends on the availability of the arga and the quality of the structure. In my observation, it can be between 10 and 20 cm, or more in special cases.

For the second layer, *ar hrog* pieces are applied in thick layers on top of the base layer, sprinkled with small amounts of water, and stamped slowly until uniform, evenly distributed, and the space between the stones is reduced. This technique is called dry stamping and can take between a half and one full day to complete. Pieces of *bar hrog* (medium-size arga) are applied to create the third layer. This layer uses little water and is supervised by the arga master. It needs to be stamped hard for a day.

The *lan khras* (fourth layer) uses *nas 'dra* (grain-like) and *ar zhib* (fine-grain) pieces. The grain-like pieces are spread

on the roof by hand. They are dry stamped for a few hours and then sprinkled with water and stamped again. This process, which takes about four days of energetic stamping, is repeated until the material becomes a paste, slowly adhering as it dries. At this stage, if the arga is not made up of small gravel pieces or if it is very sticky, a small amount of gravel can be mixed in, giving a beautiful terrazzo-like effect to the finished roof.

Sometimes *nas 'dra* and *ar zhib* are mixed and applied together. In other cases, where *nas 'dra* alone has been used, and where the roof is not sufficiently smooth, *ar zhib* is added later. The parapet walls and extremities of the roofs are surfaced using the same method, only the tools and the stamping process are different (fig. 5).



FIGURE 5 Master Kelsang (foreground) stamping the edges of the roof using a *lag bcag* tool. Photo courtesy of Tibet Heritage Fund.

Use of Water

Only a small amount of water is used for the first two layers, but water is applied to the *nas 'dra* and *ar zhib* layers until a paste is formed. The arga is then stamped until it is well compacted. At this point no more water is sprinkled, but stamping continues until it becomes completely dry.

Finishing Techniques

After the arga floor is finished, *dbur rdo* is used to polish the floor, making it smooth and even (fig. 6). The process takes one to two days.

Once the roof is completely dry, and after removing any soil or dust, an elm bark coating is applied. To prepare this layer, it is first necessary to collect the bark of the elm tree (Tib: *yom 'bog*). The bark is soaked in hot water for a half to a full day to make it soft and is then rubbed by hand to extract a liquid that is mixed into the water. This liquid is applied very generously in big strokes. It is possible that it has hydrophobic properties.

After the elm bark layer is dry, the oil layers are applied. The oil mixture is made by boiling oil (often rapeseed oil, although sometimes butter is also used) with resin, or *spos dkar* (white resin) from the *Shorea robusta* plant (Das 1902). The oil mixture is applied and left to dry before the next application (fig. 7). This step is repeated at least three times.



FIGURE 6 Workers polishing the arga with *dbur do* and cloth. After this, the *yom 'bog* mixture is applied. Photo courtesy of Tibet Heritage Fund.



FIGURE 7 The last layer, consisting of three coats of oil, which will be repeated at least three times. Photo courtesy of Tibet Heritage Fund.

Maintenance

A similar maintenance technique is used for interior rooms and roofs. The interior room floors are often polished with cloth to keep the arga shiny and smooth. Water spills should be avoided. Exterior arga floors need to be regularly maintained by repairing cracks, cleaning water drains, removing snow, and applying an oil mixture where necessary for waterproofing.

Conclusion

While the chemical composition of arga can be defined as having calcium carbonate and silicate inclusions and a silicate content ranging from 7 to 30%, not all types of such stone are considered arga or can be applied as roofing material. To correctly identify and locate it requires experience. And, according to Masters Migmar-la and Tasil-la, it also has a special taste.

In my observation, what gives arga its waterproofing qualities are the techniques used and the quality of the materials. By stamping the arga layers with the right proportion of water and labor, the mixture consolidates and forms a cement-like layer. The calcium carbonate contents of the material and the technique combine, under the arid conditions of the Tibetan plateau, to make arga a waterproof material that requires good maintenance.

Note

1 Some of these tests included visible reflectance spectroscopy, FTIR-ATR absorption analysis, and thin sections, as well as analyses for clay content, hardness, permeability, density, porosity, chloride content, hydrochloric digestion, texture, particle homogeneity, color, and porosity.

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Cob: Future Heritage of the Twenty-First Century?

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Abstract: *Cob is a traditional earth building technique, found globally and in Europe, that has a strong regional presence in northwestern France and southwestern England. The technique was abandoned during the twentieth century, when traditional skills and knowledge declined as a consequence of conflict and the synthetic construction techniques that dominated postwar reconstruction. In recent years, the conservation of historic buildings has enabled some recovery of the intangible heritage of traditional skills. However, this is a small market that remains vulnerable to loss, limiting the tradition to a backward-looking culture of preservation. The potential of cob to address the global warming challenge by reducing CO_2 emissions (the result of using a natural material without needing to burn it to make it useful) creates the possibility of fostering a living culture where cob continues to develop contemporary applications, providing greater cultural and economic security for the heritage where it is grown. The CobBauge Project adapts the traditional cob technique to modern thermal standards and construction practices through a cooperative process between scientists and traditional cob builders, in laboratories and on construction sites. The results optimize the earth-fiber mixture and enable the technique to comply with local regulations, with training and technical guidance developing from experience in the Pirate, Cordiale, and Jump projects. Making the technique more affordable and transferable will help realize the value held in traditional culture while sustaining historic tangible and intangible cultures as living traditions for future generations.*

Resumen: *El* cob *es una técnica tradicional de construcción con tierra que se puede observar en Europa y en todo el mundo; está muy presente en las regiones del noroeste de Francia y el suroeste de Inglaterra. Esta técnica se abandonó durante el siglo xx, por lo que se produjo un declive en las habilidades y los conocimientos tradicionales a causa de los conflictos y de las técnicas de construcción sintéticas que predominaron en la reconstrucción de la etapa de posguerra. En los últimos años, la conservación de los edificios históricos ha permitido recuperar cierta parte del patrimonio intangible que conforman las habilidades tradicionales. Sin embargo, como éste es un ámbito pequeño, se mantiene vulnerable a las pérdidas y limita la tradición a una cultura de preservación que mira hacia el pasado. El potencial del* cob *para enfrentar los desafíos del calentamiento global, en particular, al reducir las emisiones de CO_2, permite fomentar una cultura viva en la que se siguen desarrollando aplicaciones contemporáneas, lo que ofrece una mayor seguridad cultural y económica para el patrimonio del que surge. En el proyecto CobBauge, se adapta la técnica tradicional del* cob *a los estándares térmicos modernos y a las prácticas de obra por medio de procesos de creación conjunta de científicos y constructores tradicionales que utilizan esta técnica en laboratorios y procesos de edificación; los resultados optimizan la mezcla de tierra y fibra, y permiten cumplir con las regulaciones locales. La capacitación y orientación técnica se desarrollan a partir de la experiencia obtenida en los proyectos Pirate, Cordiale y Jump. Llegar a una técnica más asequible y transferible ayudará a hacer realidad el valor que encierran los saberes heredados y a preservar la cultura histórica tangible e intangible como una tradición viva para las futuras generaciones.*

Keywords: cob, skills, cultural heritage

Introduction

The technique of cob construction is present on almost every continent. Although the quality of soil and climate, as well as the history of local constructive cultures, has generated multiple variants of implementation, cob can be defined as a monolithic earth wall made from earth clods. In Europe, this technique is found from the north in Estonia, to the south in Abruzzo, from Ireland in the west, to Austria in the east.[1] In France this technique is present over a western arc, with the highest concentration in Normandy and Brittany. In the UK, cob is found in comparable proportions, especially throughout the southwestern part of England.

The heritage that is still visible today was built mainly from the end of the seventeenth to the end of the nineteenth century. Older witnesses attest to its recurrent use during the end of the Bronze and Iron Ages (ninth to first century BCE) and the medieval period (seventh to fourteenth century) in southwestern France (De Chazelles 2006). The oldest buildings found in Brittany and Normandy date from the sixteenth century (Bardel 2010; Patte 2010). During the twentieth century, the technique experienced a strong decline in Europe. The two world conflicts contributed to the disappearance of the related skills.

From the mid-twentieth century, earth and cob were incorrectly perceived as materials for the poor. During the 1980s, various actions[2] were taken to raise awareness of the importance of this heritage, contributing to the rediscovery and renovation of this know-how (Streiff and Patte 2007). These measures have contributed to the maintenance and renovation of this heritage. Depending on national regulations, several levers have been activated that provide incentives, including those within the Regional Nature Park of the Cotentin and Bessin Marshes (PnrMCB) or regulations as the listed heritage of Devon requiring faithful renovations. In both cases, a few companies have developed strong skills that have allowed them, for example, to save some 600 of the 10,000 buildings on PnrMCB.[3]

Contemporary Cob Architecture

Some companies have dared to leave the comfort zone of heritage renovation to offer a modern use of this vernacular technique. Cob experienced a resurgence in interest from the 1980s, stemming from counterculture movements particularly in the US.[4] Because of the simplicity and freedom of the technique, cob construction has won over many self-builders, producing numerous construction projects.

In Europe, if we disregard the few projects resulting from the counterculture responding to certain aesthetic codes and social economic schemes that rely heavily on self-building and mutual aid, motivations are often the preservation of skills, the adaptation of the technique to the climatic context, or even the nature of available soils. Cob is particularly conducive to collective work undertaken in communities and, if led by a trained builder, contemporary projects built by more conventional companies have been the source of technical adaptations aimed at both reducing the intensity of labor and developing solutions that help the technique comply with thermal regulations.[5]

The Emergence of the CobBauge Project

Based on the growing interest shared between Normandy and Devon,[6] various actors involved in earth and cob building such as the University of Plymouth (UoP), Earth Building UK and Ireland (EBUKI), and PnrMCB have joined with the École Supérieure d'Ingénieurs des Travaux de la Construction de Caen (ESITC Caen), University of Caen, and Hudson architects to develop the utopian hypothesis that cob's mixture of earth and fibers could become compatible with current thermal regulations. Besides the mixture's optimization, the improvement of the implementation would reduce the effort and costs associated with cob, thus promoting the renewal of its use. Moreover, in the context of the necessary reduction of CO_2 emissions in the building sector, the use of a raw soil requiring little transformation in conjunction with a carbon-trapping plant fiber suggests rather interesting prospects for sustainable development.

The Role of Builders in the Scientific Project

From the outset, CobBauge has utilized a dual scientific and practical approach, with a methodology that is jointly defined by scientists and professionals—combining the rigor of the scientific process and the evaluation of the laboratory test samples' on-site reproducibility. The resources have thus been identified by builders practicing earthen construction. Soil samples (six English and six French) were selected by field experience based on their availability for future use, their representativeness compared to the soils encountered in the architectural record, and their grain-size distribution (fig. 1). Fibers were also selected on the basis of their local availability and their traditional uses (flax straw and shive, hemp straw and shive, and traditional wheat straw and reed) (fig. 2).

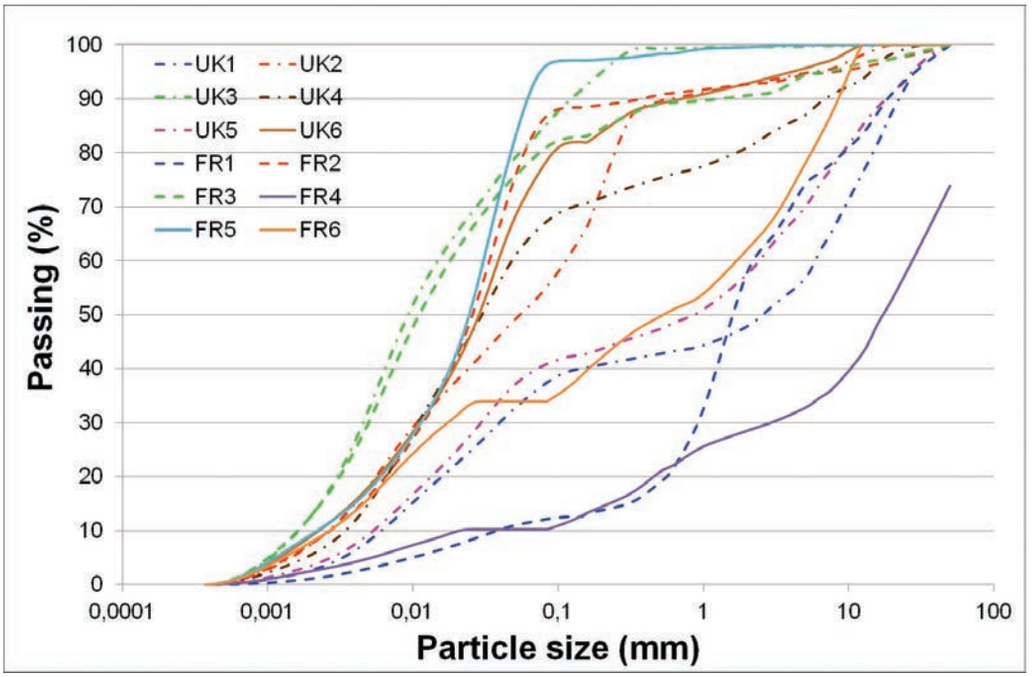


FIGURE 1 Soil particle size distribution. Illustration: Malo Le Guern, © ESITC Caen.



FIGURE 2 Six fibers from four plants. From left: reed, hemp straw, wheat straw, flax straw, flax shive, and hemp shive. Photo: Malo Le Guern, © ESITC Caen.

A first series of test blocks was made by professionals to produce the constituent mixes. These were made according to expert knowledge to determine a test protocol regarding the plasticity of a cob mix according to the fibers' nature and content. Scientists were thus able to replicate their laboratory test assays from there (fig. 3). The thermal characterization and compressive strength tests carried out on these blocks allowed the quick identification of the impossibility of obtaining a single mix that meets both mechanical and thermal performances. These results were subsequently verified by scientists (Goodhew et al. 2021), and professionals wondered how to combine a load-bearing mix, cob, and an insulating mix, light earth, to create a clayey slip with fibers such as straw or wood chips. The use of a formwork was necessary to mold the light earth. Norman formworks, which were designed with metal mesh skins to allow the cob to dry, were used to verify the technical feasibility and the cohesion of the dry mixes (fig. 4).

Cob, more efficient than the wheat straw used traditionally, is formulated with flax straw[7] dosed at 2% of the weight of dry earth, which makes it possible to obtain a mechanical resistance of 0.95 MPa to 1.5 MPa (Le Guern et al. 2018). The optimal formulation of light earth was a compromise between the mixture's thermal performance and the cohesion/mechanical strength of the mix. The goal was to ensure a simultaneous implementation of the two mixes and the cohesion of the two facings without other mechanical connections. This led to the development of a proportion of fibers[8] of 50% of the weight of



FIGURE 3 Fabrication of test blocks by French and English builders in the ESITC Caen laboratory. Photo: François Streiff, © PnrMCB.

dry earth, a slightly more dense and self-supporting cohesive mix (350 to 400 kg/m3). The simulations drawn from the results (Goodhew et al. 2021) define that for a 60 cm thick wall composed of 30 cm of cob and 30 cm of light earth, it was possible to achieve a U value of 0.26W/m²K that corresponded to the expectations of the UK, French, and a number of other thermal regulatory entities.

The Experimental Building: Questioning and Affirmation of Know-How

These first practical tests aligned with the results of the laboratory tests and constitute an encouraging basis to consider proposing this material as an alternative to conventional earth construction processes. A larger-scale step is necessary, however, to validate both the implementation process and its real performance. The construction of a full-scale prototype was started in Normandy at the end of 2019 (fig. 5). The modest project attempts to concentrate several constructive details that may confront builders, most of which are identical to those of traditional cob with regard to the load transfers of the roof and floor or the management of hooks.[9] Adaptations mainly concern the plinths and lintels due to the attention paid to thermal bridges.[10]

Traditional concrete formwork, made of aluminum, has been adapted by replacing the plywood with a mesh, thus making the Norman formwork lighter and more manageable. This modification helps to reduce the surface contact with the



FIGURE 4 First test block, built in Les Grands Ateliers by B. Little, EBUKI, and F. Streiff, PnrMCB. Photo: François Streiff, © PnrMCB.



FIGURE 5 3D simulation of the CobBauge prototype built in Normandy. Illustration: Raphaël Rattier, © PnrMCB.



FIGURE 6 Implementation of the two mixtures, cob and light earth, inside a main perforated formwork, with the help of a removable secondary formwork. Photo: François Streiff, © PnrMCB.



FIGURE 7 Implementation of the fourth lift of CobBauge using a digger. Photo: Raphaël Rattier, © ENSA Normandie.

cob and light earth mixture, allowing the earth to begin drying and hardening through the mesh (fig. 6).

The organization of the construction process itself was measured. The first results show a reduction of the implementation times between the first lift of the walls and the fifth lift by two, mainly due to the use of devices such as diggers (fig. 7). A cost analysis shows that it is possible to provide the insulation and the load-bearing wall for the same cost as a traditional cob wall if a local soil and hemp shives are used instead of reed.[11] Mixes produced by builders were monitored by ESITC (fig. 8) and demonstrated mix variability (Azil et al. 2021), which testifies to the necessary implementation of control during construction. These measures will create a life-cycle assessment (LCA) allowing for the verification of any reduction in CO_2 emissions.[12]

Moisture probes were used to measure the behavior of the walls, and first measurements seem to validate a traditional standard of a three-week drying time between cob lifts. Formworks affect drying only at their corner junctions, which increases the risk of cracking when a mixture subject to a lot of shrinkage is used or when forms are left in place for too long. These observations led us to test the use of wooden, metal, and geogrid brackets for horizontal reinforcements in corners. Considering the optimized thickness of the cob, which is lower than in traditional construction, metal and geogrid seem to give better results by avoiding the introduction of too much hyphenation on the horizontal plane.

Though this aspect was not considered in the initial project, these latest tests also open the discussion on the material's earthquake resistance. The devices required today by



FIGURE 8 Sampling of site mixtures by ESITC Caen researchers monitoring the building. Photo: Raphaël Rattier, © ENSA Normandie.

the various rules or standards on seismic stability of earthen construction (Minke 2001; Gomes, deBrito, and Lopes 2009) remain applicable with CobBauge.

A Contemporary Challenge as a Vector for Intensifying Training and Disseminating Skills

CobBauge studies and experiments open up many perspectives. The relationship established between the type of fiber and its mechanical strength makes it possible to imagine applications in terms of renovation/consolidation of historic structures. Training, an integral part of the project that has until now been based on the transmission of traditional know-how, can be enriched with new scientific information. The identification of know-how specific to CobBauge also feeds the work initiated at the European level on the validation of learning outcomes.[13]

Acknowledgments

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Notes

1 Source: Map of Earthen Heritage in the European Union, *Terra [In] cognita: Architectures de terre en Europe*.

2 The Norman Regional Nature Parks have set up technical and financial support for owners of earth buildings wishing to renovate them. Similar approaches have been implemented in other French regions, raising awareness of this heritage through exhibitions, publications, and training.

3 PnrMCB is a public structure working to preserve cob heritage since 1991. It technically supports and coordinates the network of earth builders.

4 The work done by the Cob Cottage Company in Oregon had a wide influence in the Anglo-Saxon world. In France, this influence was less strong. Cob was mainly rediscovered with the aim of preserving a devalued heritage and a forgotten knowledge.

5 Recent cob walls could be used as thermal mass walls behind glass facades or, as seen in the last building of Kevin McCabe, where cob is insulated from the outside. Other uses are to pair it with a cork insulation, as in Normandy. Many experiments have also been carried out on the mechanization of mixing and implementation by using devices and formworks to avoid paring the walls.

6 One of the themes tackled in the European project Cordiale focused on the preservation of landscapes in southwestern England and northwestern France, where cob use was typical. Comparative work on heritage, inventory, and awareness-raising approaches to cob enabled UoP and PnrMCB to share the use of traditional cob and its modern developments in both regions.

7 The use of hemp straw has been forsaken because of the size and strength of its fibers, which make mixing impossible. As the culture of flax in the UK is less important than in Normandy, the UK prototype uses traditional wheat straw (although the compressive strength is lower).

8 For light earth, crushed reed was chosen in France with a view to develop a local activity. As the reed resource is less known in the UK, hemp shives were chosen there. The thermal performance of the two materials is quite close.

9 These details are frequently illustrated in the English literature. They are also detailed in the French guides (CCTC 2018). The main difficulties lie in the use of formwork, which makes it difficult to use overhanging elements. The placement of load distribution plates must be anticipated in the formwork, and the placement of beams and joists must coordinate with the progression in height of the formwork.

10 A detailed compendium will combine English and French approaches of specific details.

11 The lack of a well-organized sector of reed harvesting and grinding contributes to purchase prices that are four times higher than for hemp shive.

12 These results are expected by the end of 2022 after the construction of two pilot buildings currently in the design phase.

13 The Pirate and Jump projects provide the framework for the assessment of learning outcomes on earthen construction and training for change.

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PART 15

Traditional Practices / Prácticas tradicionales

Safeguarding Authenticity of Intangible Heritage: Revitalizing Traditional Construction Technologies in the Middle East

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Abstract: *Traditional construction technologies are being lost in the Middle East, particularly in the Gulf region where modernization has been rapid and with little thought of preserving built vernacular traditions. One exception has been Yemen, a Middle Eastern hinterland where traditional construction technologies still thrive and the level of craftsmanship is high. However, even in Yemen, some technologies have not survived.* Qudad*, a form of burnished lime waterproofing made hydraulic with volcanic pumice, was recovered through trial and error by the team that restored al-ʾAmiriya in Radaʾ and is now used in lieu of cement as waterproofing throughout northern Yemen on important stone monuments bedded in mud mortar. In the Wadi Hadhramaut, the equivalent material applied as waterproofing to the stone foundations of mud brick tower houses is* ramad*, produced by mixing lime putty with wood ash. In addition to being forms of intangible heritage, traditional technologies are typically more compatible with historic masonry than modern materials. They tend to be labor-intensive occupations and, therefore, can also work toward a community's capacity building. The question is whether they can be revived in the Persian Gulf region. In Saudi Arabia, the typical response has been to import Pakistani craftspeople to preserve historic mud brick structures, but there is a tendency to experiment with modern materials as a way of prolonging the cycles between maintenance. These materials often do not work, and materials that are compatible with traditional construction, such as lime putty, are no longer readily available. While skilled Yemeni craftspeople could be hired to train workers, there is a genuine lack of interest among locals in pursuing a career in the building trades. Projects involving traditional technologies have an important role to play in safeguarding intangible and tangible heritage.*

Resumen: *Las técnicas de construcción tradicionales están en proceso de desaparición en el Oriente Medio, sobre todo en la región del Golfo, donde la modernización se produjo aceleradamente y no se pensó en preservar las tradiciones vernáculas de la construcción. Yemen fue una excepción, un remanso del Oriente Medio en el que todavía prosperan las técnicas de construcción tradicionales, siendo muy alto el nivel del trabajo artesanal. Sin embargo, incluso en Yemen desaparecieron algunas técnicas.* Qudad *es una forma de impermeabilización con cal bruñida que se vuelve hidráulica con piedra pómez volcánica. El equipo a cargo de restaurar el al-ʾAmiriya in Radaʾ recuperó esta técnica por medio del método de ensayo y error que ahora se utiliza en lugar del cemento en todo el norte de Yemen como método de impermeabilización de monumentos importantes. Además de ser una forma de patrimonio intangible, las técnicas tradicionales suelen ser más compatibles con la mampostería histórica que los materiales modernos e incluyen tareas que requieren mucha mano de obra, por lo que también pueden contribuir al desarrollo de las habilidades de una comunidad. La cuestión es si se pueden revivir en la región del Golfo Pérsico. En Arabia Saudita, la respuesta típica fue atraer a artesanos pakistaníes para conservar las estructuras históricas de adobe, pero existe una tendencia a experimentar con materiales modernos como forma de prolongar los plazos entre los ciclos de mantenimiento. Muchas veces, estos materiales no funcionan. Los materiales compatibles como la masilla de cal ya no se encuentran disponibles. Si bien se podría convocar a hábiles artesanos de Yemen para capacitar a los pobladores locales, estos demuestran una auténtica falta de interés por seguir un oficio en el sector de la construcción. Los proyectos que incluyen las técnicas tradicionales desempeñan un papel importante en la protección del patrimonio tangible e intangible.*

Keywords: authenticity, intangible heritage, lime plasters

Introduction

Since ancient times in the Middle East, construction technologies were developed suitable to local geography and climate. As seen from excavations, the earliest construction materials were lime plasters, rubble stone with earthen mortar, and mud bricks, either hand-shaped or made using wood molds. At Jericho, the aceramic village (4800 BCE) was constructed of hand-shaped mud bricks. Burnished lime plaster coated earthen floors, which continued up the walls (Kenyon 1957). At Tell Atchana, mud brick walls from the earliest occupation are whitewashed (Woolley 1955).

Many of these techniques prevailed into the twentieth century and some, where the traditional technology has survived or been reinvented, are still in use today. From the 1950s onward, however, there has been a loss of vernacular construction traditions, particularly in the Persian Gulf region, as nomadic, agricultural, and pearling economies gave way to those based on oil. With the influx of oil money, it became possible to ignore the local climate and build with modern materials. Vernacular architecture, which provided passive cooling and heating but required cyclical maintenance, was abandoned. With an impetus by Gulf countries to have World Heritage Sites, interest is growing in preserving what is left of traditional construction.

Conservation of Yemeni Traditional Construction

Traditional construction materials tend to be weaker than many modern materials; the latter are mostly incompatible with the former because they lead to the preferential deterioration of the original materials. For instance, cement has little place in traditional construction. It can introduce chlorides and is much more rigid and inflexible, and its pores are small, contributing to the intake of moisture into adjacent connected materials but not to evaporation.

In Yemen, where traditional construction technologies are still practiced, cement was first introduced in the 1930s, but did not find widespread application until the 1990s. As a result, some traditional technologies used for waterproofing, like *qudad* and *ramad*, were lost. Both are lime putty–based plasters, which are burnished in labor-intensive applications.

However, the ability to produce high-quality lime putty persisted. In northern Yemen, a seismically active region, there is abundant *hashash* (volcanic-pumice aggregate). When combined with *nura* (lime putty), the fines cause a hydraulic set and qudad (a durable plaster) is formed after burnishing.



FIGURE 1 Al-ʾAmiriya in Radaʾ, Yemen, following completion of restoration in 2005. All photos: P. Jerome.

An early example is found at the ancient Marib Dam, dating to the eighth century BCE, where the last phase of rebuilding occurred in the fifth century BCE (al-Radi 1997). Yemenis understood the hydraulic properties of combining reactive aggregates, or pozzolans, with lime putty perhaps even before the Romans. Burnished lime plasters can be found across the Indian Ocean route, from the stuccoed coral-stone houses of Zanzibar (al-Radi 1997) to the roof of the Chausath Khamba tomb in Hazrat Nizamuddin Basti of New Delhi, India.[1]

The rediscovery of the qudad technique was accomplished by trial and error at al-ʾAmiriya, a sixteenth-century mosque and madrasa (1504 CE) in Radaʾ, Yemen, restored from 1985 to 2005 (fig. 1). Qudad has a 500-year service life and the building still had its original failing coating. Patches and crack repairs made with cement-based mortars unsuccessfully prevented water ingress to the painted domed ceilings (al-Radi, Nardi, and Zizola 2005).

When al-ʾAmiriya's restoration began, the building had structural issues from the loss of earthen mortar bedding the rubble stone. A *ʿusta* (master mason) supervised the stone stabilization. Attention was focused on re-creating the qudad rendering, although none of the older masons recalled the proportions of the mix. Through experimentation, the correct mixture was achieved.

According to Yemeni preservation architect Abdullah Hadrami, the proportions depend on the slaked lime's quality.[2] For al-ʾAmiriya, the lime was slaked for two weeks, and for finer work, two to three months. At al-ʾAmiriya, one part lime putty was mixed with two parts aggregate and pounded



FIGURE 2 Preparation of the qudad mix at al-ʾAmiriya.



FIGURE 3 Pounding qudad waterproofing on the roof of the new ablution building for the Grand Mosque of Shibam Cocoban, Yemen.

together, crushing the aggregate to the size required (fig. 2) (al-Radi 1997). The lime putty must first be cleaned of lumps of partially fired limestone so that it is smooth, per Hadrami, and has a *lebna* (strained yogurt) consistency. Lower layers utilize larger aggregate the size of corn kernels. For the middle layers at al-ʾAmiriya, the ratio changed from one part lime putty to one part finer-sized aggregate, and at the uppermost layers, two parts lime putty was mixed with one part very fine aggregate (al-Radi 1997).

The substrate has to be prepared to receive qudad. If it is a roof, part of the temporary earthen plaster surface is removed and the remaining material is manually compacted using a 10 kg iron cylinder. A 6 cm layer of *midhar* (medium-size rounded river pebbles) is placed on the prepared surface. Prior to applying qudad, these stones are dampened so that water is not absorbed from the mix, causing an improper cure. A 2 m^2 area is worked at a time. The first layer of qudad is applied in a 5 cm thick layer and beaten with flat, palm-size, sharp-edged stones for a day until it dries. This layer is left rough to provide a key. The next layer is also applied 5 cm thick and beaten for a day until it dries. This continues for three or four layers (fig. 3). At al-ʾAmiriya, the final thickness of the roof qudad was 12.5–15 cm, whereas exterior facades required 10 cm and protected interior courtyard facades only 5 cm. In addition, each layer is kept moist with limewash, per Hadrami.

The final stage is to burnish the qudad repeatedly using *rashah* (limewash) and a smooth, rounded river pebble. The burnishing is kept up until the qudad takes on a marble-like finish and no more hairline cracks appear. The polishing is done day after day at first, then repeated weekly. When ready, *n'ukh* (boiled bone-marrow animal fat) is applied with a rag to polish the qudad. This improves its waterproofing abilities (al-Radi 1997) as animal fat is a saponin and adding a primitive soap to lime causes calcium stearate and related compounds to precipitate, enhancing water repellency (Jerome, Chiari, and Borelli 1999). If unburnt or partially fired limestone nuggets are present near the surface when the animal fat is applied, they explode and create holes in the qudad (al-Radi 1997).

The application of qudad is more difficult on vertical surfaces. The wall is dampened and cleaned and the joints raked out for mechanical keying. Qudad is hurled with force until it begins to stick to the joints and stays on the wall surface. It is then worked through, pounding layer upon layer, until the desired thickness is achieved (al-Radi 1997). The process is labor-intensive, and the result is a superior waterproofing that, with regular maintenance, is purported to last 500 years. The conservation activity undertaken at al-ʾAmiriya has led to the qudad's reintroduction and use on monuments undergoing restoration in northern Yemen. This ancient technology was the typical waterproofing for cisterns in the past. The qudad restoration of the cistern at Thula's historic fort, under the direction of Abdullah Hadrami, is an example.

In the Hadhramaut, where volcanic pumice is not available, a similar exterior ramad (burnished lime waterproofing) was achieved by adding wood ash to lime putty (Jerome 2006). According to *muʾallim* (master mason) Salim Awadh Muswaniq of Shibam, the proportion of ramad is one part lime putty to one part wood ash (Jerome, Chiari, and Borelli



FIGURE 4 Restored Shibami tower house, with the ground floor converted into a shop. The battered stone base is waterproofed with ramad.

1999). The ten-year Shibam Urban Development Project (2000–2010), a collaboration of Deutsche Gesellschaft für Internationale Zusammenarbeit (GTZ, now GIZ) and the General Organization for the Preservation of Historic Cities in Yemen (GOPHCY), used restoration to improve economic conditions at the World Heritage Site of Shibam by organizing the masons to repair its iconic mud brick tower houses (fig. 4). Project director Omar Abdulaziz al-Hallaj noted that convincing the masons to use ramad rather than cement for the stone foundations of Shibami mud brick buildings was simple when put to them in economic terms. Cement is expensive and takes very little labor to apply; ramad's raw materials cost little, but because of the repeated applications and burnishing, its application is labor-intensive. They opted to utilize ramad because they made more money.[3]

In addition to the excellent craftsmanship in lime, there remain abundant masons who still build tower houses with *madhar* (mud bricks) in southern Yemen, and with *medmac* (cob) in northern Yemen. Highly skilled carpenters produce decorative windows and doors, interior columns, and cabinetry. In Yemen, traditional building crafts are alive and well.

Authenticity of Intangible Heritage

The continuity of traditional construction technologies from ancient times through the present in Yemen is a remarkable feat of intangible heritage. The same is not true for the Middle East's Gulf region, where there is a lack of local artisans who



FIGURE 5 Elastomeric paints are incompatible with earthen plaster, as seen in this example in al-Ghat, Saudi Arabia.

are knowledgeable in traditional construction materials. In Saudi Arabia, the preservation of vernacular construction is almost exclusively performed by foreigners, typically Pakistani craftspeople. However, the materials they have used in Saudi Arabia are questionable and incompatible.

At the site of al-Ghat, an abandoned mud brick village in Saudi Arabia that is being converted into a heritage destination, elastomeric paint coats earthen plaster on restored buildings. The paint film is peeling and unsightly (fig. 5). Vapor transmission must remain unimpeded for materials to be compatible. The author also saw drums of silicone concrete-formwork release. When the Pakistani foreman was asked, he responded that the silicone was used as a waterproof coating for earthen plaster to prolong maintenance cycles. There have been over fifty years of experimentation with chemical applications to earthen mud plasters and mud brick construction (Hurd and Jerome 2010) and with perhaps the exception of ethyl silicate, most have caused more damage than good.

In the Najran province of Saudi Arabia bordering Yemen, examples of medmac buildings are still present, albeit not necessarily inhabited. These are small clusters of farm buildings, as the urban areas have been rebuilt with concrete. Repairs that do occur are executed by Yemenis who have immigrated to the region.

In the city of Najran, the Emara Palace has been restored as its centerpiece. The historic medmac structure contains sixty-five rooms and was the former seat of government. When touring the interior, the author saw evidence of leakage through the mud roofs despite the building's recent restoration. A closer review of the roofs revealed a loose, single-ply EPDM membrane laid under the top few centimeters of soil. Wherever exposed, it was compromised with holes, probably due to UV exposure, thereby allowing moisture to be trapped under the membrane (Jerome and al-Aidaroos 2018). In addition, the vulnerable areas of the roof (base flashings and parapets), which would have traditionally been coated with lime putty–based renderings, were instead coated with what appeared to be white cement-based plaster (or perhaps hydrated lime); this was also the case in al-Ghat. The plaster is no longer adhered to the wall surfaces, permitting moisture ingress.

In order for materials to be compatible, two things must occur: vapor transmission cannot be impeded, and thermal expansion and contraction must be similar. Lime has large pores and therefore readily permits water vapor transmission. It is also less rigid in terms of thermal expansion/contraction. It is extremely compatible with both earthen and stone substrates and provides protection from the weather. From the author's several visits to various areas in Saudi Arabia, it is obvious that the tradition of lime putty manufacturing and usage has been lost. Even more problematic is the fact that few locals appear to be interested in learning how to make and apply these labor-intensive materials.

Conclusion

Instead of trying to find a modern "magic bullet" that will prolong the service life of traditional materials, projects involved with the restoration and/or partial reconstruction of vernacular heritage should be considered an opportunity to revive traditional crafts. At the World Heritage Site of al-Dir'iyah, near Riyadh, some of the cultural significance derives from the fact that the site, the first Saud state, was destroyed by the Ottomans. The site carries significance because it is a ruin (Jerome, al-Aidaroos, and Hurd 2016). This type of site should not be reconstructed (fig. 6), and the same applies for archaeological sites.



FIGURE 6 Al-Dir'iyah, an archaeological World Heritage Site near Riyadh, Saudi Arabia, was reconstructed despite expert advice to the contrary.

On the other hand, buildings that can be reused, either for their original purpose or through adaptation, can be restored or even reconstructed. Depending on how well this is done and the use of original construction technologies for the work, authenticity of intangible heritage can be achieved. The *Nara Document on Authenticity* (ICOMOS 1994) has taught us to recognize that concepts of authenticity vary from culture to culture. Authenticity does not lie only in the original fabric. This is fine for heritage sites of monumental stonework, but the same standards cannot apply to heritage constructed of ephemeral materials like wood and earth.[4]

Furthermore, the *Nara + 20* document takes authenticity in practice one step further by promulgating:

- The need to recognize the diversity of heritage practices;
- Understanding that heritage values evolve through time;
- Acknowledging the rights and responsibilities of multiple stakeholder groups;
- Addressing heritage conflicts and conflicting interpretations;
- Integrating principles of sustainable development into heritage practice. (ICOMOS 2014)

By reviving traditional building crafts, intangible heritage survives. The knowledge of these tried-and-true building systems, perfectly suited to their environment and geographical locale,

took years to evolve and be adapted as suitable technologies. The lesson learned from the vernacular is that it is the most sustainable form of architecture. Designed and erected by masons and carpenters, as opposed to diploma-carrying architects and engineers, it is the proven method of passively providing climate-controlled interiors. This is exactly what has been forgotten in the rush to modernize. Therefore, any projects that involve the revival of traditional construction technologies should be viewed in light of their ability to safeguard intangible and tangible heritage.

Notes

1 Personal communication with Stuart Tapin, structural engineering consultant to the Aga Khan Trust for Culture for the Nizamuddin Basti Urban Renewal Initiative, October 2013.

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4 Stone is formed under tremendous pressure and/or through chemical processes deep within the earth into igneous, sedimentary, or metamorphic rock. It is more durable than earthen materials, which are barely transformed from their original state, basically water, soil, and chopped straw (and sometimes dung or lime are added to increase durability).

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Conservation of Traditional Settlements in the Himalaya: The Case of Leh Old Town

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Abstract: *In recent decades, the conflicting needs of urban development and the conservation of historic architecture have created different gradations and meanings in architectural preservation in Asia. Often the decisions that prioritize economic development are made so quickly that there is no time to create adequate conservation plans for historical sites, resulting in the loss of authentic buildings and spaces and their heritage value. This paper presents the work of the Tibet Heritage Fund (THF) as a conservation approach to historic urban sites in Asia, focusing on the Old Town of Leh, Ladakh, and suggests how living architectural forms can be adapted without losing their heritage or economic values. This approach emphasizes the participation of residents and the community as a means of ensuring the success of conservation initiatives. The paper shows that involvement of local craftspeople trained in local building technologies is essential and that preservation and renewal of these traditions are key to architectural conservation. Ideally, for conservation interventions to be successful, the local government, community, craftspeople, and conservation experts need to work together.*

Resumen: *En las últimas décadas, las necesidades conflictivas del desarrollo urbano y la conservación de la arquitectura histórica han creado diferentes escalas y significados en la salvaguardia patrimonial en Asia. A menudo, las decisiones que priorizan el desarrollo económico se toman tan rápido que no hay tiempo de crear planes de preservación adecuados para los sitios históricos, lo que ocasiona la pérdida de edificios y espacios auténticos, y su valor patrimonial. Este artículo presenta el trabajo de Tibet Heritage Fund como un enfoque de conservación en torno a las urbanizaciones históricas de Asia, con énfasis en el antiguo pueblo de Leh, Ladakh, y sugiere cómo las formas arquitectónicas habitadas se pueden adaptar sin perder su valor patrimonial ni económico. Este enfoque destaca la participación de los residentes y la comunidad como medio para garantizar el éxito de las iniciativas de conservación. El artículo muestra que la participación de los artesanos locales capacitados en tecnologías de construcción local es clave, y que la permanencia y actualización de estas tradiciones son esenciales para la conservación arquitectónica. Para que las intervenciones sean exitosas, el gobierno local, la comunidad, los artesanos y los expertos necesitan trabajar juntos.*

Keywords: conservation, living architecture, inhabitants, Ladakh

Introduction

In the past two decades, Asia has seen rapid development that has left people little time and space to understand how these changes will impact their lives, lifestyle, and culture. Often the decisions that prioritize economic development are made so quickly that there is no time to create adequate conservation plans for historical sites, resulting in the loss of buildings and their heritage value.

Communities often face the dilemma of choosing between maintaining traditional ways or embracing new technologies and lifestyles. In the case of new construction, there is frequently not enough information available for the general public to evaluate and make informed decisions about issues such as quality, benefits, hidden costs, environmental impact, building maintenance, safety, and the life span of materials. Decisions then tend to be made solely on a financial basis according to considerations of cost and profit.

Tibet Heritage Fund (THF) has been working in the field of cultural heritage conservation since 1996, and our team is one of the leading sources of expertise in the region. In Ladakh, THF works with its local branch, Leh Old Town Initiative (LOTI), registered as an NGO in India since 2006. The core of this work, Leh Old Town Conservation Project, is to preserve the entire historic town of Leh. Over the past fifteen years, THF/LOTI has restored more than sixty historic houses, monuments, and religious buildings, including the Central Asian Museum Leh. The group has worked to improve infrastructure with projects such as the installation of water taps, improved drainage, and renewed street paving with slate stone (fig. 1).

Geographic and Historical Background

The Union Territory of Ladakh (capital: Leh) is in the far north of India, bordering both Pakistan and China. With an average altitude of over 3000 m above sea level, the region has an extremely dry climate, strong sunlight, and large seasonal temperature variations. It is sometimes described as a cold desert.

Leh became a royal domain in the early fifteenth century and, during the reign of King Senge Namgyal (r. 1624–42), for whom the Lachen Pelkhar palace was built, became the royal capital. The king is said to have invited leading Ladakhi families from the surrounding areas to settle within the fortified town below the palace, and remnants of the city walls from that time can still be seen. From the mid-nineteenth century, when the Namgyal dynasty and Ladakh's independence ended, Leh was transformed from a royal seat into a commercial town. It only officially became a city in 2005 and is still expanding; today the urban district has about 43,000 inhabitants.

Conservation Strategy

The strategy for preserving vernacular architecture and settlements developed by THF through its work in Lhasa in the 1990s was applied in the Leh Old Town Conservation Project as follows.

Architectural Survey and Documentation

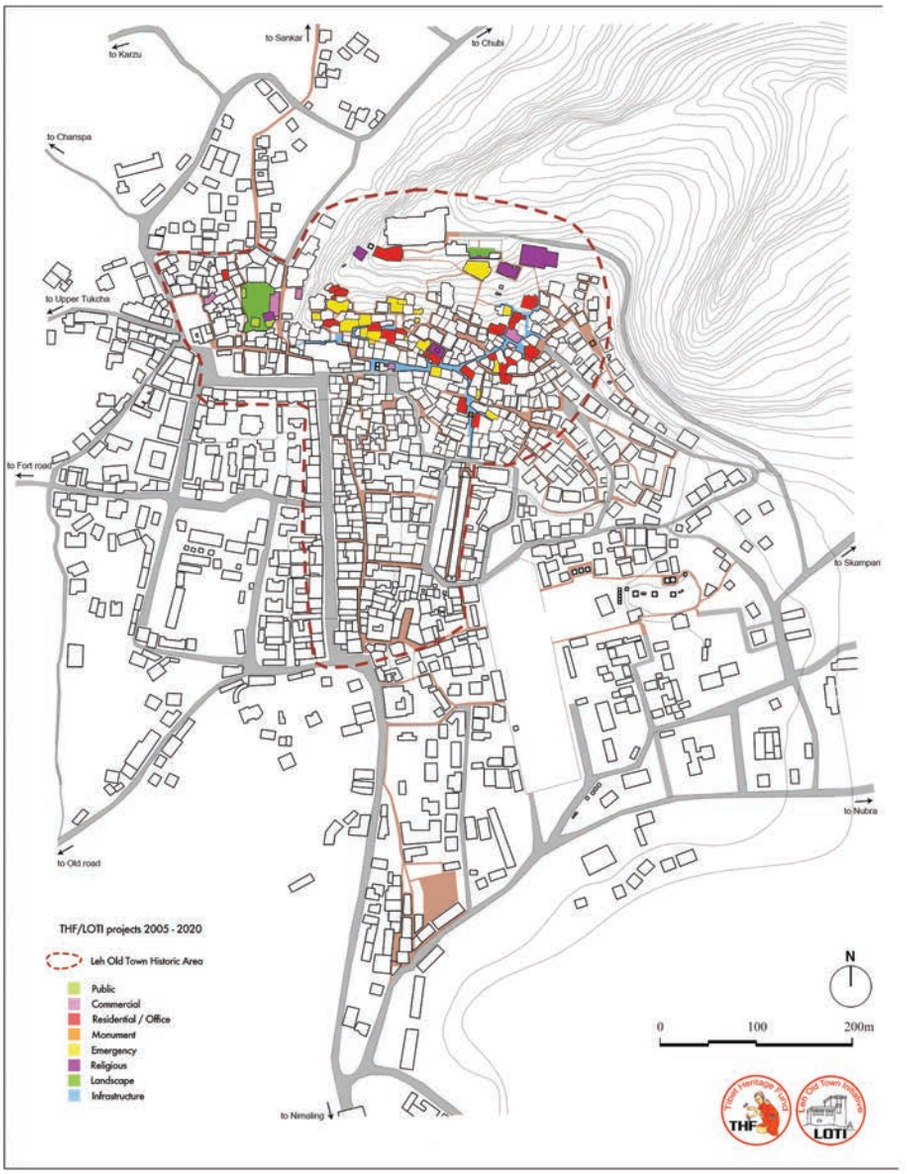
Surveys and documentation in the form of maps, drawings, interviews, photos, and research provide the groundwork for project planning and implementation as well as a record of the architectural features and interiors for posterity. We have surveyed approximately 80% of the existing traditional structures in Leh Old Town to date. While several of these houses have collapsed or been replaced, there are about 150 buildings still standing today. We also organize heritage walks and talks to share memories of the town as a way for locals and tourists to discover and understand its history and built heritage.

Restoration of Historic Buildings/Monuments[1]

Since the concept of conservation and restoration as they are understood in the West was new, and due to the fast development of the region, THF/LOTI developed a cofinancing system for the restoration and rehabilitation of the houses where the homeowner or long-term tenant contributes 50% of the costs for renovation. This can be paid in material or labor by those lacking financial means. Poor families unable to contribute (e.g., single mothers or elderly people) are exempted.

We create cluster zones of repaired buildings that the residents are proud of, and these become examples for others who may be interested in repairing their houses. We also carry out emergency repairs and upgrades in many old houses (e.g., leaking roofs, broken windows, collapsing walls) to maintain the buildings and prevent replacement by new construction (fig. 2).

The results of these projects created awareness within the community and, through THF/LOTI, residents were able to access both the skills and financial means to repair their homes as well as understand the value of their houses as cultural heritage. Since people do not always value things that are available for free, the cofinancing system gives



S.N.	Building name	Year	Use
1.	Sofi House	2005 - 2006	Residential
2.	Choldey House	2005 - 2006 / 2017	Residential
3.	Hanupa House	2005 - 2007 / 2017	Residential
4.	Norchun House	2005 - 2007	Residential
5.	Red Mitreya Temple	2005 - 2006	Religious
6.	Chenrenzig Temple	2005	Religious
7.	Lonpo House	2005	Office
8.	Leh Guru Lhakhang	2005 - 2006	Religious
9.	Lakruk House	2005 - 2006 / 2017	Residential / Office
10.	Hor Yarkandi House	2005 - 2006	Residential
11.	Stago Philok Street (92m)	2005	Infrastructure
12.	Gonpa Soma Courtyard	2006	Religious / Landscape
13.	Sankar Labrang House	2006	Commercial
14.	Nagso House	2006	Emergency
15.	Stago Philok Stupa Gate	2006 / 2019	Monument
16.	Mani Khang Area (55m)	2007 - 2009	Infrastructure
17.	Masjid Sharif	2007	Religious
18.	Gotal House	2008	Commercial
19.	Tehsidar Haveli Gate	2008	Monument
20.	Rupshu Goba House	2008 - 2009	Emergency
21.	Hor Tsering House	2008	Emergency
22.	Central Asian Museum Leh	2008 - 2015	Public / Landscape
23.	Dolma House	2009 / 2017	Residential
24.	Roqia Bano House (east)	2009 / 2017	Residential / Office
25.	Roqia Bano House (west)	2010	Residential
26.	Khargokpa House	2010 / 2017	Residential
27.	Kawoo House	2010 - 2012	Commercial
28.	White Mitreya Temple	2010	Religious
29.	Ama-Yangchen House	2010-2011	Residential
30.	Ama-Yeshi House	2011 / 2016	Residential
31.	Lhaba House	2012 - 2013	Residential
32.	Akbar House (south)	2013	Residential
33.	Zarokpa House	2013	Commercial
34.	Thagan House	2012 - 2016	Residential
35.	Stalam Street (282m)	2012 - 2013	Infrastructure
36.	Stago Philok Alley (23m)	2013	Infrastructure
37.	Stalam Alley (17m)	2013	Infrastructure
38.	Gogsum Street (56m)	2013	Infrastructure
39.	Ladakhi Kitchen Museum	2013 - 2014	Public
40.	Denjong-pa House	2014 - 2015	Emargency
41.	Lakruk House (north)	2014 - 2015	Residential
42.	Bakery Building (Museum)	2014 - 2015	Commercial / Office
43.	Lhaba Yangchen House	2014	Residential
44.	Akbar House (north)	2014	Residential
45.	Seli House	2015	Emergency
46.	Kushu House	2015 - 2016	Residential / Office
47.	Dzomskit House	2015 - 2016	Residential / Office
48.	Onpo House	2016 - 2017	Residential / Office
49.	Gotal Murup House	2016 - 2017	Residential
50.	Tsering Langtang House	2016	Emergency
51.	Choklung House	2017	Emergency
52.	Chagon House	2017	Emergency
53.	Khangsar House	2017	Emergency
54.	Spon House	2017	Emergency
55.	Nomochok House	2017	Residential
56.	Tarchid House	2017	Emergency
57.	Tarchid Nangso House	2017	Emergency
58.	Mahey House	2017	Residential
59.	Sergar House	2017	Emergency
60.	Tsangspa House	2017	Emergency
61.	Kacho House	2017	Emergency
62.	Lower Kharyok Street (72m)	2017	Infrastructure
63.	Kalmak House	2017 - 2018	Residential / Office
64.	Bijal House	2017	Emergency
65.	Gotal Rigzin House	2018 - 2019	Residential / Office
66.	East Stupa Gate	2018 - 2019	Monument
67.	Shangara House (west)	2018	Residential
68.	Bailay House	2019 - 2021	Redidential
69.	Stalam Alley (20m)	2020	Infrastructure
70.	West Stupa Gate	2020 - 2021	Monument
71.	Rigsum Gonpo Stupa	2020 - 2021	Monument

FIGURE 1 THF/LOTI conservation projects in Leh Old Town, 2005–2020. Map: Yutaka Hirako, courtesy of Tibet Heritage Fund.

responsibility to the owners and tenants to maintain and care for their houses. We have restored over sixty buildings, and the impact on the town is visible and is influencing projects in rural areas as well.

Mural Restoration and Conservation Training

In addition to preserving religious buildings, THF also preserves their wall paintings, spreading awareness of the possibility of saving these valuable treasures instead of repainting them.

THF brought in a qualified team of wall paintings conservators to work on projects in Ladakh and, at the same time, to help us train local people in conservation. We have preserved ancient murals in three temples and one Stupa gate in Leh.

Training in Traditional Building Skills

Preserving the skills, materials, and techniques used to construct traditional buildings is fundamental to sustaining both traditional architecture and the development of modern structures. In addition to our day-to-day training work, we set up the Artisans, Artists, Architects House (AAAH) as a platform to preserve, develop, and continue the building and craft traditions.



FIGURE 2 Restored historic Kushu house (left) and Dzomskit house (right) below the Leh Palace. Photo: Yutaka Hirako.

Promotion of Vernacular Architectural Style and Natural Construction Materials

Part of our strategy is to promote the use of vernacular styles and materials in new buildings while improving older structures to better withstand climate change. The Central Asian Museum Leh is a good example of this (fig. 3).

Water and Sanitation

We implement water and sanitation projects to improve conditions for the residents and the community by installing water pipes, building drains, and paving alleys (a total of 617 m so far). Community members' participation is important to understand their needs and to properly maintain public spaces.

Public Space Design and Renovation Planning

There are spaces in Leh Old Town that have lost their function and have become rubbish dumps or dead ends. We study these and design ways that the community can make the spaces useful again. Prominent examples include the Gonpa Soma courtyard, where monastic mask dances are performed, and the Tsas-soma garden in the museum complex.

Case Studies

In this paper, we present five case studies of approaches that were used at different sites in Leh, as described below:

- Tehsildar monument: we followed a conservation approach, keeping the original as much as possible with minimum intervention;
- Gotal house: we followed a restoration approach, and the facade was restored to its original condition while minor modifications were made to bring more light and warmth into the building;
- Kushu house: we used the rehabilitation approach, strengthening the weak structure and improving facilities for the family;
- Zalok-pa house: we used the adaptive reuse approach as it was necessary to rearrange the interior space, changing the building's function from residential to commercial;
- Stalam Street upgrade project: we improved water and sanitation to create a comfortable environment for the residents.



FIGURE 3 THF/LOTI team members in front of the Central Asian Museum Leh. Photo: Yutaka Hirako.

These projects were innovative, updating the general approach of replacing traditional houses with concrete structures. They set examples of how traditional houses can be adapted to modern times while preserving their heritage value and

contributing to tourism, which now dominates the local economy.

Tehsildar Haveli Gate: Monument Conservation

Leh had city walls and entrance gates when it was a royal capital. Many gates have since disappeared, along with most sections of the old city walls. The local community requested that THF/LOTI help in preserving the Tehsildar Haveli Gate in Naushar Bazaar. The wooden gate, with its rich carvings, was built in the 1840s in the Mughal style by the representative of the Maharaja of Jammu. Two German wood conservators, along with the local team, carefully cleaned all the surviving elements, replaced missing areas, reinforced the entire structure, and constructed a new, waterproof roof. This project used a pure-conservation approach so as to preserve the original and made only essential interventions.

Gotal House: Restoration

The Gotal house is one of the large historic buildings preserved in the Old Town. While the facade was restored to its original condition, minor modifications were made to bring more light and warmth into the building. The roofs were waterproofed and improved with natural, traditional materials, the parapet was reconstructed with slate stone, and skylights were added to allow more natural light. Most of the space and layout were kept in their original configurations. Interior walls were replastered with dust-free *gobri*[2] and the kitchen area was carefully restored, keeping the original wooden elements and clay stove intact (fig. 4). A washing room was added to improve the service area.



FIGURE 4 The traditional Ladakhi kitchen at Gotal house after restoration. Photo courtesy of THF.



FIGURE 5 The summer kitchen at Kushu house after restoration, with improved natural light from the skylight and lightwell. Photo: Yutaka Hirako.

This project used a restoration approach that respected the original facade, layout, and important elements while introducing minor improvements.

Kushu House: Rehabilitation

Kushu house is a medium-size, three-story building in the Kharyok area, below the palace. Due to decades of abandonment, the building was in poor condition and required intensive renovation work. The collapsed western part of the building was reconstructed and adapted with new lattice windows and railings. Light wells were installed to bring adequate natural light into dark rooms. We also conserved the original clay stoves in the winter and summer kitchens (fig. 5), designed new spaces in the building such as a glazed sitting room and home library, introduced a modern kitchen and bathroom with running water, and fixed the electrical wiring inside of the walls.

This rehabilitation approach can be applied to historic buildings in dilapidated conditions that require major structural work for the safety of residents. In such cases, we can consider rearrangement of the space and improvement of facilities to increase comfort.

Zalok-pa House: Adaptive Reuse

Zalok-pa house is a small two-story house in Zangsti area, at the western end of the Old Town. The current owner approached THF/LOTI to repair her house and improve the space to accommodate a café shop and provide a residential space for the family.



FIGURE 6 Zalok-pa house after renovation. A balcony, *yaps,* was created on top of the original building. Photo: Yutaka Hirako.

In order to change the building's function from residential to commercial, it was necessary to rearrange the original space. It was decided, however, to keep the original two-story facade intact, adding a new balcony on the rooftop terrace (fig. 6). The ground floor originally consisted of four small rooms partitioned for different domestic animals and granaries, and we rearranged the space into two rooms: a bedroom and a living room for the family.

The small rooms on the first floor were made into a shop space by removing the partition walls and erecting a pillar-bracket structure in their place. A dry toilet was built in a corner and a skylight opening was placed above the kitchen counter. A wooden staircase was built for access to the rooftop terrace.

This project used the adaptive reuse approach, rearranging the original space and building additional structures to accommodate commercial usage. This approach should be carefully planned, and it can only be recommended for abandoned historic houses. In keeping with its original character, Leh Old Town should remain a principally residential area rather than be completely converted to commercial and touristic use.

Stalam Street Upgrade: Historic Townscape / Hygiene Improvement

Stalam Street, one of the main streets in the Old Town with many intact historic houses, is an important area in the conservation strategy. THF/LOTI improved Stalam Street with drain gutters and slate paving (fig. 7). This project achieved positive impacts: a proper drain line for gray-water disposal, and a well-paved street that leads to Leh Palace and has become a popular walk for tourists as well as locals.

Stalam connects to Manikhang and Stagophilok, other streets that THF/LOTI had previously upgraded. We recommended paving all the streets and alleys of the Old Town with slate stone to keep the town clean, free of drain water, and easily navigable.



FIGURE 7 Stalam Street upgrading work, showing the drain gutter and paved street with slate stone. Photo courtesy of THF.

Leh Old Town and Heritage Zone Protection

Leh Old Town has no conservation regulations or guidelines and only the seventeenth-century palace falls into the category of protected buildings.

The Archaeological Survey of India (ASI) maintains and protects listed structures and, while there has been increasing awareness in recent decades of the value of Leh Old Town by the public, tourism industry, and government bodies, there are no legal regulations or guidelines in place yet.

THF/LOTI has organized symposiums, discussions, and public talks with local communities, the general public, NGOs, scholars, and the government to raise awareness and move forward with guidelines and to create a Heritage Zone and Buffer Zone for Leh Old Town (fig. 8). Proposals for regulations and guidelines have been continuously submitted to Ladakh's administrative and government bodies.

In March 2021, we proposed the Framework for Leh Old Town Heritage Management System to the administration of

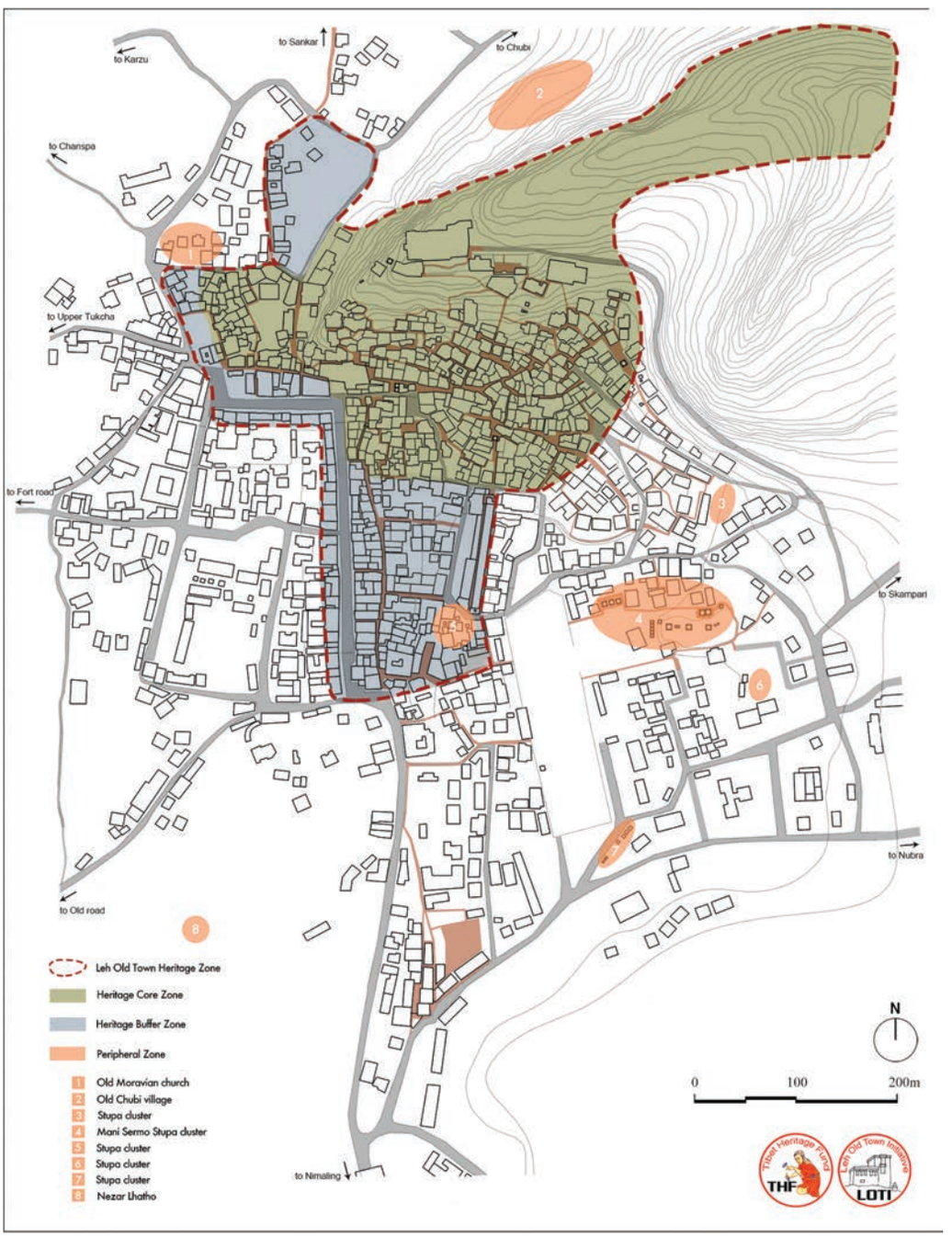


FIGURE 8 Leh Old Town Heritage Zone, proposed by THF/LOTI to the local authorities. Map by Yutaka Hirako courtesy of THF.

the Ladakh Union Territory. This framework consists of creating a Heritage Cell inside the government to provide loans to the owners of historic houses for their restoration.

Conclusion

Although conservation and restoration projects like ours help to preserve the architectural heritage and the living culture of Ladakh, these efforts need to be consolidated by the support of the government.

The results of our projects in Leh Old Town have had an impact on local approaches to conservation and restoration. Although we propose that the area remain residential, houses restored by non-resident owners can be rented out or redesignated as galleries, cafés, and craft centers. Heavy commercialization is a threat to living heritage, the keyword for a community-based conservation approach and the sustainability of historic towns. We are now at a threshold where decisions need to be made for the future of this well-preserved Himalayan town.

Notes

1 This umbrella includes the conservation, restoration, or rehabilitation of vernacular architecture, religious buildings, and monuments.

2 *Gobri* is a wall finishing technique for making a flat plaster surface. We use the locally available sedimentary clay near the Indus riverbank, called *markalak*, or "buttery clay." The clay is soaked overnight to make a paste and then mixed with a certain proportion of river sand as fine aggregate. The plasterer splashes the liquid on the wall and spreads it with a trowel to create a fine finish layer.

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Transmisión del patrimonio construido en tierra: Prácticas indígenas guaraní en el Brasil contemporáneo

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Resumen: *Este artículo analiza la manera en que los guaraní de dos tierras indígenas del litoral brasileño piensan, viven, construyen y transmiten su patrimonio material e inmaterial. Se dejará evidencia de cómo las culturas constructivas locales reflejan una relación singular del ser humano con la Tierra, específicamente, mediante un elemento de la arquitectura vernácula, la casa de rezo (*opy*). Hecha de madera y tierra, la* opy *es considerada el centro de la comunidad, como lugar donde se practican la cohesión social, la gobernanza, la transmisión del saber colectivo, así como la conexión con el medio ambiente y sus elementos. Basándonos en observaciones y entrevistas realizadas en campo, así como en cartografías y levantamientos arquitectónicos propios, mostraremos cómo su arquitectura, materiales y técnicas constructivas utilizadas revelan una concepción multiescalar del mundo. Además, en la tradición guaraní, la* opy *no pasa necesariamente por un proceso de mantenimiento preventivo, sino por reconstrucciones periódicas. Este aspecto se debe a un proceso cultural histórico propio, que esclareceremos en el artículo. En estas ocasiones la obra comunitaria se constituye como un lugar social de transmisión, mediante la práctica del patrimonio material e inmaterial. El saber y el saber-hacer colectivo pasan así a ser la herramienta principal de transmisión del patrimonio inmaterial y de perpetuación del patrimonio material. Trataremos de resaltar cómo el patrimonio material e inmaterial se vuelven medios de resistencia cultural y territorial, haciéndose indispensables para el mantenimiento del modo de vida guaraní en nuestra contemporaneidad.*

Abstract: *This article analyzes the way in which the Guaraní of two Indigenous territories along the Brazilian coast think, live, build, and pass on their tangible and intangible heritage. It will show how local building cultures reflect a unique relationship between human beings and the earth, specifically through an element of vernacular architecture, the house of prayer (*opy*). Made of wood and earth, the* opy *is considered the center of the community, a place that supports social cohesion, governance, and the transmission of collective knowledge, as well as a connection with the environment and its elements. Based on observations and interviews carried out in the field, as well as maps and architectural surveys of our own, we will show how the architecture, construction materials, and techniques used reveal a multiscale conception of the world. Furthermore, in the Guaraní tradition, the* opy *is not necessarily subject to preventive maintenance but, rather, goes through periodic reconstruction. This is due to its own historical and cultural process, which we will clarify in the article. As part of this process, the community work becomes a social space where tangible and intangible heritage is passed on through practice. Collective knowledge and know-how thus becomes the main tool for passing on intangible heritage and perpetuating tangible heritage. We will attempt to highlight how tangible and intangible heritage becomes a tool for cultural and territorial resilience, an essential aspect for maintaining the Guaraní way of life in our contemporary society.*

Palabras clave: territorio, cultura constructiva guaraní, transmisión, cosmología

Introducción

El patrimonio material está profundamente vinculado al patrimonio inmaterial. Materializa una relación social con el territorio, con el cual el ser humano convive. En Brasil, las montañas, los ríos y los valles son parte integrante de la cultura de cada pueblo. Sus nombres evidencian la geografía cultural y se refieren a los componentes de un territorio habitado por los antepasados. Incluye tanto aspectos materiales como elementos geográficos, humanos y no-humanos, propios de su ecología; aspectos simbólicos relacionados con las dinámicas de territorialización. Estas territorialidades constituyen los aspectos identitarios y de relación vital con el entorno.

Este artículo contribuye a la comprensión de cómo la cultura constructiva de grupos guaraní refleja una relación singular del ser humano con lo no-humano y el territorio, a través del estudio de las arquitecturas vernáculas de dos Tierras Indígenas (TI) en Brasil.

Enclavada entre tres autopistas y la periferia de São Paulo, la TI del Pico del Jaraguá ha sido habitada desde la década de 1950 y reconocida por el gobierno desde 2015. Actualmente (2002), cuenta con unos 700 miembros, distribuidos en seis comunidades, en una superficie de 532 hectáreas (fig. 1). La TI de M'Biguaçu, localizada cerca de Florianópolis (Estado de Santa Catarina) está regularizada desde 2004. Tiene una superficie de 58 hectáreas atravesada por una autopista. Allí viven unos 115 Guaraní,[1] juntos en una sola comunidad (fig. 2). En ambos casos, se trata de mostrar cómo la arquitectura de su "casa de rezo" (*opy* en guaraní), elemento central de las comunidades, refleja parte de su cosmología. Además, este trabajo mostrará cómo los materiales y las técnicas de construcción implementadas, así como los procesos de construcción y las prácticas cotidianas, revelan una concepción multiescalar del territorio. Por último, se explicará por qué, tradicionalmente, la *opy* no implica necesariamente un proceso de mantenimiento preventivo, sino de reconstrucción periódica. Los estudios de

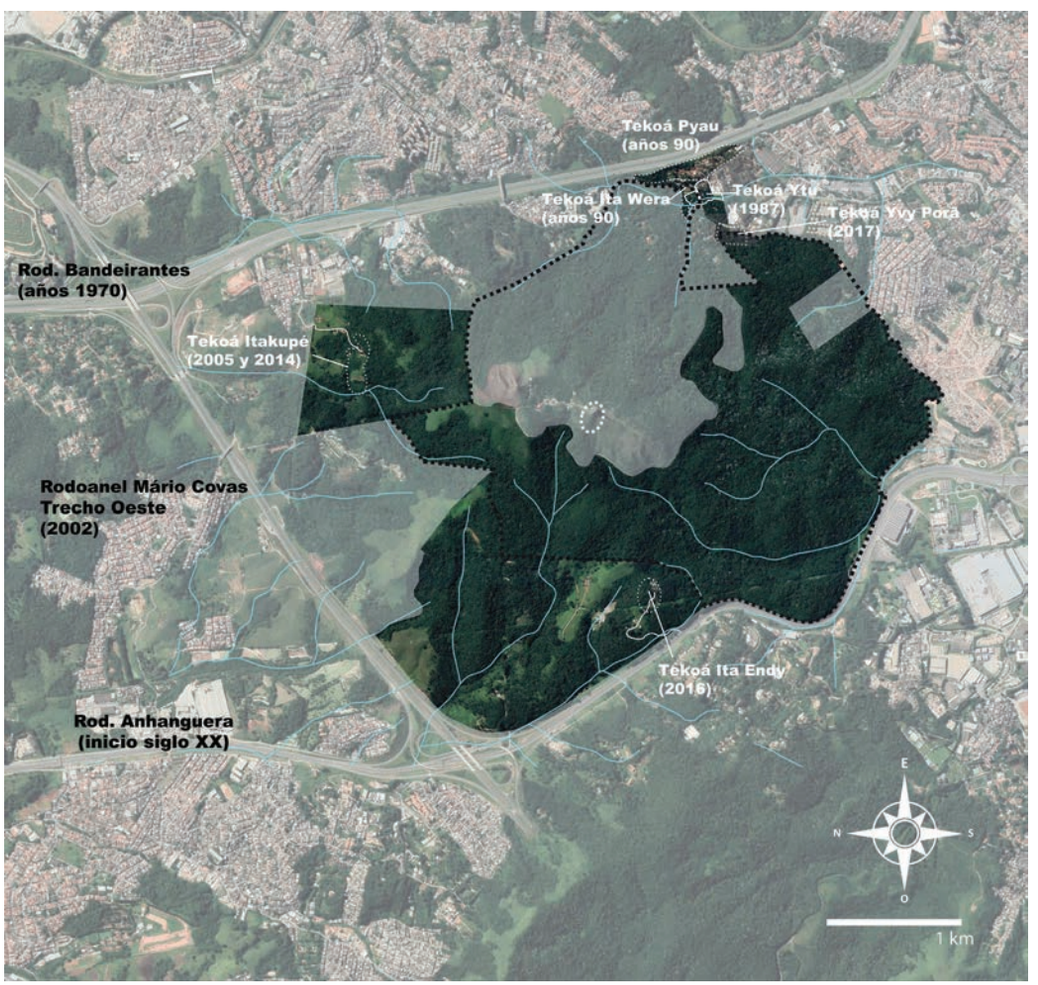


FIGURA 1 Tierra Indígena del Pico del Jaraguá, São Paulo, Brasil. Localización de las *tekoá* de la Tierra del Jaraguá. Dibujo: Anaïs Guéguen Perrin.



FIGURA 2 Tierra Indígena de M'Biguaçu, Florianópolis, Brasil. Localización de la *opy* y otras construcciones colectivas. Dibujo: Anaïs Guéguen Perrin.

campo realizados en las dos TI, que sirven de base para este trabajo, consisten en observaciones y entrevistas, principalmente con Sônia Ara Mirim, Irene Jaxuka Mirim, Poty Poran, Jurandir Augusto Martim, David Karai Popyguá y Marcio Boggarim en la TI de Jaraguá, y Celita Antunes, Hyral Moreira y Augustinho Wherá Tukumbo en la TI de M'Biguaçu.

Cultura constructiva guaraní

Tradicionalmente, las construcciones de la región costera del Brasil estaban hechas de estructuras de madera y relleno de barro, con materiales del bosque atlántico, como el cedro (*yary* en guaraní) o la palma (*pindó*), dos especies importantes en la cosmología guaraní. El *pindó* corresponde a las cinco palmas azules inmateriales que mantuvieron el primer mundo y permitieron a los Guaraní escapar del diluvio (Ladeira 2008, 119). También indica la presencia del agua en el territorio y se utiliza en la construcción, la alimentación y la medicina tradicional. El cedro *yary* está relacionado con *Nhanderu*, el creador de los mundos, y estructura el mundo actual. También simboliza la reciprocidad entre la tierra y el cielo, debido a que tiene un volumen equivalente de ramas y raíces (Prudente 2007). Así, utilizado en una construcción, garantiza su robustez y su anclaje espiritual. También se utiliza para la realización de objetos rituales en la *opy* o para la medicina tradicional durante las ceremonias. La estructura principal de cedro se plantaba directamente en el suelo, al igual que la estructura secundaria, que recibía una estructura terciaria de bambú *takuara*. Ésta era destinada a ser cubierta por la tierra local para garantizar condiciones térmicas de confort. La *takuara* y la tierra también tienen un significado simbólico: la *takuara* se asocia con lo femenino y la tierra, con la energía del planeta y la vida. La cubierta se confeccionaba según la fibra disponible: las hojas de la palma *pindó*, la *takuara* o el *sapé*, una gramínea local.

Hasta 2015, en la TI del Jaraguá, sólo se mantenía sistemáticamente la *opy* de cada comunidad en tierra. Ahora, en un contexto de relativa estabilidad en sus asentamientos, los

Guaraní están llevando a cabo actividades de construcción destinadas a afirmar su cultura en el territorio, lo que incluye el uso de la técnica de construcción tradicional como una marca paisajística propia de las comunidades más recientes. Sin embargo, aunque la demarcación de las TI proporcione cierta seguridad en el uso del suelo, tiene como consecuencia la inmovilización de las comunidades en espacios restringidos. Además, la TI del Pico del Jaraguá tiene una biodiversidad alterada por antiguos procesos de monocultivos sucesivos y de urbanización acelerada. Así, los recursos se han vuelto escasos, y los Guaraní han adaptado sus técnicas al contexto local. Sustituyen la madera tradicional de la estructura principal por eucalipto, a veces tratado contra termitas. La estructura secundaria es de eucalipto rollizo (cortado *in situ* o comprado localmente); el bambú de la estructura terciaria se sustituye, generalmente, por listones de madera, y las fibras del tejado, por láminas consideradas ecológicas o fabricadas con materiales reciclados. En sus "experimentos de actualización cultural" (Gallois 2006, 21), los Guaraní buscan hacer un uso moderado de los materiales locales o ecológicos, para lograr un bajo impacto ambiental, una cierta frugalidad y un grado de autonomía, garantizado en particular por el acceso a los recursos materiales y por el saber hacer asociados.

Opy, la casa de rezo de los Guaraní

Para los Guaraní, la *opy* es considerada el corazón de cada comunidad. Alberga prácticas cotidianas que contribuyen a la cohesión social, como la toma de decisiones importantes. Asimismo, se considera la escuela ancestral, donde se transmite parte del conocimiento colectivo y los valores culturales, y permite la conexión física y espiritual con el entorno. Por lo tanto, su centralidad no debe considerarse en términos geométricos, sino en términos de función cultural.

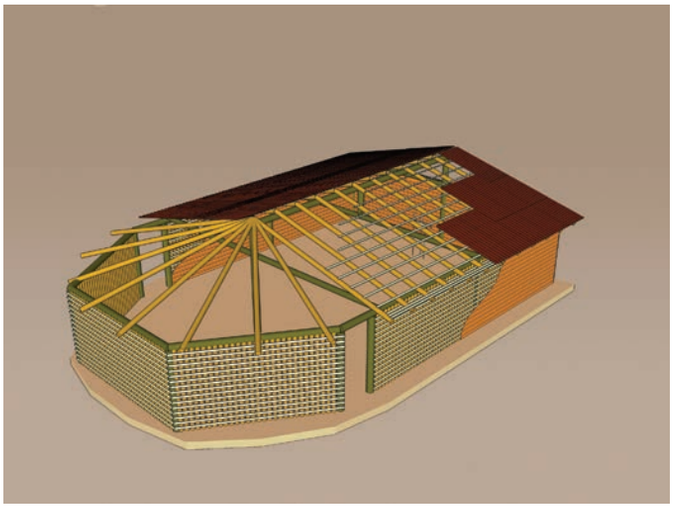
En la TI del Pico del Jaraguá, la *opy* de cada comunidad tiene una planta de base rectangular, cuyo eje longitudinal se orienta tradicionalmente de este a oeste, en referencia a la dirección de la salida del sol y del *yvy marãey*, la tierra sin mal,[2] hacia la que se dirigen las oraciones. Los Guaraní se consideran profundamente vinculados a la Tierra, que les da fuerza vital y energía, y los mantiene vivos. Por lo tanto, el suelo de la *opy* debe ser de tierra apisonada, para mantener esta conexión del cuerpo con la Tierra. Utilizada en las paredes de barro, ella aporta la energía protectora de la Tierra alrededor del espacio de oración, manteniendo a los espíritus malignos fuera del edificio que alberga los ritos. Hay que señalar que la *opy* tiene como única apertura una o dos puertas, dependiendo de la *opy*, para evitar cualquier intrusión espiritual desapercibida. Tradicionalmente, el barro de las paredes se cubría a veces con ceniza en su superficie exterior. Por su reacción química, la ceniza endurece la superficie, aumentando su resistencia, y, por su olor, enmascara el de los humanos que podría atraer a los espíritus hostiles dentro de la *opy*. La parte superior del muro del hastial oriental está formada por hojas de palmera o ramas espaciadas que dejan entrar los primeros rayos de sol en el edificio. Al iluminar el altar y el suelo, el sol limpia el lugar de las energías negativas de la noche. En algunas *opy* del Jaraguá, el muro occidental se redondea en el sitio donde se encuentra el fuego que permite calentarse durante las oraciones nocturnas y cuyo humo protege de los espíritus dañinos. Aquí, la forma redondeada permite que todos disfruten del fuego por igual. A otra escala, diferentes artefactos en cedro, *pindó* o *takuara* son asociados al hombre, la mujer y eventos cosmológicos. Por ejemplo, el *ambá*, altar hecho de cedro, simboliza las cuatro direcciones y lleva las almas de los antepasados (fig. 3).

El fenómeno de la identificación cultural en el territorio a través de la técnica constructiva tradicional es específico de la TI del Jaraguá. De hecho, en la TI de M'Biguaçu, la mayoría de las casas se construyeron con materiales convencionales, porque los tradicionales son escasos y la comunidad ha recibido compensaciones económicas del gobierno como consecuencia de la realización de infraestructuras que afectan a la TI. Sin embargo, su *opy* expresa parte de su cosmología y sigue siendo central, aunque físicamente se encuentre en su margen, protegiéndola del acceso no deseado.

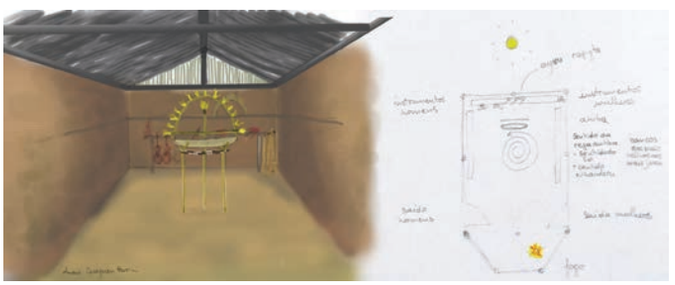
Como en el Jaraguá, los Guaraní de M'Biguaçu rezan mirando al este y utilizan los mismos artefactos. Sin embargo, la forma de la *opy* es diferente, pues presenta una estructura octogonal cubierta de *takuara*, y la forma del techo está definida por las vigas que marcan las principales direcciones de la cosmología guaraní. Éstas coinciden con los cuatro puntos cardinales y el centro corresponde a un *axis mundi*, vinculando nuestra realidad a las diferentes materialidades. Representados por cuatro pares de vigas, los cuatro puntos cardinales simbolizan los pares de guardianes, compuestos por lo masculino y lo femenino, afirmando la complementariedad de los géneros. En un simbolismo de diferentes escalas, la forma circular de la *opy* y su fuego sagrado al centro representan el planeta, así como el sol y el sistema solar, y la energía primordial de *Nhanderu* en el universo. En este caso específico, esta *opy* fue hecha de piedra rosa, para una mejor permanencia. Este material tiene una función similar a la de la tierra, siendo las piedras guardianas de la memoria



(a)



(c)



(b)

FIGURA 3 *Opy* de la TI del Pico del Jaraguá. (a) Fachada este, *Tekoá* Yvy Porã. (b) Altar y pared este, *Tekoá* Ytu. Ilustración de la parte interna con la pared este y el *ambá* (que no se puede fotografiar). Al fondo, del lado derecho, están los *takuapú* (palo de bambú que las mujeres utilizan para golpear el suelo durante las oraciones diarias); al fondo, del lado izquierdo, están los instrumentos de los hombres; y al centro se encuentra el *ambá*, que simboliza a los cuatro puntos cardinales y el ciclo de la vida humana, material e inmaterial. (c) Representación 3D de *Tekoá* Yvy Porã. Fotos y dibujos: Anaïs Guéguen Perrin.

de la Tierra, al igual que las montañas. Sin embargo, esta permanencia conlleva una reducción de la transmisión de conocimientos técnicos, como se notó cuando tuvieron que mantener el tejado de bambú de la *opy* (fig. 4).

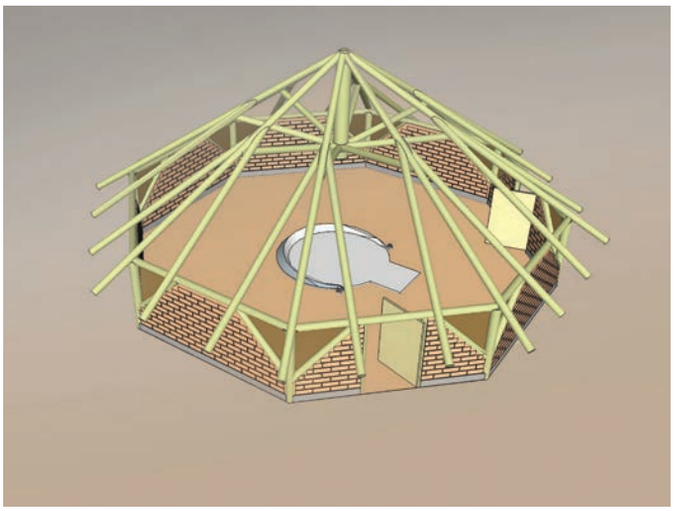
En las dos TI estudiadas, la *opy* materializa diferentes escalas de la cosmología, con diferentes tipologías, lo que ilustra las distintas maneras en que puede tomar forma. Sin embargo, las prácticas diarias y anuales asociadas a ella son similares. Estas construcciones y las prácticas asociadas sirven como medio para transmitir concepciones y percepciones del mundo según un paradigma común.

Movilidad, transmisión y permanencia

Tradicionalmente, las comunidades guaraní realizaban desplazamientos colectivos, cada cinco a diez años, para crear un *tekoá*[3] o reocupar uno antiguo, generalmente identificado en la oralidad (Grünberg 2008). Esta territorialización dinámica respetaba la resiliencia de los lugares, garantizando la posibilidad de volver más tarde a una *tekoá* que ya pertenecía a la geografía cultural. Generalmente asociado al ecosistema del bosque atlántico, el territorio costero de los Guaraní integra los elementos de la geografía cultural, los *tekoá* y los caminos que los unen (Noelli 2019). Hoy en día, la demarcación de las TI les permite garantizar un derecho a la tierra reconocido institucionalmente. Sin embargo, simultáneamente, limita las migraciones colectivas. Así, esta práctica se mantiene individualmente o por núcleo familiar, entre los *tekoá* existentes, perpetuando un sistema social de relación de parentesco y transmisión de conocimientos culturales, o mediante la creación o retomada de algunos *tekoá* en el territorio tradicional. Debido a las migraciones, la *opy* no era destinada a ser muy duradera. En el Jaraguá, sin embargo, se conservan los principios tradicionales de construcción. Por lo tanto, si la *opy* presenta algún deterioro, y el contexto lo permite, los Guaraní privilegian la reconstrucción, manteniendo así una cierta periodicidad en el proceso de construcción colectiva. Sólo se renueva cuando los recursos son escasos. La reconstrucción puede hacerse en el mismo lugar o en un lugar más conservado, según la evolución del *tekoá*. Así, la reconstrucción



(a)



(c)



(b)

FIGURA 4 *Opy* de la TI de M'Biguaçu. (a) Fachada este. (b) Estructura del techo. Fotografía de la estructura del tejado, donde se pueden ver a las vigas que indican a los cuatro pares de guardianes, mujer y hombres: Karaí al este (representa al fuego), Jakaira al norte (representa a las nieblas y los vientos), Tupã al oeste (aguas, lluvias y rayos), y Nhamandu al sur (representa al sol y el tiempo-espacio). (c) Representación 3D con el lugar del fuego al centro y las dos puertas. Fotos y dibujos: Anaïs Guéguen Perrin

periódica permite la transmisión de la técnica constructiva a los más jóvenes mediante la práctica y la observación.

La cultura constructiva tradicional sigue siendo fundamental para el grupo porque los procesos de construcción colectiva contribuyen a la conservación de la cohesión y los ritmos de la comunidad. En efecto, cuando se construye una casa familiar, participan los miembros cercanos, mientras que cuando se construye la *opy* colaboran los miembros de toda la comunidad, y a veces los aliados no indígenas, que se distribuyen las actividades en función de sus capacidades. Las mujeres suelen encargarse de la comida, apoyadas por los jóvenes adultos que abastecen el horno de leña colectivo. Los hombres serán generalmente asignados a la estructura de la casa, y los niños, así como las mujeres y los hombres, a la preparación y aplicación del barro.

La transmisión de la técnica a los más jóvenes y los métodos de organización se realiza mediante una inmersión activa, en una práctica constructiva colectiva. Incluye

diferentes grados de observación y colaboración activa en la realización. La cultura constructiva se transmite así, simultáneamente, de forma oral y a través de la experiencia, lo que permite una comprensión técnica y cultural. De este modo, el cantero comunitario de la *opy* y los conocimientos colectivos y técnicos asociados se convierten en herramientas para transmitir parte del patrimonio inmaterial y perpetuar el patrimonio material.

Conclusiones

Por el uso de materiales locales portadores de valores simbólicos, por la importancia de la técnica constructiva en el proceso de afirmación del anclaje al territorio y por la imagen de alteridad que envía a los no indígenas en los procesos de derecho a la tierra, entendemos que la *opy es* territorio, cosmología y comunidad. Además, para los Guaraní, el cuerpo es Tierra. Estos son inseparables, así como la espiritualidad es inseparable de los seres del territorio y de otras materialidades. De esta manera, percibimos que la relación de los Guaraní con la arquitectura, el territorio y el cosmos presenta una concepción multiescalar, fractal, donde ciertos elementos se encuentran a diferentes escalas imbricadas entre sí, ilustrando una realidad holística.

El patrimonio material y las prácticas asociadas sirven así de soporte para transmitir parte del patrimonio inmaterial y el paradigma guaraní, basado en una ontología relacional. En la actualidad, estas prácticas constituyen una resistencia cultural, común a diferentes grupos guaraní y etnias de Brasil. Forman parte de una estrategia de visibilidad de la causa indígena y de mantenimiento de la cultura entre los más jóvenes, valorando el sentimiento de pertenencia cultural al territorio y al planeta.

Notas

1 "Guaraní" con mayúscula se refiere al Pueblo indígena, y "guaraní" en minúscula es utilizado como adjetivo (por ejemplo, para la lengua guaraní).

2 En la cosmología guaraní, existen diferentes plataformas y materialidades relacionadas con la realidad que vivimos. *Yvy marãey* es la primera que se practica después de la desencarnación y se ubicaría en el este (Pierri 2018).

3 *Teko* significa "vida" y el sufijo *-a* hace referencia al lugar. Entonces, *tekoá* designa el espacio que presenta los aspectos necesarios para mantener la vida.

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A Study of Gwari (Gbagyi) Traditional Earthen Architecture and Conservation

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Abstract: *The Gwari (Gbagyi) are one of the ethnic groups in central Nigeria. Traditionally, they are farmers who live in homesteads whose buildings are fabricated predominantly of earth (adobe or cob walls with thatched roofs). They remain one of the few ethnic groups in Nigeria that still preserve their culture and architecture despite the threat posed by multiethnic habitations. Unique to Gwari (Gbagyi) earthen architecture are the granaries and their ventilation systems, which have proven very effective in food preservation. This earthen architecture is imbued with superstitious beliefs that are also practical for the warm and wet climate of central Nigeria. For example, the residential units have no windows due to the belief that evil spirits could gain access through these openings. Doors are usually oriented along the north–south axis, thus avoiding the northeastern and southwestern trade winds that are responsible for the microclimate. An earlier study by the authors focused on documentation of the earthen construction technique of the Gwari (Gbagyi). The aim of this paper is to further the earlier research by focusing on the documentation of the group's superstitions and critically analyzing their importance using scientific evidence. We also identify the Gwari (Gbagyi) traditional practices that have the potential for adaptation to contemporary architecture in areas with similar climatic conditions.*

Resumen: *Los Gwari (Gbagyi) conforman uno de los grupos étnicos de Nigeria central. Tradicionalmente, son agricultores y viven en casas que, en su mayoría, son de tierra (muros de adobe o tapia, y techos de paja). Están entre los pocos grupos étnicos en Nigeria que aún preservan su cultura y arquitectura, a pesar de la amenaza que representa la ocupación multiétnica. Un componente singular de la arquitectura de tierra de los Gwari (Gbagyi) es su granero y su sistema de ventilación, que han resultado ser muy eficaces para la preservación de alimentos. La arquitectura de tierra está asociada a creencias místicas que, además, resultan prácticas para el clima cálido y húmedo de Nigeria central. Por ejemplo, las unidades residenciales no tienen ventanas, y las puertas suelen estar orientadas en base al eje norte-sur, lo que evita los vientos alisios del noroeste y el suroeste, que afectan el microclima. Un estudio anterior de los autores se enfocó en la documentación de la técnica de construcción de tierra de los Gwari (Gbagyi). El objetivo de este artículo es ampliar la investigación previa con un enfoque en la documentación de los saberes místicos del grupo y analizar de forma crítica su importancia usando evidencia científica. También se identifican las prácticas tradicionales que tienen potencial de adaptación a la arquitectura contemporánea en áreas con condiciones climáticas similares.*

Keywords: *dobwi* (granary), *tukutyi* (earth bricks), sustainable conservation

Introduction

Nigeria is a very diverse country in terms of ethnicities and cultures, and the Gwari are one of over 300 ethnic groups in the country (Salawu 2010). The Gwari people are found in Kaduna, Nassarawa, and Niger states as well as in the Federal Capital Territory (FCT) in central Nigeria. Despite occupying such a large territory, and with a population of over a million people, the Gwari are one of many ethnic groups considered to be a minority in Nigeria. However, their language and culture are still preserved due to limited interaction with other ethnic groups. Although they are referred to as Gwari, the word is a Hausa term and Natives refer to themselves as Gbagyi (Na'Ibi and Hassan 1961). Similarly, the Nupe (Gwari's neighbors in Niger State) and Yoruba refer to them as Gbari (Hyman and Magaji 1970). Recently, there has been serious objection to the name Gwari (Gideon Ketti and Ishaya Ishaku, pers. comm.), with residents arguing that the word *gwarri* means "yam" in their language. The objection to the old name is a recent trend, and the name Gbagyi is gradually gaining popularity and has been used in recent publications. For these reasons, this ethnic group will be referred to as Gbagyi in the remainder of this paper.

Historically, the Gbagyi were predominantly farmers and lived in sparsely populated homesteads, hamlets, and small villages (Hyman and Magaji 1970). Their lifestyle was centered on farming crops for food, mainly millet, sorghum, beans, and yams. The agrarian life was so strong that Gbagyi culture, religion, and architecture were centered on it. Marriages, children's naming ceremonies, and other related events were held during the dry season when the community was not occupied with farming activities. Similarly, religious festivals were carried out at the beginning of the farming season and during the harvest.

The most dominant structure in any Gbagyi settlement is the granary, which is called *dobwi* and is used for both long- and short-term storage of farm produce. Other buildings such as the bedrooms and kitchen are less elaborate and are simple to construct. The majority of the Gbagyi are still farmers, and those who practice this profession still live on homesteads and have retained most of their cultural heritage.

Just like many cultures in Nigeria, Gbagyi traditional architecture has seen slight changes in terms of the form, methods, and use of materials. Earth is used as walling material and the dobwi still maintains its importance. The traditional thatched roof, however, is gradually being replaced with corrugated metal sheeting.

Findings by the authors at the village of Ketti, a Gbagyi settlement in the FCT, show that despite encroachment of culture and religion, this settlement still maintains its traditional architectural character. Similarly, even though most of the inhabitants of Ketti have converted to Christianity or Islam, they still hold on to the beliefs influenced by their traditional religion, which plays a major role in Gbagyi architecture.

Study Rationale and Methodology

Architecture is one of the tangible aspects of every culture. It evolves over time, but for those civilizations who employ architectural conservation methods, buildings represent major objects of history (Vecco 2010; Polimeni 2019). Despite the preservation of Gbagyi traditional architecture, there is limited local scholarly literature, and structures are often misconstrued as those of other neighboring ethnic groups. For example, in a discussion of the Abuja (now Suleja) architecture of the Hausa who migrated from Zaria (Zazzau), Dmochowski (1990) did not acknowledge that the structures contained traditional Gbagyi influences despite the glaring evidence. According to Dmochowski, the Hausa people of Abuja use ball-shaped *tubali* (Hausa for sun-dried adobe brick) for walling. However, this technique is Gbagyi. The Hausa use conical-shaped tubali (Moughtin 1985). Other regional studies, such as those written by Aiyedun and Oyerinde (1990) and Ogundele (2004), were focused on demography and ethnography, respectively, not architecture.

The limited scholarly literature on Gbagyi architecture prompted the decision to carry out a study on an existing Gbagyi village. The village of Ketti in Abuja, Nigeria's federal capital city, was chosen as the study area and fieldwork was conducted in January 2021. The fieldwork was composed of housing surveys and interviews with the village inhabitants that were led by the *esu* (community leader). Both men and women were interviewed because they each play major roles in the construction of buildings. Similarly, an architect with the Abuja Municipal Area Council (AMAC), who is Gbagyi from a neighboring community, was also interviewed with the aim of authenticating the authors' fieldwork findings.

The Study Area

In 2004, the authors carried out a housing survey in the Ketti settlement in Abuja for a different purpose. Although this housing survey was not published, it provided a basis for this



FIGURE 1 Panoramic view of Ketti village (the study area). All figures: T. Shittu.

study. The study found that the proximity of Ketti to the central business district of Abuja has attracted many other ethnic groups to that settlement. Despite the presence of varying cultures, the Gbagyi compounds still maintain their traditional characters, making them distinguishable from buildings belonging to other ethnic groups.

Ketti was intentionally chosen for three reasons: (1) its proximity to the Abuja central district gave us the opportunity to identify to what extent modernity and cultural heterogeneity (due to cross-cultural migration) have influenced Gbagyi architecture and beliefs; (2) to understand how the Gbagyi have responded or adapted to changes resulting from external cultural influences; and (3) to identify lessons that can be learned and adapted to vernacular architecture from similar climates in Nigeria. As seen in figure 1, Ketti is a typical Gbagyi village that is situated on a hilltop with many outcroppings that suit the construction of the Gbagyi dobwi. Farming activities take place in the fertile valley below.

Gbagyi Architecture: Design Concepts, Meaning, and Techniques

The principal building materials in Gbagyi communities are traditionally earth and thatch for walling and roofing, respectively (Aiyedun and Oyerinde 1998). Ball-shaped *tukutyi* (sun-dried earth bricks, a word derived from *tubali*) are used for masonry walls. The walls are then rendered with a mixture of earth that is reinforced with straw and natural additives such as cow dung. The tukutyi for making dobwi are usually smaller in size than those used for any other building, because these structures have narrower diameters and smaller tukutyi are more suited to the smaller curvatures. According to Ishaya Ishaku (pers. comm.), earth was carefully sourced from borrowed pits, mixed with straw and water, and then covered with straw for three days. Water is sprinkled over the covered earth mixture until the fourth day, when the mixing process is repeated, and it is re-covered with straw. On the ninth day, water and sometimes straw are added one last time before the mixture is molded into bricks that are sun-dried before being used.

According to Gideon Ketti (pers. comm.), cow dung is sometimes added to the earth mixture for additional strength. Both Ishaku and Ketti noted that buildings are constructed by both men and women. The men mold the bricks and construct the earthen walls and thatch roofs while the women do the floor finishes. Cob techniques were also used for dobwi construction in areas where clay-rich soil is available. Ishaku and Ketti reckoned that the cob walls are faster to construct, making it easier to achieve the globular, carinated, or cylindrical shapes required for dobwi. The carinated-shaped dobwi are used by women in Ketti.

In traditional Gbagyi settlements, building construction was through either self-help (individual family) or communal effort. This practice still exists today in Ketti (Gideon Ketti, pers. comm.) and every adult member of the community contributes to construction work. Even children are involved, fetching water to support the workforce. Once the tukutyi are ready, shallow foundation trenches are dug and filled with rubble stones to provide solid bases for the masonry walls. The prefabricated roof trusses, made from *awyi kuwyi* (corn stalks), are secured to the walls using a twine-like rope made of *lawun* (jute) and are then thatched.

Women are responsible for the flooring. Clay-rich soil is first applied to the floor and sprinkled with water before being continuously rammed until the floor becomes hard. A final, waterproofing coating consists of earth stabilized with cow dung and a solution of *olo 'nyi* (locust bean) to give the floor a smooth, hard, and shiny surface that resists wear and tear for at least a year. Traditionally, there were no windows in Gbagyi rooms for fear of evil spirits. Door openings in the walls had no shutters, allowing air circulation to the interior spaces. And because considerable time was spent inside the kitchen and *ataboknu* (pounding or grinding room) during the day, these buildings also had openings without shutters to provide ventilation. However, this is no longer the case. Modern Gbagyi residences have windows and lockable doors, which provide



FIGURE 2 Women's dobwi, constructed of three sections.

ventilation in what are now densely populated communities, as well as security.

The women's dobwi, usually located within the compound, consist of three sections: the lower part that is made of stone with earth render; the storage chamber, which is traditionally made with tukutyi; and the roof, traditionally thatch (fig. 2). The space on the raised plinth in the dobwi serves multiple functions. First, it prevents direct contact with the ground, providing additional ventilation to the granary. Second, the space is fumigated annually by heating this lower area for hours before new grain is stored. Third, the space is used for poultry.

The sites for men's dobwi are chosen farther away but still visible from the respective compounds. The men's granary is usually constructed on rocky terrain to avoid termites since this structure is used for long-term storage. As shown in figure 3, the men's dobwi sit directly on the rock.

As observed during fieldwork and confirmed by Ishaku and Ketti, there have been a few changes in the architecture of the people of Ketti. They also confirm that these changes are



FIGURE 3 Men's dobwi, built directly on rock.

common in all the Gbagyi settlements in central Nigeria. The major changes observed in the compounds include the use of adobe blocks instead of the traditional tukutyi, the use of rectangular plans instead of the traditional circular plans as shown in figure 4, and the application of cementious render on earthen walls as shown in figure 5. The only change on the dobwi is on the roof. Corrugated metal sheets are now used instead of thatch.

Another notable change is the location of the husband's dobwi, which in the past used to be farther away from the compounds. It is now located within the vicinity of the residential areas due to several incidences of theft of the stored grains by non-locals who live within the proximity of the Gbagyi settlements. Despite conversion to Christianity or Islam, traditional religious beliefs still play a crucial role in Gbagyi contemporary settlements, and the residents still believe that any form of theft will be punished by spirits. Thus theft is rare among the heterogeneous Gbagyi communities.

Gbagyi Architectural Conservation and Sustainable Practices

The preservation of many elements of Gbagyi culture and architecture was possible due to their sustainable qualities. For example, the dobwi remains one of the only healthy solutions to food preservation without the use of chemical pesticides that are harmful to animals and plants.

Being central to the lives of the Gbagyi settlement, dobwi design and method of construction has not changed despite encroachment of cultures. According to Ketti, the corrugated metal sheets now used for dobwi roofing are more durable and

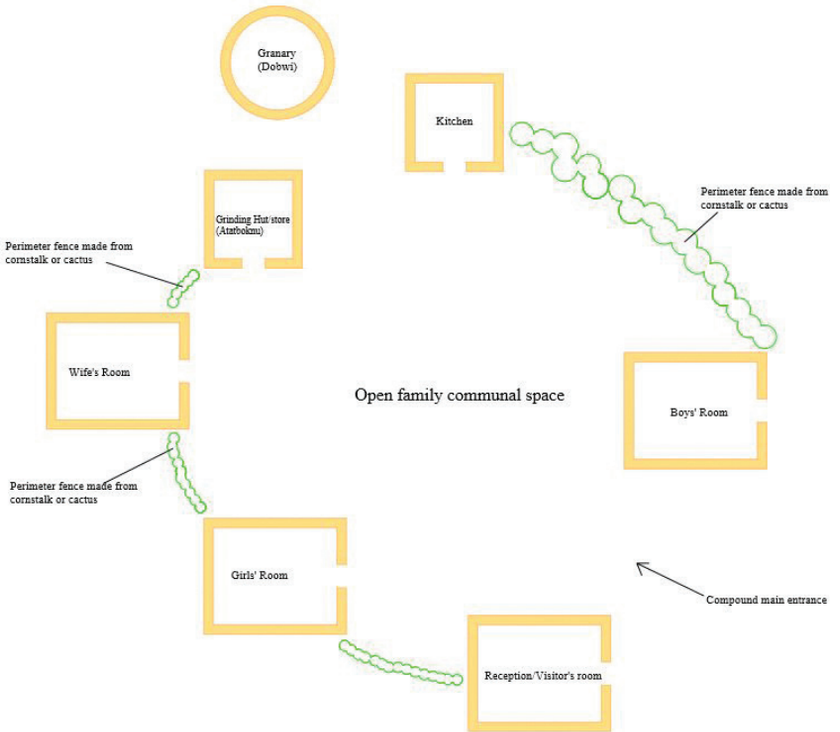


FIGURE 4 Illustration showing the traditional circular layout of a Gbagyi household.



FIGURE 5 A *dobwi* with cementitious render.

provide more protection for the earthen walls, thus reducing the frequency of maintenance. Furthermore, the corrugated metal sheets transmit more heat from the sun to the interior of the dobwi, which further helps in keeping the stored grains dry and fresh.

According to Ketti, grain preservation within the dobwi begins by arranging neem leaves from the floor of the dobwi up to approximately 200 mm high. Grain is then poured on top of the leaves, reaching about 500 mm in height before another 200 mm thick layer of neem leaves is added. This process is repeated until the pile reaches the brim of the dobwi, and the roof is then lifted to cover the space. As shown in figure 2, the dobwi has a circular ventilation hole and, although its contents are covered with the neem leaves, this allows air infiltration into the structure's interior. The neem tree (*Azadirachta indica*), called *dogon yaro* in Hausa, translates as "tall person" or "male child" because of its height. Dogon yaro is also believed among the Gbagyi to have medicinal value as an antibacterial and for curing malaria (Ketti, pers. comm.). It is for this reason that there are many of the dogon yaro trees in Ketti. The medicinal value of dogon yaro has been the subject of scholarly research (Brahmachari 2004).

According to Na'Ibi and Hassan (1961), trees are the property of the occupant of the land, and those on uncultivated

land or communal spaces within the settlements belong to the community. It is forbidden by traditional Gbagyi law to fell an economy tree (trees that produce fruits or edible seeds) even if it is on fallow land. This traditional belief system helps in conservation of the vegetation in Gbagyi communities, which helps to ensure both the abundance of thatch and straw (two major building materials) used for roofing and the reinforcement of earth mixture, respectively. Only the non-economy trees are felled for fuel. Na'Ibi and Hassan (1961) noted that during the dry season, when grasses are cut for thatching, a significant portion of land was deliberately left untouched to attract animals. Although the practice of land fallowing still exists, however, hunting has since ceased.

It is of critical importance that building maintenance among the Gbagyi, including the Ketti community, is undertaken through communal effort. According to Ishaku and Ketti, the Gbagyi believe that once a building is constructed, it has become the property of the community, hence the use of communal labor in its continuous preservation. The house owner usually provides food and beverage as an incentive, as well as a token monetary reward (which is usually far lower than an actual wage), for the help. This practice of the use of communal labor for earthen building maintenance should be emulated for conservation of earthen buildings in Nigeria.

Conclusion

Although simple, the traditional architecture of the Gbagyi is highly sustainable and relevant to contemporary needs. However, this architecture and construction culture is endangered by other cultures that are gradually encroaching into their communities. One of the aims of this paper is to document this endangered culture. The Indigenous people of Ketti still maintain their agrarian lifestyle as well as a traditional food preservation method, thus the dobwi remain effective and integral parts of this settlement. The authors are convinced that the Gbagyi food preservation technique can be adapted in larger scale across regions with similar climates, as can the communal means of earthen building maintenance. However, this will require collaboration and dissemination among other Indigenous communities in Nigeria.

Acknowledgments

We would like to thank all the residents of the Ketti community, most especially Mr. Gideon Ketti, as well as Mr. Ishaya M. Ishaku of FCDA, for their time, hospitality, and valuable contribution to the making of this paper, which would not have been possible without them.

Note

Oral interviews were conducted with the people of Ketti a Gbagyi settlement in AMAC Abuja. Most of the responses were from the community leader, Mr. Gideon Ketti. The interviews were conducted between January 20 and 23, 2020. The second person interviewed was Mr. Ishaya M. Ishaku, an architect and Indigenous Gbagyi. He is currently the chief architect at the Federal Capital Development Authority (FCDA), and the interview was conducted by phone. Information gathered from these two individuals and discussed in the paper is noted as personal communications (pers. comm.) in the text.

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PART 16

AlUla Old Town and Oasis Symposium / Simposio del pueblo y oasis de AlUla

AlUla Old Town and Oasis: An Introduction to AlUla and the Old Town Survey and Conservation Project

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Abstract: *This paper introduces the AlUla region—AlUla Old Town and the Oasis—and the project to record and document the historic AlUla Old Town. The project is led by the Royal Commission for AlUla (RCU) and is one of the most ambitious development projects underway in Saudi Arabia. A historical overview of the AlUla region is followed by a description of the digital 3D survey directed by Jamie Quartermaine (Oxford Archaeology) and Yann Gayet (Geokali). This crucial survey faced complex challenges due to the magnitude of the site, its intricate features, and the large accumulation of data that was acquired and processed. This innovative initiative illustrates the value of providing a highly detailed record of conditions before and after conservation and delivers baseline information essential for RCU's development projects already underway at the site.*

Resumen: *Este articulo presenta la región de AlUla, el Pueblo Antiguo de AlUla y el Oasis, y el proyecto de documentación y registro del Pueblo Antiguo. El proyecto está dirigido por la Comisión Real para AlUla (RCU, por sus siglas en inglés) como uno de los proyectos de desarrollo más ambiciosos actualmente en marcha en Arabia Saudita. A una descripción histórica de la región de AlUla le sigue una descripción del sondeo en 3D dirigido por Jamie Quartermaine (Oxford Archaeology) y Yann Gayet (Geokali). Este crucial estudio tuvo que enfrentarse a complejos desafíos debido a la magnitud del sitio, a sus intrincadas características y a la gran acumulación de datos adquiridos y procesados. Esta innovadora iniciativa ilustra el valor de obtener un registro detallado de las condiciones antes y después de los trabajos de conservación, y ofrece información básica esencial para los demás proyectos de desarrollo de RCU que ya se están llevando a cabo.*

Keywords: AlUla, earthen architecture, 3D modeling, laser scanning, Simultaneous Localization and Mapping (SLAM), photogrammetry, 3D survey, ortho-photo, drone survey

Introduction

The town of AlUla (Arabic: ٱلْعُلَا – *al-ʿulā*) lies within the modern county of AlUla in the northern Hijaz of Saudi Arabia, 300 km north of Madinah and 135 km inland from the Red Sea port AlWajh. It is located in the Wadi AlQura, a valley that is oriented north to south between the lava fields of the Harrat Uwayrid on the west and the sandstone massif of the Jabal AlThumayid to the east, rising over 1000 m above sea level.

Archaeological surveys have identified over 30,000 sites in AlUla County that indicate human presence from the Paleolithic to modern times. Underground water resources and a strategic location at the crossing of caravan routes connecting Arabia, the Near East, and the Mediterranean world have contributed to the significance of the region from at least the late Bronze Age to the present day.

The historically significant settlements of Dadan (AlKhuraybat), Qurh (AlMabyat), and Hegra (AlHijr / Madain Saleh), which was inscribed on the UNESCO World Heritage List in 2008 (fig. 1), and AlUla Old Town characterize the region. Archaeological remains have established a chronological sequence of large settlements beginning at Dadan in the first millennium BCE. Evidence from Hegra dates from the same period, although the site is better known for its Nabataean cultural remains dating from the first century BCE until the site was annexed into the Roman province of Arabia in 106 CE. Roman presence is attested into the third century by Latin legionary inscriptions. With the arrival of Islam in the seventh century CE, the area became part of the Syrian Hajj Route, connecting Damascus with the holy cities of Madinah and Mecca (fig. 2). The Hijaz Railway, constructed in 1907, modernized the route while simultaneously facilitating the movement of troops. AlUla Station was the farthest south that non-Muslims were allowed to travel.

The establishment of AlUla can be traced in the literary record to the ninth century CE, when the name first appears in Muslim pilgrimage itineraries. Named after the famous Muslim commander Musa bin Nusayr (figs. 3, 4), the fortified hilltop citadel stands on a high sandstone outcrop at the center of the town, commanding extensive views throughout the valley. Archaeology has yet to confirm whether the site was continuously occupied for 800 years, but the town was finally abandoned when the last family left in 1983.

The town of AlUla is situated on the western side of an oasis bordered by high sandstone cliffs, affording protection from both enemy raids and the flash flooding that results from

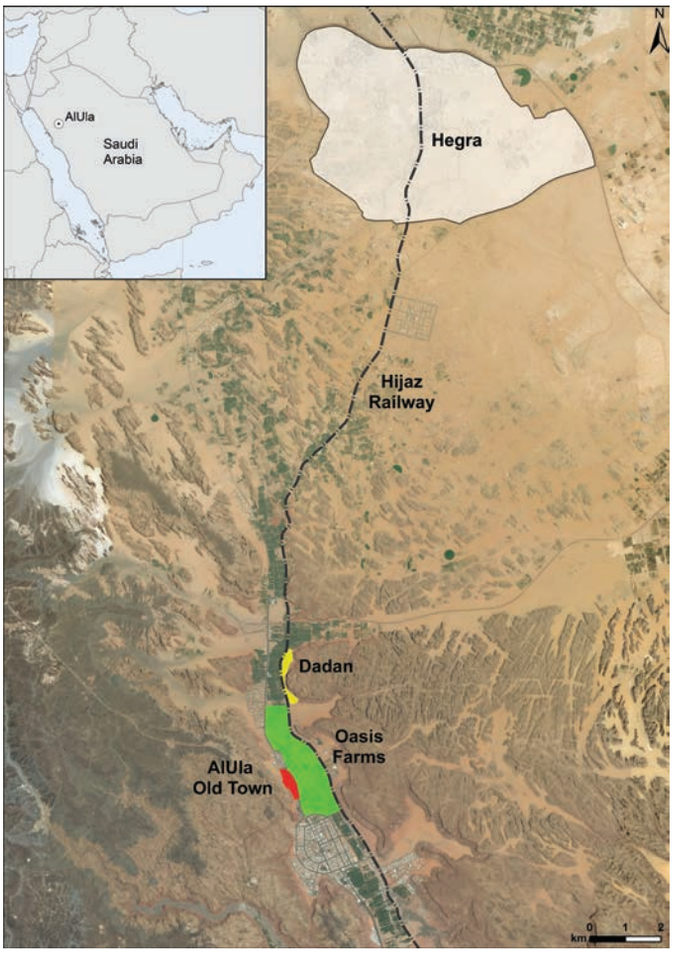


FIGURE 1 Map showing AlUla Old Town and associated historic sites. Illustration: Laura Morabito, courtesy of RCU.



FIGURE 2 View of the Wadi AlQura with AlUla Old Town in the center. Photo: Khalil Nabelsi, courtesy of RCU.



FIGURE 3 Aerial view of the Oasis Farms (left) and Old Town (right). Photo: Khalil Nabelsi, courtesy of RCU.



FIGURE 4 Aerial view of Old Town with Musa bin Nusayr Citadel at the lower center. Photo: Khalil Nabelsi, courtesy of RCU.

occasional rainfall. To the east of Old Town is an area known as the Oasis Farms, or Summer Farms. Prior to the construction of the new road layout in the 1990s, the Old Town and Oasis Farms were two parts of a single settlement. The Oasis Farms are agricultural gardens delineated by earthen walls that form narrow streets known as *suqs*. It was customary for the people to leave their densely packed houses in Old Town during the heat of summer and relocate to the spaciousness of the Oasis Farms, where they would stay until the date harvest in late October. During this time, they would undertake repairs and maintenance on their Old Town homes.

The Royal Commission for AlUla

In July 2017, the Royal Court decreed the formation of the Royal Commission for AlUla (RCU) under the patronage of His Royal Highness Mohammed bin Salman bin Abdulaziz AlSaud: "reaffirming it [AlUla] as one of the country's most important archaeological and cultural destinations and preparing it to welcome visitors from around the world." RCU's development work in AlUla encompasses a broad range of initiatives across archaeology, tourism, culture, education, and the arts, reflecting the ambitious commitment to cultivate tourism and leisure in Saudi Arabia, outlined in Vision 2030 (https://www.rcu.gov.sa/en).

A cooperative agreement was signed with France the following year, initiating the creation of the French Agency for AlUla Development (AFALULA) to support the goal of reviving the historical town and oasis. Initiated by RCU in 2018, Heritage Conservation Consulting (HCC) and CRAterre began a major conservation program to create a 3D record of the site prior to any modifications, including the documentation needed to commence conservation treatment. Detailed and extensive architectural and topographic surveys were carried out under the control, supervision, and methodology prepared by HCC. The record needed to be both accurate and detailed to reflect the complexity of the structures. It also had to be rapid so as not to impede the intensive ongoing conservation program, taking into account the fragility of the environment that is subject to dramatic changes (particularly the nearly annual collapse of destabilized structural elements frequently following rainfall).

A program was established by Oxford Archaeology and Geokali, using a range of innovative 3D survey techniques to generate a comprehensive 3D record of the town. Their hybrid technique, which merges aerial and ground-based photogrammetry with millimetric precision static laser scanning,

was implemented by Geokali to generate highly textured and precise 3D models of the external surfaces of the buildings, including street facades and terraces. This technique was also applied to the survey of the interiors of a single block of twenty houses. It was not, however, suited to recording the confined interiors of all 950 buildings within the limited timeframe.

Considering the large number of buildings to survey, and the difficulty in accessing most of them, another approach was applied by Oxford Archaeology to record the interiors of all buildings within the town. This technique involved a handheld mobile laser scanner, also known as Simultaneous Localization and Mapping (SLAM), a lightweight device that locates itself using an Inertial Measurement Unit (IMU) to create a real-time 3D point cloud. The operator captures the data at a slow walking pace and can record inaccessible locations in the field considerably faster than with a conventional scanner. This method does, however, generate an output with a lower resolution and more noise than the conventional scanner.

The combination of the two methods ensured that a very comprehensive, fast, and economical 3D survey of all buildings was completed in advance of conservation works.

Geokali High-Resolution Hybrid Survey

The so-called hybrid survey technique implemented by Geokali merges static laser scanning with photogrammetric data (fig. 5). Therefore, the photogrammetric processing is not constrained by a limited number of ground control points but is instead based on the millions of points obtained with the laser scanner. In the resulting 3D model, the geometrical quality of the laser scan dataset is preserved and extended to the area invisible to the scanner (roofs, upper walls, etc.). The dataset is processed in separate elements without losing the geometrical consistency and geo-referencing.



FIGURE 5 Sample output from Geokali's Old Town hybrid 3D model of the streets located to the north of the Citadel. Illustration: Yann Gayet, Geokali.



FIGURE 6 Automatic vectorized extraction from the hybrid 3D model. Illustration: Yann Gayet, Geokali.

The laser scan survey was conducted with a Zoller + Fröhlich (Z+F) scanner, producing up to one million points per second with millimetric precision. Approximately 1400 scans were necessary to record all the streets and the interiors of twenty houses. The accuracy of the entire static laser scan dataset is 3.15 mm. The consolidated laser scan point has been used as a postprocessing geometrical reference for the mobile scanner.

Although it lacks textural information and the geometry of terraces and courtyards, this static laser scan dataset alone is a very precise geometrical documentation of the Old Town streets for topographical, hydrological, and structural analyses. This missing information was obtained through the photogrammetric dataset.

To generate a high-density textured 3D model, the laser point clouds were merged through an automated process with aerial and ground images. More than 240,000 high-resolution images were necessary, including 50,000 aerial images. The average resolution of the images is 2.5 mm per pixel. The final 3D model is a textured mesh (fig. 6). Based on the quality of this mesh, automated vectorized plans, elevations, and sections were extracted on demand, along with high-resolution ortho-photos.

In November 2020, after HCC completed the conservation works, Geokali resurveyed the southern streets and several buildings. The geo-referencing consistency between the two surveys is 5 mm, despite significant changes in the area. Two missions of three weeks each were necessary, in January and November 2020, to complete the survey.

Oxford Archaeology Handheld Mobile Scan Survey

The SLAM Scanner (GeoSLAM Zeb Horizon) was the key to achieving the extensive coverage of the house interiors across the Old Town. It recorded 300,000 survey points per second and had a range of 100 m. Its output, albeit not as high resolution as the hybrid technique, was able to rapidly record the enclosed spaces that were otherwise difficult to access with conventional scanners. The relative accuracy of the technique was 10–20 mm and the resolution varied depending on the proximity of the detail; it was able to more than adequately generate the elevations, cross sections, and ground plans. The scans also reflected ceiling plans that were required for the conservation architects.

A typical scan session would allow for 30 minutes of data capture during which the operator walked through the individual buildings, requiring only seconds of scanning within each room (fig. 7). It therefore proved possible to record up to four buildings, each with an average of four rooms, within each scan session. Allowing for survey control setup and the downloading and transfer of data, it was possible to undertake an average of eight scans per day. Ultimately, the survey of 950 buildings and approximately 3500 individual rooms was undertaken with the generation of 215 scans and was completed over two three-week survey seasons in 2019 and 2020.

At the time, the survey was believed to be the largest and most extensive integrated building survey ever undertaken using the SLAM technique (GeoSLAM, pers. comm.), demonstrating that it is possible to survey large, complex urban centers in 3D. Many of the buildings were in a state of collapse with no safe access, but even in these cases it was possible to obtain workable data by inserting the scanner on an extendable pole into remote locations through apertures. The limitation of the technique has been, if anything, in the processing of the survey data. The survey generated 24 terabytes of data and it was only possible to process, merge, and geo-reference relatively small areas of the town at a time. This was due to the limitations of software and computer processing capability, such that the processing took far longer than the data capture.

Because of the complexity and scale of the data, it could only realistically be examined with powerful computers and proficient operators. In order to provide workable data for the conservation team, 2D plans of all levels, cross sections, and elevations were generated in AutoCAD. While the dataset is large, the data are in .LAS and .DWG formats, which can be transferred and made accessible for other operators. There have been significant improvements in the processing software and the capabilities of the hardware in the three years since the data were processed, meaning that processing is now significantly quicker and can be undertaken in larger blocks.



FIGURE 7 Technician conducting a mobile SLAM scan survey in house interiors in Old Town. Photo: Jamie Quartermaine, Oxford Archaeology.

Conclusion

The task posed by the present study—to rapidly record the enormous complexity of such a walled town in 3D—is not a commonly faced challenge. The work necessitated the application and development of the most sophisticated building-recording techniques presently available. Carrying out the survey has highlighted the enormity of the challenge, both



FIGURE 8 Sample output from the mobile SLAM survey. Illustration: Jamie Quartermaine, Oxford Archaeology.

in being able to access all the structures and in the processing and management of the data. Nevertheless, and despite these constraints, it has been possible to complete the survey and achieve all the project goals: to generate a detailed 3D record of the Old Town and Oasis buildings, inform the conservation process, and provide a pre-intervention record.

The experience of developing these techniques has allowed the teams to use them for recording all comparable structures. The benefits of the strategy are considerable, since they have enabled an accurate recording of what are certainly quite irregular structures, mitigating the inevitable modifications on the structures imposed by conservation works. The capture of 3D data allows an understanding of the Old Town in ways that would not otherwise be possible, providing a better understanding of the historic development of the buildings, the hydrology, and the topography. Thus, the graphic and digital platforms enabled the analysis of the development of individual structures and, ultimately, of the whole town. In the longer term, these 3D models will also create invaluable archives for future generations of AlUla inhabitants keen to understand their heritage (fig. 8).

While the procedure has highlighted the challenges of processing the data, it has more than anything demonstrated that the way forward in the recording of architecture is to embrace 3D technology for all complex building remains. These essential data constitute the foundation of future conservation programs in the Old Town. One of these programs, the rehabilitation project of the buildings along the old caravan route, was started in 2020, directed by the RCU Site Management Department, and carried out by Environmental Quality International (EQI). It aims to revitalize AlUla Old Town both as a tourist attraction and as a socioeconomic development project. This is the starting point for other, future projects for AlUla Old Town that will focus on preservation through rehabilitation, with an embedded community engagement approach. In the longer term, and with a growing rehabilitation program aimed at providing modern relevance to the abandoned town, this 3D model will provide the only record left of AlUla Old Town prior to its revival.

Materials

Static Laser Scanner, Zoller + Fröhlich, www.zf-laser.com

Hand Scanner, Zeb Horizon, GeoSLAM Ltd., https://geoslam.com

AlUla Old Town and Oasis: Preliminary Results from the Study of the Farms Conducted within the Framework of the AlUla Cultural Oasis Project (Kingdom of Saudi Arabia)

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Abstract: *The main objectives of the AlUla Cultural Oasis Project (UCOP), led by Archaïos, funded and steered by the French Agency for AlUla Development (AFALULA) on behalf of the Royal Commission for AlUla (RCU), are to record long-term human occupation in the AlUla Valley (Hejaz region, Kingdom of Saudi Arabia) and to gain a better understanding of the oasis's long-term development in light of landscape archaeology. This is a research angle that has never been thoroughly developed to date. Archaeological structures were systematically recorded to create an accurate map of the oasis and enhanced documentation and detailed topographic surveys of significant architectural elements were conducted. This paper discusses one of the major components of the oasis, the farms, which are functional units comprising one or several cultivated plots and earthen buildings that serve both agricultural and domestic purposes according to previous ethnographic studies. They are now mostly abandoned. The spatial distribution of the farms in the oasis, their internal layout and organization, their structures, and their construction materials are presented and compared. Our work shows evidence that the 170 farms recorded so far are concentrated in three groups. It also confirms the domestic function of these farms, which comprise domestic units, reception areas, latrines, and, in some cases, baths. Furthermore, we highlight the fact that the distribution of most farms in two groups, separated from each other, demonstrates a social reality: the tribal structure of AlUla's society.*

Resumen: *El Proyecto del Oasis Cultural de AlUla (UCOP) está dirigido por Archaïos, financiado y coordinado por la Agencia Francesa para el Desarrollo de AlUla (AFALULA) y realizado en conjunto con la Comisión Real para AlUla (RCU); sus objetivos principales son registrar la ocupación humana a largo plazo del valle de AlUla (región de Hedjaz, Reino de Arabia Saudita) y comprender mejor el desarrollo del oasis a largo plazo ante un problema de arqueología del paisaje. Este es un enfoque de investigación que nunca ha sido desarrollado en profundidad hasta el momento. Se registran de manera sistemática las estructuras arqueológicas para elaborar un mapa preciso del oasis, y se realiza una tarea exhaustiva de documentación y estudios topográficos detallados de los elementos arquitectónicos importantes. En este estudio se debate acerca de uno de los componentes más importantes del oasis: las granjas, unidades funcionales de una o varias parcelas cultivadas y edificios de tierra que cumplen una función tanto agrícola como doméstica, según estudios etnográficos anteriores; estas granjas, en su mayoría, se encuentran actualmente abandonadas. Se presenta y compara la distribución espacial de las granjas en el oasis, la disposición y organización interna de cada una, y las diferentes estructuras que las componen, al igual que sus materiales de construcción. Nuestro trabajo ha permitido demostrar que las 170 granjas registradas hasta el momento se concentran en tres grupos. Asimismo, se confirma la función doméstica de estas granjas, que cuentan con unidades de vivienda, áreas de recepción, letrinas y, en algunos casos, baños. Se destaca también que la distribución de la mayoría de las granjas en dos grupos separados entre sí es la evidencia de una realidad social, la estructura tribal de la sociedad de AlUla.*

Keywords: archaeology, field survey, architecture, heritage, oasis, Saudi Arabia

Introduction

Oases represent a threatened worldwide cultural environment, notably due to urban development as well as climate change (Purdue, Charbonnier, and Khalidi 2018; Lavie and Marshall 2017). As they constitute illustrative examples of long-term human adaptation to arid environments, i.e., sustainable development, their protection and investigation is of prime importance.

The AlUla Oasis (northwestern Saudi Arabia) is one of Arabia's most significant oases, which thrived from the first millennium BCE due to the availability of water and its location on trade and/or pilgrimage routes (AlSuhaibani and Nehmé 2019). Archaïos has been investigating this stunning anthropogenic landscape since September 2019 in the framework of the AlUla Cultural Oasis Project (UCOP), funded and steered by the French Agency for AlUla Development (AFALULA) on behalf of the Royal Commission for AlUla (RCU). The priority of this interdisciplinary project is to understand the history of the AlUla Oasis and the joint evolution of its settlements, gardens, and water systems. UCOP also aims to contribute to the preservation of this unique heritage in the framework of the RCU master plan. This will be achieved through the identification of archaeological sites or heritage buildings that will be restored and conserved in order to be presented to the public. Indeed, one of RCU's goals is to make AlUla a world-class tourist destination as part of the Vision 2030 program carried out by the Kingdom of Saudi Arabia.

The AlUla Oasis, which now covers ca. 4000 ha, is located in the northern foothills of the Hejaz Mountains (fig. 1) at an altitude of 700 m above sea level, in a ca. 30 km long, north-to-south-oriented valley surrounded by sandstone plateaus. The area is characterized by a hyper-arid climate with low and irregular winter-spring rainfalls (Courbon 2008). Before the oil boom, the oasis was composed of the Old Town, located along the western cliff of the valley and currently investigated by other projects (see Gandreau et al., this volume; Bendakir, this volume), and a cultivated area, which extended to the center of the valley along the wadi channels. Groundwater appears to have been the main resource of the oasis and was exploited thanks to qanats and wells.

Currently, dates are the prevailing crop within the cultivated area of the oasis, but other fruit trees including various kinds of citrus, pomegranate, fig, and grapevines are also to be found. Up to the 1980s, cereals were an important part of the economy and were cultivated in open fields (Nasif 1988). Until recently, according to Nasif, inhabitants of AlUla Old Town (located on the western edge of the cultivated area) lived in secondary houses in their gardens from early summer to the beginning of fall, until the date harvest in October (Nasif 1988, 131). Nasif mentioned these "farms"—functional units comprising one or several cultivated plots (usually enclosed by walls) and buildings, serving both agricultural and domestic purposes—but they have not, to date, been fully inventoried and studied. Although many old gardens are still cultivated, houses were mostly abandoned during the late twentieth century.

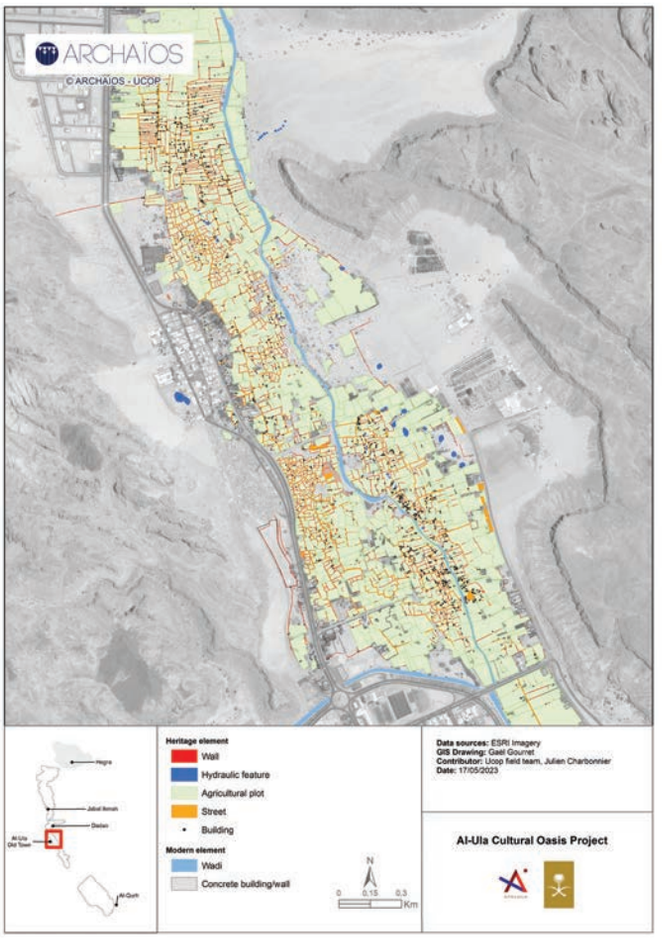


FIGURE 1 Archaeological map of AlUla's historical oasis. Map: G. Gourret, © Archaïos.

This paper focuses on the AlUla farms, and we make a distinction here between simple agricultural plots—devoid of any house—and farms, which include one or several buildings with domestic functions in addition to the plot. We provide information regarding their location and spatial distribution in the oasis as well as their architecture.

Methodology

Archaeological Survey

UCOP methodology derives mainly from landscape archaeology. To create the archaeological map of AlUla Oasis, the first step was the systematic inventory and recording of archaeological structures of any period, using survey forms. Survey teams also carried out photographic documentation and preliminary mapping of structures using printed copies of a 5 cm resolution ortho-photo map (kindly provided by RCU). Archaeological surface material was also collected, using structures as spatial contexts. In the lab, surveyors filled the project's database with information noted on the forms and sorted/processed photographs.

In parallel, a dedicated Geographic Information System (GIS) team vectorized archaeological structures in the UCOP geo-database (see fig. 1). Information was extracted by GIS specialists from the survey forms and sketch maps. Orthophoto maps and digital elevation models (DEM), obtained through Light Detection and Ranging (LiDAR) surveys, were also used as visual support for this process.

Architectural Survey

The architectural survey methodology was divided into two distinct steps. The first, in the field, was the architectural description of identified structures, including the definition of construction materials and their implementation. At the end of this phase, significant architecture (i.e., that displaying patrimonial, historical, and/or technical values) was identified in order to complete their detailed documentation. This second phase involved topographic surveys, notably comprising the elaboration of plans, sections, elevations, photogrammetric models, detailed architectural and technical descriptions, and complementary interviews with former inhabitants. The primary objective was to provide analytical documentation to be used as a reference and a reliable basis for further research on Arabian oases. In addition, the general state of preservation of the remains was registered in order to highlight the main threats to this valuable heritage.

Results

Organization of the AlUla Oasis and Spatial Distribution of Farms

About 280 farms have been identified in the vicinity of the Old Town to date, an area that corresponds to the historical core of the oasis. On the contrary, the northern part of the oasis, which was developed in the second half of the twentieth century, is almost devoid of farms (fig. 2). On the scale of the surveyed area, the farms appear to form three distinct groups. To the northwest, the first group includes eighty clustered, fairly large[1] east-to-west-oriented farms. A second group, to the southeast, is composed of about 120 farms with multiple orientations. These farms are smaller[2] and more scattered than those of the first group, rendering it difficult to delimit the extension of this second set. Between these two, a third group comprises about eighty scattered and poorly preserved farms. These farms all incorporate agricultural plots and domestic units, and frequently also include latrines. It should be noted that the first two groups of farms include animal pens, as well as distinctive facilities such as *majlis* (reception areas) and bathhouses.



FIGURE 2 Spatial distribution of farms within the oasis. Map: J. Gravier, © Archaïos.

By comparing the data of the farms' surface area with information regarding the types of activities attested in each of them (agriculture, domestic work, small-scale pastoralism, etc.), there seems to be no correlation between the size of farms and related activities (see fig. 2). Rather, one observes a wide variety of cases that range from large farms with few structure-specific activities to smaller farms with multiple functions (fig. 3, top graph).

Still, one observes a link between the size of farms and the presence of particular facilities (majlis and/or baths). Indeed, even though examples are numerous (fig. 3, bottom graph), farms with a Majlis are on average 25% larger than those without, while those including a bath are on average 10% larger. Moreover, the smallest farms with a Majlis or a bath are systematically larger than roughly the first quarter of farms devoid of such facilities. In other words, the owners who built structures dedicated to hosting visitors and/or bathhouses usually had larger properties.

Detailed Investigation of Three Selected Farms

In order to outline the different characteristics of the oasis farms, we present the analysis of a well-preserved block, delimited on all sides by streets. Located in the first group of farms (see fig. 2), this block includes at least six farms and two agricultural plots devoid of any construction (fig. 4). So far, three farms of this block were thoroughly investigated in spatial, technical, and functional terms. A comparative study was also undertaken.

The comparison of the different available data collected since 2019 enables the observation of certain regularities, particularly in regard to material choices and construction techniques. However, these recurrences do not exclude the existence of a variety of patterns. Indeed, the three farms, recorded as "heritage places" OS_00206 (fig. 5), OS_00218 (fig. 6), and OS_00617, are contiguous and their delimitations relatively similar. However, their analysis showed that they all display their own characteristics. These differences manifest notably in the organization of internal spaces, the circulation dynamics, and the function of the different parts of the farms. At least two main occupation phases were observed. However,

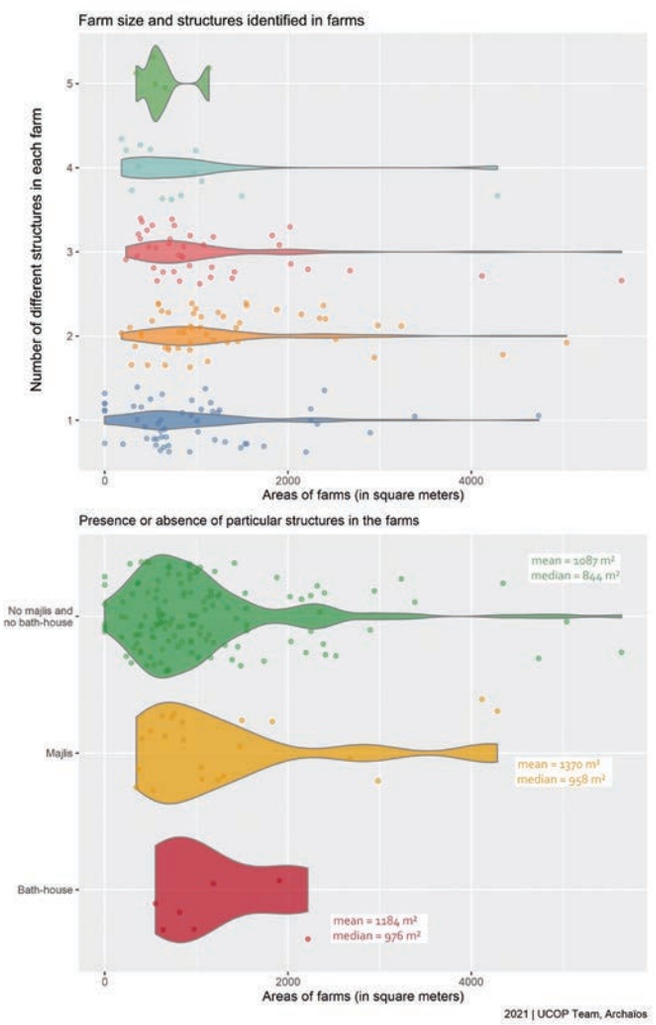


FIGURE 3 Comparison between the size of the farms and the types of structures identified in them. Graphs: J. Gravier, © Archaïos.



FIGURE 4 Detailed map of the farm block under study. Map: J. Gravier, © Archaïos.

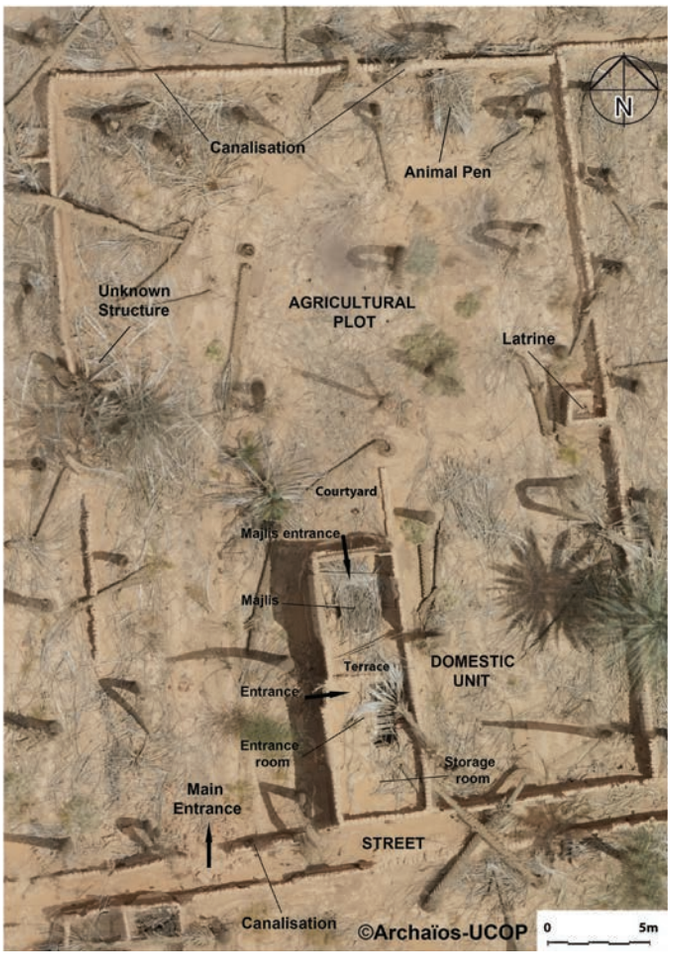


FIGURE 5 Interpreted ortho-photograph of farm OS_00206. Illustration: E. Devaux, © Archaïos.

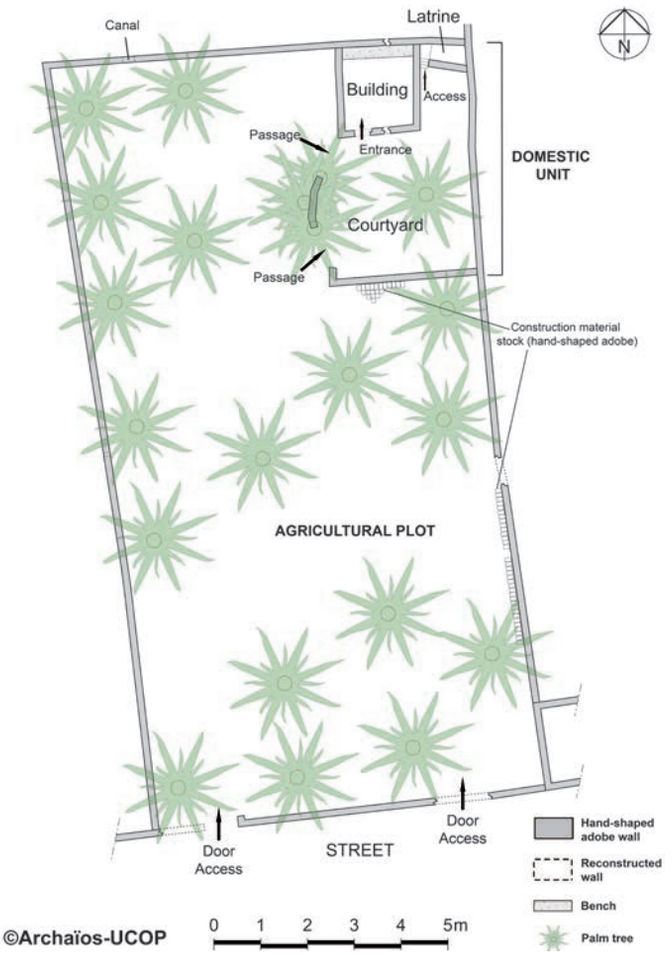


FIGURE 6 Plan of farm OS_00218. Illustration: A. AlHemiddi and E. Devaux, © Archaïos.

in the current state of our research, the first phase is not yet completely understood. We shall not discuss these evolutions in detail in the context of this article, but will focus on the final and current state of these farms, corresponding to the second phase.

In addition to rectangular agricultural plots mostly dedicated to date palm cultivation, the farms studied include vernacular constructions (either in front or to the rear of the farms) that display domestic functions, regardless of their size and internal divisions. The analysis of the latter will be published in a forthcoming, more detailed study. What distinguishes each farm are the multiple facilities it contains, such as latrines, animal pens, Majlis, and other structures whose uses are still uncertain, as seen in figure 7. All of these structures, including the domestic unit, are mostly adjacent to the plot boundary. The presence or absence of facilities might reflect, in addition to the surface area of the plot, the presence of sophisticated architectural elements, the overall construction quality of the farm's various parts, or the social status of the landowners.

As far as building materials of the farms are concerned, three main raw materials are noted: stone, earth, and vegetal elements. These materials perfectly match the local natural resources. Builders had to adapt to their environment in the choice of appropriate materials to achieve the best possible solid and watertight constructions that would both last and meet the environmental constraints. Earth is predominantly used in the construction of farms and their annexes, particularly in the form of hand-shaped adobe clods.[3] Molded mud bricks and stones, seen in the door masonry for farm entrances or domestic units, are less frequently used in construction. Mud was used to manufacture the mortar and coating required for wall construction and solidification. The use



FIGURE 7 Associated structures on farms. Photos: E. Devaux, © Archaïos.

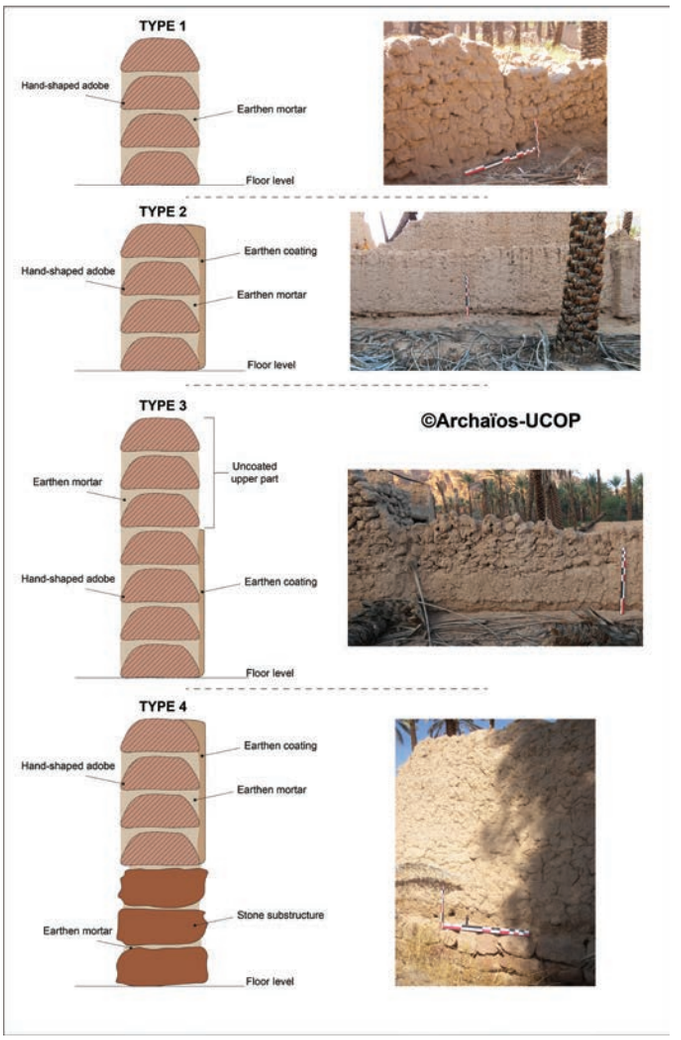


FIGURE 8 Four types of wall construction techniques identified at the studied farms. Illustration: Y. Kanhoush, © Archaïos.

of wood and vegetal elements is also widely documented, particularly for the roofing of the various structures in the oasis or for the construction of stairs, shelves, etc.

Our observation of the farms' building techniques revealed a great diversity, where a mix of several methods might be used on one farm. Four construction techniques could be identified in the masonry of the enclosure walls of the different structures under consideration (fig. 8). The use of a specific technique has no impact on the structure's function, except for some types of construction intended for domestic use requiring special attention to ensure their long-term stability (e.g., stone foundations or impermeable coatings for structures in close contact with water).

The preliminary study of AlUla Oasis Farms, through the detailed analysis of these three examples, highlights their diversified character in terms of spatial organization, construction techniques, architectural details, and, above all, activities that took place there, materialized by structures with specific corresponding functions. However, one ought to keep in mind that the presence or absence of such structures does not necessarily imply the non-practice of a specific activity. On the other hand, it may provide insights into the socio-economic status of the farm owners.

Conclusion

Our preliminary study of AlUla's farms suggests they are to be considered as an extension of the Old Town, to which they

were connected by circulation axes. Furthermore, these farms also served as seasonal dwelling places in which at least part of the Old Town's inhabitants lived during summer, approximately five months per year according to Nasif (1988, 131). Our survey confirms this information and provides evidence that the cultivated area was more than just a place devoted to agricultural activities. Indeed, the farms comprised—in addition to cultivated plots—domestic units, reception areas, latrines, and sometimes baths, and thus also served a clear domestic purpose.

Moreover, in many ways the cultivated area mirrors the Old Town and its urban structure. It is characterized by a dense and hierarchized street network, with main streets known as *Souq* (just like in the Old Town), and secondary alleys, public squares, and mosques located exclusively within the farm clusters (see figs. 1, 2).

To date, two main clusters of farms have been identified: Group 1 to the north of the Old Town and Group 2 to the southeast. Our preliminary results show that this spatial organization identifies a social reality—the structure of AlUla's society. Although preliminary in nature, our interviews with former inhabitants revealed that Group 1 was populated by members of the Shuqaiq clan and Group 2 by those of the Hilf clan (see fig. 2).

In recent periods and up to today, AlUla's population is essentially made up of members of these clans. This social division was also materialized spatially in the Old Town, with each clan living in a specific district—the Shuqaiq to the north and the Hilf to the south (Nasif 1988, 133). Hence, our work reveals a similar spatial division within the cultivated area of the oasis. We also learned that Tidaʿil qanat (north of the Old Town), and its associated irrigation system, extended toward the east and southeast and used to belong to the Hilf clan (Nasif 1988, 173). One is therefore left to wonder if all land and water systems in AlUla were divided in the same way. Further investigations will hopefully help shed light on this question.

Thus, our objective for the coming years is to develop a detailed analysis of the AlUla farms for two main reasons: (1) this kind of vernacular environment that mixed agricultural and urban purposes has never been analyzed in northern Saudi Arabia, and (2) because, as this preliminary study demonstrates, this landscape is of inestimable scientific and patrimonial interest. Additionally, our study should help in establishing guidelines for restoring the farms and making them accessible to local and foreign visitors. Indeed, the cultivated space of the oasis is as important as the Old Town and other major pre-Islamic settlements.

Acknowledgments

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Notes

1 The average size of the first group of farms is 1396 m², while the median is 1028 m².

2 The average size of these farms is 1179 m², while the median is 933 m².

3 Thick, manually shaped clods. After being cast, they are left to dry in the sun.

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AlUla Old Town: Interdisciplinary Approaches to Assess the Heritage Values of an Ancient Oasis City in Saudi Arabia

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Abstract: *The Old Town of AlUla, partially built with earth, has been the subject of an innovative research program linking architecture, archaeology, ethnology, and heritage conservation approaches since November 2019. The objectives of this research program are to assess the heritage values of this particularly dense and compact agglomeration in an oasis context and to contribute to the definition of appropriate guidelines for its long-term management and conservation, as requested by the Royal Commission for AlUla (RCU) and the French Agency for AlUla Development (AFALULA). In the first part of this paper, the specific research program led by CRAterre in conjunction with various scientific partners (EVEHA, HCC, Archaïos) and the local community is presented. The specific features of the Old Town under study are described, the research hypotheses are presented, and research methodologies reflecting the interdisciplinary character of the project are explained. In the second part, the following preliminary results are discussed: (1) characterization of the earthen building materials, (2) evolution of the built fabric, and (3) construction cultures and building principles by associating early bioclimatic approaches at different scales (buildings, streets, quarters, towns, and farms). The third part elaborates on the possible contributions of this research on the Old Town, built with local materials, to the sustainable development of the wider AlUla region.*

Resumen: *Desde 2019, el pueblo antiguo de AlUla, construido en parte con tierra, es objeto de un innovador programa de investigación que une arquitectura, arqueología, etnología y enfoques de conservación del patrimonio. Los objetivos de este programa de investigación son evaluar los valores patrimoniales de esta aglomeración particularmente densa y compacta en el entorno de un oasis, y contribuir a la definición de las pautas adecuadas para su gestión y conservación a largo plazo, según lo solicita la Comisión Real para AlUla (RCU) y la Agencia Francesa para el Desarrollo de AlUla (AFALULA). En la primera parte de este artículo, se presenta el programa de investigación específico que dirige CRAterre junto a diferentes socios científicos: Études et Valorisations Archéologiques [ÉVEHA], Heritage Conservation Consulting [HCC], Archaïos, así como la comunidad local. Se describen las características específicas del pueblo antiguo que se estudia, se presentan las hipótesis de la investigación y se explican las metodologías que muestran el carácter interdisciplinario del proyecto. En la segunda parte, se analizan los siguientes resultados preliminares: (1) las características de los materiales de construcción de tierra; (2) la evolución del tejido urbano; y (3) las culturas constructivas y los principios de edificación. Este análisis se realizó por medio de la asociación de los primeros enfoques bioclimáticos a diferentes escalas (edificios, calles, barrios, pueblo y granjas). En la tercera parte, se profundiza en las posibles contribuciones de esta investigación del pueblo antiguo, construido con materiales locales, al desarrollo sostenible de la región de AlUla en general.*

Keywords: AlUla Old Town, earthen heritage values, interdisciplinary, construction cultures, heritage, development

Introduction

Situated on the edge of Wadi AlQura, AlUla is at the heart of Saudi Hijaz territory, which for centuries has been crossed by caravan routes linking the southwest to the north of the Arabian Peninsula. The first urban settlements of Dadan (AlKhuraybat) from the sixth century BCE; Hegra (Madain Saleh), abandoned in the fifth century CE; and Qurh (AlMabyat) in the Islamic period bear witness to this millennia-old history linked to the commercial exchanges that built the reputation of this singular region (Nehme 2019; Rohmer and Charloux 2015).

Occupied until the end of the 1970s, the Old Town of AlUla is heir to this history. Fifty years ago, it was still the main settlement in the valley (Nasif 1995). Despite four decades of neglect and a state of advanced ruin in some areas, the Old Town proudly unfolds with its two main districts on either side of the fortress: the Al Halaf district in the north and the Al Shaiq district in the south.

The 900 or so houses, winding streets and alleys, squares, mosques, and other public buildings bear witness to the last phase of its urban development. The town was then linked to the airy gardens and houses of the Oasis Farms below on the eastern side, where the inhabitants came to seek comfort during the hottest periods of the year (fig. 1).

Since November 2019, and at the request of the French Agency for AlUla Development (AFALULA) and the Royal Commission for AlUla (RCU), CRAterre has been leading a research program aimed at assessing the heritage values of this particularly dense and compact agglomeration in an oasis context. This research is undertaken in conjunction with scientific and operational partners involved in field activities: EVEHA, Archaïos, HCC (Heritage Conservation Consulting Inc.), and the participation of the local community.

The heritage values of the Old Town and the Oasis Farms are being assessed holistically, including architectural and urban analyses, archaeological investigations, and anthropological studies. This integrated methodological approach, based on a series of linked interdisciplinary activities, will allow for the implementation of adapted conservation/rehabilitation measures at the highest international standards and will contribute to the sustainable development of the wider AlUla region.

Preliminary Results

Characterization of Earthen Building Materials

Field tests and grain-size distribution analysis carried out on thirteen samples of mud bricks from different locations in the Old Town and the Oasis Farms revealed a high similarity of the soils used (Gandreau et al. 2021). These results tend to confirm a very local provenance of the raw material resource as conveyed by former inhabitants of the Old Town.

In addition, the analysis of twenty-five soil samples from potential quarries within a radius of 20 km from the Old Town made it possible to select two of them and to develop materials



FIGURE 1 General view of the Old Town and Oasis Farms from the west. Photo: Sébastien Moriset, © CRAterre AFALULA.



FIGURE 2 Production of mud bricks to be tested as part of the research protocol for the conservation of earthen structures in the Old Town and Oasis. Photo: Sébastien Moriset, © CRAterre AFALULA.

suitable for the conservation of earthen structures (fig. 2). In order to carry out all these analyses, a field laboratory was installed directly on the site.

Evolution of the Built Fabric

By comparing the current state of the town with the archive photos taken by Jaussen and Savignac at the beginning of the twentieth century, research has demonstrated certain evolutions of the built fabric from the Ottoman period onward (Jaussen and Savignac 1914). In particular, the images show that buildings on the northernmost side have replaced gardens that existed in 1910. These historic photos also show that there have been some changes along the Incense Route, which runs along the western edge of the town at the foot of the cliff. Modifications are particularly remarkable in the area of the southernmost gate, showing an evolution of the defensive system during or after the Ottoman period (Gandreau et al. 2020).

A number of other clues are inscribed on the town walls and in its foundations. Architects and archaeologists have been carrying out initial studies over the past two years in order to identify tangible evidence that could help to understand the urban evolution of the town. They include an ongoing systematic inventory of each building, listing all the significant elements and organizing them under various typologies ranging from the presence of inscriptions on the stones to the shape of the openings or the decoration patterns and motifs. At the same time, the archaeological study of two selected areas built in the center and south of the town has revealed multiple phases of construction (Fiocchi et al. 2020).

Construction Cultures and Building Principles

The studies show how, over the centuries, the inhabitants and builders of this oasis set up an optimal lifestyle with very limited resources. This remarkable human settlement offers a real lesson in sustainability derived from a precise analysis of essential needs and a perfect understanding of the available natural resources.

Recent research in vernacular architecture shows that an oasis in the desert, as an island in the sea, always provides the best examples of adaptation, due to the fact that geographical isolation offers no other option for survival (Guillaud et al. 2014; Correia, DiPasquale, and Mecca 2014). Long, empty distances make it difficult to import materials in great quantities and material resources are therefore restricted to the surroundings. Meanwhile, intangible resources come with the flow of travelers crossing the desert, from Syria or even western and northern countries, to Medina and Southern Yemen (Al-Ghaban 2019). Pilgrims and caravan trails along the Incense Route arrived regularly in AlUla and stayed there for some time before continuing their journey. Typical for oases and islands, this happened continuously over the centuries, so the normal evolution of a vernacular culture is reinforced in these cases by the exchange of knowledge between sedentary and traveling populations.

Knowledge and skills acquired through this culture of exchange are of great value in a desert environment. In the case of AlUla, nature provides everything in large quantities: sandstone and basalt rocks, palm and tamarisk trees, earth, sand, and water. Over the past 800 years,[1] an entire building culture has progressively developed with these types of raw materials alone. Walls, floors, roofs, stairs (fig. 3), parapets, *tayaras* (private rooms over public streets) (fig. 4), stone patterns, carvings, and decorations are some of the architectural elements found and described in AlUla Old Town Conservation Guidelines. These were all built using only stone, earth, fibers, and wood (Gandreau et al. 2021).

In terms of adaptation of this architecture to the realities of the valley, the first striking feature is the consideration given to natural hazards. Thanks to an intelligent urban settlement layout, AlUla Old Town withstood the elements for centuries despite the region's heavy and windy winter rains. Most of the streets avoid facing the winter winds coming frontally from the northwest, and, at the same time, their slopes channel rainwater from the west's high rocks toward the lower, eastern Oasis Farms. Water-resistant stone basements and smart drainage devices are the fundamental shields protecting these



FIGURE 3 A stone staircase with a large floor supported by a pillar in an Old Town house. Photo: Nuria Sánchez Muñoz, © CRAterre AFALULA.



FIGURE 4 An example of the most common pattern for a *tayara* facade in the Old Town. Photo: Nuria Sánchez Muñoz, © CRAterre AFALULA.

earthen walls, which otherwise would easily turn from stone to mud. Earthen materials keep their strength as long as they are allowed to dry out after the rains. The same applies to the ground on which houses are built: water stagnation reduces the bearing capacity of the ground and leads to structural deformations. Deformed walls and heavy wet roofs create a danger of collapse. AlUla Old Town walls and roofs are not covered with waterproofing materials. They are exposed to the rain, but they also easily dry. This process, which kept buildings stable for centuries, was under the control of AlUla builders and inhabitants. If the Old Town is caught up in an accelerating degradation process, it is because it has been abandoned



FIGURE 5 Chiaroscuro effect of a street in AlUla Old Town. Photo: David Gandreau, © CRAterre AFALULA.

for more than forty years, and building maintenance and the vital clearing of spouts, streets, and underground channels have been neglected.

This vernacular culture has also coped with extreme hot weather. The use of earthen materials and stones is of great advantage here, as these materials have good thermal inertia that allows them to keep interiors cool and comfortable when temperatures fall during the night. But a more specific feature of AlUla's urban design is its canopy of *tayara*s covering the narrow streets (fig. 5). *Tayara*s, also named *saqaif*, were supported by the walls of the houses on both sides of the street. An owner wishing to build a *tayara* would ask his neighbor for permission. If it was accorded graciously, the builder would give the name of his neighbor to his own *tayara*. This shows that the fabric of AlUla Old Town was solid at both an urban and a social level.

Finally, AlUla inhabitants used intelligent, adaptive ways of living. They lived in the Old Town during wintertime and moved to their farms during hot summers. The Oasis Farms are part of AlUla and form a coherent entity with the Old Town. Local resources (stones, soils, plants, and water), the knowledge developed (building, farming, and water management), and the culture of hospitality and exchange make AlUla an excellent example of a constantly evolving cultural landscape throughout history.

Contribution to the Sustainable Development of the Wider Region

Looking Back

When one looks at the Old Town from the air—its dense and tight network of streets, the outer walls of the peripheral

houses that serve as natural ramparts, and the acropolis where the inhabitants sought protection—its structures are reminiscent of many cities of the ancient Near East from the Bronze Age to the pre-industrial era. It is as if this pattern of city development has remained unchanged through the ages.

Similarly, stone and mud brick were the main construction materials in the region for several millennia until the last quarter of the twentieth century, according to a chain of operations (for a step-by-step analysis of a production process) that remained almost unchanged. These materials were available and within reach in the fertile lands in the shade of the palm groves.

However, the study of mud brick domestic architecture has long been neglected in favor of monumental constructions. The recent investigation of the architecture in AlUla seems to have allowed reinvestment in an area of research that had been abandoned for too long, possibly because of its perceived unimportance, but also due to the fact that the remains on archaeological sites are too deeply buried or simply have disappeared. More research is being done today, but it requires an interdisciplinary approach that combines archaeological data with anthropological information and written sources, fundamental to understanding the plurality of the manufacturing process and its evolution through the ages. The holistic approach undertaken this way on such recent remains will undoubtedly lead to a better understanding of archaeological sites where only the foundations or first courses remain, for which the degree of uncertainty in any reconstruction is very high.

Moving Forward

The oasis's cultural landscape values underpin the master plan for AlUla's development, titled A Journey through Time. The intention of this plan is reflected in the quality of new construction and renovation projects: architectural jewels, urban fabric, buildings, new infrastructure, landscaping interventions, farm regeneration, water management, and projects addressed to the local population and to tourism. All of these aspire to reconcile human development and nature preservation. AlUla is a major component of Saudi Arabia's Vision 2030. Drawing inspiration from its rich heritage, the kingdom aims to move toward a sustainable future as a model of cultural creativity across the region.

The projects at AlUla Old Town and the Oasis Farms were departure points for this new vision, and their preservation has been the result of the work of a range of actors coming from very different backgrounds: architecture, archaeology, history, anthropology, ethnology, sociology, and biology. These interventions help the Old Town regain life and stimulate reflection on the different ways of revitalizing such a complex without destroying its authenticity. Conservation guidelines and participatory workshops are in development to build awareness and share the acquired experience (fig. 6). The materials' study (Gandreau et al. 2021), together with the construction of sample walls (Sanchez Munoz, Moriset, and Venton 2019) (fig. 7), shows that the soil used for centuries was of very good quality, but also that other local soils can



(a)



(b)

FIGURE 6 (a) Participants in a Discovering Soils Workshop for AlUla community members held in March 2021 in the Old Town, and (b) participants in a Discovering Earthen Plastering Workshop. Photos: Nuria Sánchez Muñoz, © CRAterre AFALULA.



FIGURE 7 Sample wall with decorative plastering options. Photo: Sébastien Moriset, © CRAterre AFALULA.

serve in the production of new materials for contemporary developments.

In order to move on to an operational phase of reviving ecologically responsible architecture, two pilot production units have been established—one for earthen materials and one for vegetal fibers. These new production centers will allow for the creation, testing, characterization, and use of locally manufactured building materials. The testing units will also host small-scale production efforts in order to help develop best practices and guidelines and will lead training programs targeting building professionals in order to scale up at all levels. Initially, local materials, know-how, and knowledge will be provided to architects who will be asked to design high-quality demonstration buildings that will make everyone want to acquire these local materials.

This work seeds two larger projects: the Knowledge Centre, entirely devoted to hands-on training and ongoing research in more sustainable architecture, and the Industrial Production Unit, where the large-scale production of materials will be launched and products can therefore economically compete for public sale. Current producers of industrial materials will also be supported to help them diversify their production and invest in the manufacture of non-polluting local materials rather than in the fabrication of conventional cement blocks or energy-embodied items.

The program is huge and complex, but its principles are clear. Building codes under development aim to respect nature by minimizing the ecological footprint going forward. This involves matching building materials, colors, and textures with the environment in order to do at least as well as former civilizations did.

Note

1 Extract from AlUla Old Town Draft Conservation Guidelines: "yet a few questions about its origin and development remain unclear. Current research aims to clarify the information provided by ancient texts, mentioning in particular a visit of the Prophet Muhammad to AlUla during the Tabûk expedition in 630, as well as an important development linked to the decline of Qurh from the 12th century onwards" (Gandreau et al. 2020, 54).

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AlUla Old Town and Oasis: Pilot Project and Best Practice Conservation Guidelines

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Abstract: *The Royal Commission for AlUla (RCU) appointed HCC Heritage Conservation Consulting Inc. to implement a conservation program at AlUla Old Town, Kingdom of Saudi Arabia, including associated structures in the adjacent Oasis Farms. Work started in October 2019 to carry out an accurate 3D laser scanning survey of the site, identify and study causes of deterioration, and implement conservation work. A multidisciplinary team of specialists has been proposed by HCC to develop best practice strategies to inform guidelines for executing large-scale conservation and stabilization work. This paper describes the work of the HCC team, focusing on conservation work in a pilot area comprising thirty-one units, two mosques, and 275 linear m of streets. The causes and processes of decay have been mapped and a building-by-building inventory developed. In addition, a hydrogeotechnical study addressed environmental, hydrological, and structural factors and investigated traditional stormwater drainage management. Within the pilot area, structural stabilization and preventive conservation techniques have been tested on houses in danger of collapse. The main tasks included testing conservation and stabilization methods and techniques, identifying and testing traditional materials (with CRAterre), proposing protocols for archaeological cleaning (the removal of collapsed materials inside the units and streets to be able to reach the original ground floors), developing a training program, improving site drainage, stabilization and minor repairs to street facades and for* tayarah*s covering alleys, stabilization and support for walls and roofs (thirty-one houses), and preventive conservation work for selected features, including timber doors and wall paintings. A technical guidebook has been produced reflecting the results of studies and work implemented in the pilot area and providing guidelines, methodologies, and techniques for the conservation and restoration of historic earthen buildings.*

Resumen: *La Comisión Real para AlUla designó a Heritage Conservation Consulting Inc. (HCC) para implementar un programa de conservación en el pueblo antiguo de AlUla, que incluye las estructuras relacionadas con éste en el oasis adyacente. Los trabajos comenzaron en octubre de 2019 y consistieron en realizar un escaneo láser en 3D de todo el sitio, estudiar las áreas seleccionadas, identificar y corregir las causas del deterioro, e implementar trabajos de conservación preventiva. HCC propuso un equipo multidisciplinario de especialistas y partes interesadas para el desarrollo de las estrategias de prácticas adecuadas que sirvan de guía a la hora de ejecutar los trabajos de estabilización a gran escala. En este artículo, se describe el trabajo del equipo de HCC, con un enfoque en los trabajos de conservación en un área de prueba que comprende 31 unidades, 2 mezquitas y 275 metros lineales de calles. Se identificaron las causas y los procesos de deterioro, y se elaboró un inventario de todos los edificios con evaluaciones detalladas de su estado. En los estudios hidrogeológicos/geotécnicos y estructurales, se abordaron los factores ambientales, hidrológicos y estructurales, y se investigó la gestión tradicional de las aguas superficiales. Dentro de la zona de prueba, se ensayaron los trabajos de estabilización estructural y conservación preventiva en casas con peligro de derrumbe. Los trabajos principales incluyeron probar los métodos de conservación y las técnicas de estabilización, identificar y probar los materiales de conservación (con CRAterre), proponer protocolos de limpieza arqueológica, desarrollar la capacitación, mejorar los drenajes, estabilizar y hacer pequeñas reparaciones en las fachadas y a* tayaras *que cubren los callejones, estabilizar y dar soporte a paredes y techos de 31 unidades, y realizar trabajos de conservación preventiva de elementos seleccionados, incluidas las puertas de madera y las pinturas murales. Se ha elaborado una guía técnica en colaboración con CRAterre que refleja los resultados de los estudios y trabajos realizados anteriormente en la zona de la prueba piloto; esta guía contiene pautas, metodologías, procedimientos y técnicas para la conservación y la restauración de edificios históricos de tierra.*

Keywords: AlUla Oasis, AlUla Old Town, earthen architecture, 3D modeling, laser scanning, conservation strategies, heritage preservation

AlUla Oasis: A Landscape of Heritage, Nature, and Culture

AlUla, and its adjacent Oasis Farms, is an outstanding example of a typical oasis settlement. It has been a significant commercial center in the northwestern Arabian Peninsula since ancient times. Situated on the west side of Wadi AlQura, at the intersection of caravan trails linking southern Syria and northern Hijaz to the Arabian desert, its location makes the oasis of AlUla an important stop on both the north–south and east–west traverses of the Arabian Peninsula, and a landmark on the pilgrimage route between Syria and the holy cities of Mecca and Madinah.

AlUla Old Town (Hayy AlDairah) comprises a dense urban fabric in which residential units are crammed together and linked by a network of narrow streets. The Old Town covers a built area of approximately 67,286 m² with 908 housing units and five historic mosques. These are connected through a network of 3135 linear m of streets and covered alleys and about 260 *tayarahs*,[1] which span the streets at the first-floor level. The urban fabric is composed of two historic neighborhoods divided by the rock where the Qalat Musa Bin Nusayr citadel stands. To the south is the AlHalaf quarter and to the north, the AlShqaiq quarter (fig. 1).

The buildings of AlUla Old Town and Oasis Farms are constructed from materials obtained locally in a combination of earthen and stone architecture, and their design was influenced by the demands of climate. Materials comprise soil for bricks, sandstone blocks, palm and *athl* (tamarisk) wood, and palm fronds. Stone masonry bonded with mud mortar was used in foundations and ground-floor walls while the upper floors were built primarily with handmade or molded mud bricks. This technique is typical throughout AlUla and has been used from ancient times until the modern era (fig. 2).[2]



FIGURE 1 View of the pilot project area and Old Town, looking north toward the AlShqaiq quarter. Photo: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.



FIGURE 2 Remedial conservation work in the Oasis Farms. Photo: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.

Conservation Strategy

This program was designed to prepare an approach and methodology for the safeguarding and long-term preservation of all the buildings within the Old Town and its adjacent Oasis Farms. This has included:

- Performing a comprehensive architectural and topographical survey and a full physical study to ensure that each area is fully documented and assessed;
- Carrying out urgent stabilization and immediate conservation works on a number of buildings in extreme risk of collapse;
- Developing a pilot project for small-scale testing of conservation materials and techniques in a real setting to establish best practice guidelines for future site conservation and development.

These activities will enable the creation of the technical and scientific database needed to prepare the conservation plan and guidelines for any future development strategy. The

conservation guidelines guarantee the implementation of internationally accepted standards, already tested and evaluated on-site, during the future conservation of all historic buildings in the core and buffer zones of the Old Town and Oasis Farms. Thus, the guidelines support the overall strategy for the revitalization of the Old Town and its adjacent Oasis Farms.

Our activities involved the development of projects and studies for the identification, inventory, mapping, and documentation of all heritage buildings and implementing remedial work for buildings and structures in danger of collapse. These were achieved by:

- Collecting existing documentation;
- Completing a building inventory and condition assessment (Geographic Information System [GIS] database platform);
- Performing architectural and topographical surveys;
- Executing remedial conservation treatments: site cleaning, drainage, repairs, and temporary stabilization of structures in danger of collapse;
- Preparing best practice conservation guidelines (Conservation Guidebook);
- Encouraging local community participation, training, and the development of local capacity and skills;
- Preparing the site maintenance program.

In parallel with the above, preventive conservation works were implemented in an experimental pilot project as a first step for safeguarding, conserving, and maintaining the site.

Given the extent of the site and the large number of buildings to be conserved and stabilized, this project posed challenges of a scope rarely attempted before. The fragility of the buildings and their poor condition, together with a lack of skills and standards in urban and earthen architectural heritage conservation, presented a serious challenge. Priority was given, therefore, to testing and training in order to build local capacity and define appropriate conservation techniques and materials before applying treatments on a large scale. A test area was selected, and a multidisciplinary team was engaged to carry out remedial conservation works on selected buildings. The results will guide future conservation and development projects throughout the Old Town and Oasis Farms.

Site Documentation and Studies

Prior to physical intervention, a full survey and studies for documenting the current conditions of urban and architectural fabric were needed. Advanced methods of 3D laser scanning were used. This work was carried out under the control and supervision of, and according to the methodology prepared by, HCC. This work was a joint effort with Oxford Archaeology North, who undertook an indoor building survey, and Geokali, who worked on the outdoor survey of buildings and street facades. The results of these two techniques were used as the basis for the full set of architectural and topographical drawings produced by the HCC drawing team and as a reference for all conservation, adaptive reuse, and site development projects in historic AlUla (fig. 3).

Building Inventory and GIS Database Platform

The building inventory was implemented by HCC in collaboration with Archaïos and CRAterre to provide an existing condition record of all buildings. Each building was surveyed to collect as much information as possible, thus providing the basis on which to add information as buildings become more accessible or for planning future conservation intervention.

The amount of information produced and managed, along with the need for spatial information and cartographic views, made the development of a database a vital necessity. Thus, a GIS platform was required for this stage of the project to save time on repetitive data collection and to minimize errors in data recording fieldwork.

The software selected for this purpose is a free, open-source software (FOSS), QGIS, designed to gather all data in a single database that comprises a building inventory, condition assessment, and archaeological survey (pilot area only). The QGIS platform can be used for the statistical analysis of data collected to determine significant site-wide pattern distributions as well as for the analysis of different layers to study the suitability of future intervention on the site.

Condition Assessment

As with many earthen heritage sites in Saudi Arabia, AlUla Old Town was abandoned in the 1980s, and the subsequent lack of maintenance is the most significant cause of deterioration. Human factors including urban stress, vandalism, and poor-quality, post-abandonment conservation works have added to the site's degradation.

A detailed survey and full building-by-building inspection involving a complete examination of historic structures was proposed to identify the sources of threats and to map all the decay processes. This study was based on visual observation



FIGURE 3 CAD drawings showing (top) street facades and (bottom) overall ground-floor plans for AlUla Old Town. Drawings: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.

of foundations, walls, ceilings, and roofs to assess the quality of building materials and other threats. The nature and sources of erosion and their effects and threats were identified, examined, and documented. Decay processes caused by natural conditions and human activities post-abandonment such as neglect, vandalism, recent restoration works, and modern urban development were studied. The condition assessment covered all observed erosion patterns to increase our understanding of the decay processes and to establish a scientific understanding of typical pathologies affecting historic structures.

Observed causes of degradation and collapse were identified, documented, and studied. These covered natural decay factors, water-related pathologies, structural pathologies, human factors, and animals and termites. A typology of all observed pathologies was established by grouping them according to their origins, and a pictogram was proposed for each erosion indicator to simplify diagnosis. For each pictogram, appropriate solutions were proposed. Thus, for each unit assessed, a summary diagnosis form was established with corresponding recommendations for technical treatments.

Drainage Study: Site Drainage and Topography

The natural slope of AlUla Oasis runs downward from Old Town on the west to the Oasis Farms on the east. Traditionally, the streets and alleys were important for this drainage, where rainwater flowed along the streets toward the oasis gardens. Results of the drainage study, corroborated by local knowledge, show an underground network of *saradib* (channels) constructed to conduct rainwater to the gardens beneath the dense urban fabric. The progressive collapse of buildings over the last forty years has created a new site topography that requires urgent intervention. Rubble and garbage must be

cleared to improve drainage, to safeguard the fragile buildings by reducing risks of further collapse, and to provide safe access for visitors and teams working in Old Town.

Rainfall and the resulting severe flooding are the main threats to the preservation of Old Town. Recent changes in topography, including modern developments to the west and east of Old Town, including the construction of the dual carriageway between Old Town and Oasis Farms, have severely impacted traditional water management systems. A list of recommendations, resulting from the drainage study and hydrological and hydraulic modeling of the critical surface water flow patterns, was proposed and submitted to RCU. The modeling shows the main flash stream flows, flood zones, and water stagnation areas (fig. 4).

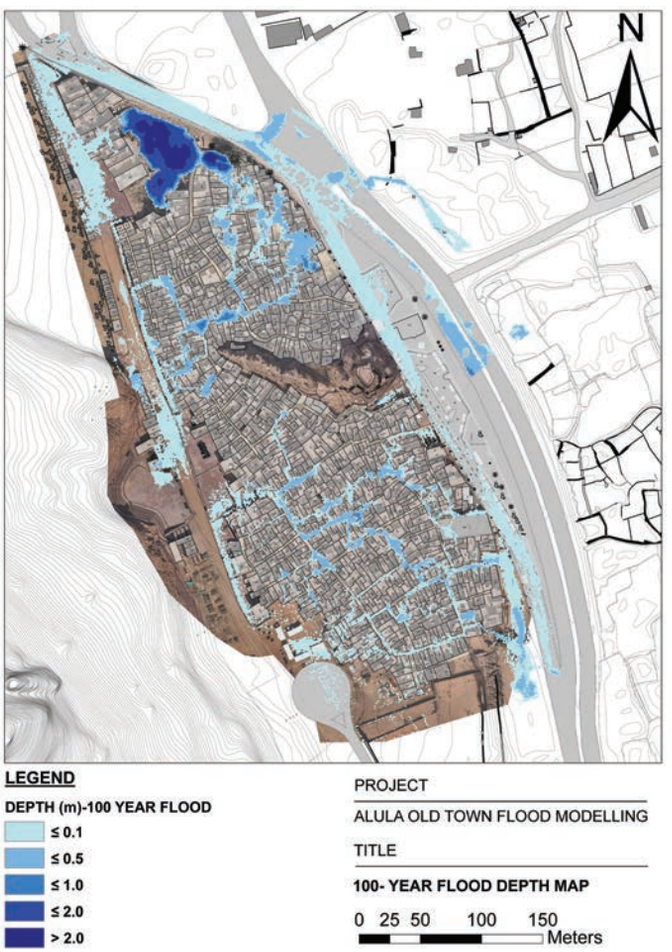


FIGURE 4 AlUla Old Town flash flood modeling. Image: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.

The Pilot Project and Selected Areas

The pilot project proposed during the first phase of conservation work was an opportunity for heritage specialists, architects, conservators, archaeologists, surveyors, masters, and local masons to work together to test and define quality standards for conservation and reuse of the urban and architectural heritage of AlUla Old Town (fig. 5).

The main objectives of the pilot project were to:

- Test conservation and stabilization techniques;
- Identify, produce, supply, and test conservation materials: mud brick, stone, wood, hydrated lime, plasters, and mortars;
- Test and propose appropriate techniques for propping, shoring, and scaffolding;
- Test adapted equipment and tools;
- Develop training programs for local contractors, professionals, and workers for the implementation phase;
- Propose and implement archaeological cleaning and investigation;
- Collect and record artifacts during archaeological cleaning;
- Improve site drainage for the pilot area;
- Stabilize street facades and execute minor repairs;
- Stabilize, install propping and shoring systems, and execute minor repairs for tayarahs;
- Stabilize, install propping and shoring systems, and execute minor repairs for walls and roofs of thirty-one houses;



FIGURE 5 Aerial view of the pilot project area after conservation work. Photo: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.



FIGURE 6 Execution of remedial conservation work on the Blue Street. Photo: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.

- Test mud plastering and sacrificial protective mud layers for walls;
- Test protective measures for wall paintings and original wooden doors;
- Test techniques for improving drainage and rainwater runoff through changes in site topography and removal of barriers and debris;
- Conserve, stabilize, and rebuild collapsed roofs of two historic mosques;
- Undertake regular site inspections to evaluate maintenance priorities and repair needs.

Areas selected:

1. The pilot area: Covering an area of approximately 2031 m² at the extreme south of the AlHalaf quarter, close to the Hasna Gate, this area comprises thirty-one buildings, 116 m of streets and alleys, and seven *tayarah*s.
2. Two mosques: AlZawiyah and Hamad Ibn Yunus Mosques along the Blue Street were selected for conservation work, building archaeology, and salvage excavations.
3. Blue Street: This street, located in the AlHalaf quarter south of the citadel, was selected to demonstrate the implementation of preventive conservation methods and structural stabilization techniques adapted for streets, covered alleys, and *tayarah*s (figs. 6, 7).



(a)



(b)

FIGURE 7 3D high-resolution modeling of Unit 587 on the Blue Street (a) before and (b) after conservation work. Photos: © HCC-RCU-GEOKALI, Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.

Best Practice Conservation Guidelines

The Conservation Guidebook for AlUla Old Town was prepared based on the results of the experimental pilot project and the remedial conservation work within two mosques and the Blue Street. The guidebook includes the results of preliminary studies, site documentation, the building inventory, the condition assessment, and the drainage study. It includes international references for the field and provides guidelines, protocols, and techniques. It also defines appropriate materials, conservation methods, and restoration and adaptive reuse suggestions for historic buildings within AlUla Old Town and the Oasis Farms. Adapted methods and appropriate techniques tested in a real setting are described in the guidebook to support partners in best practice for heritage development projects and their conservation.

The main objectives of the AlUla Old Town conservation guidebook are to:

- Provide appropriate guidelines;
- Define the approach and method for implementation phases;
- Propose phased steps of intervention and precise protocols for each;
- Provide adapted methods and techniques for treatment;
- Specify and explain conservation techniques;
- Define and recommend adapted materials and tools.

Engagement and Training of Local Communities

The core mission of RCU is to safeguard the cultural heritage of AlUla, promote public awareness by developing and running training programs and thematic workshops, bring benefits to the local community, and encourage the sustainable development of this unique oasis community. The engagement of local community members in jobs generated by the project and the need to build local capacity in heritage conservation are top priorities. The AlUla Old Town pilot project was an opportunity to implement practical workshops in field training that introduced local institutions, professionals, and trainees to basic methods of site maintenance, preventive conservation, archaeological cleaning, propping and shoring techniques, conservation materials, and mud brick production (fig. 8).



FIGURE 8 Encouraging the participation and training of the local community. Photo: © Mahmoud Bendakir, Heritage Conservation Consulting Inc., HCC-RCU.

Notes

1 *Tayarah* is a characteristic architectural element of AlUla Old Town, providing cover over the streets and alleys for shade and coolness, and increasing living areas by adding a room above the street.

2 For more information about the project, visit the HCC website: https://hcc-heritage.com/en/projects/old-town-alula-architectural-survey-and-conservation-guidelines/.

PART 17

Hopewell Ceremonial Earthworks Symposium / Simposio de Hopewell Ceremonial Earthworks

Earthen Architecture of the Ancient Ohio Valley

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Abstract: *Nearly 2000 years ago, American Indians built dozens of huge, precise, intricate, earth-walled enclosures in the American Midcontinent, centered in present-day southern Ohio. Masterpieces of earthen architecture, these monuments were the principal ceremonial centers of an Indigenous, socio-religious movement whose influence spread far across the continent. In September 2023, eight of these Hopewell Ceremonial Earthworks were inscribed on the UNESCO World Heritage List. This paper describes the unique and exceptional attributes supporting this inscription: their enormous scale, geometric precision, and astronomical alignments, as well as their eloquent testimony to the ceremonial and domestic lifeways of their builders—dispersed, nonurban societies without hereditary leadership or intensive agriculture. People gathered here, among magnificent timber temples, for ceremonies of celebration, burial, and world renewal. They laid down exquisite ritual artifacts, having fashioned them from exotic materials brought from distant parts of North America. They piled multicolored soils into vast and elaborate spatial enclosures that marked new ways of understanding both the land and the sky. This paper focuses on the remarkable sophistication and intricacy of this earthen architecture qua architecture: principles and techniques of geometric planning, calibrations of celestial knowledge, consistencies of dimension shared across a wide region, patterns of ground preparation and soil selection, methods of construction, design of special features involving stone and water, and the effects and challenges of their vast spatiality.*

Resumen: *Hace casi dos mil años, los indígenas americanos construyeron docenas de recintos con paredes de tierra, enormes, precisos e intrincados, en la región central del continente americano, en especial, en lo que hoy en día es el sur de Ohio. Estos monumentos, obras maestras de la arquitectura de tierra, fueron los principales centros ceremoniales de un movimiento indígena (social y religioso) cuya influencia se extendió por todo el continente. En septiembre de 2023, ocho de estos "terraplenes ceremoniales de Hopewell" fueron inscritos en la Lista del Patrimonio de la Humanidad de la UNESCO. En este artículo, se describen las características únicas y excepcionales que respaldan la nominación de estos monumentos: su enorme escala, precisión geométrica y alineación astronómica, así como su condición de elocuente testimonio de la forma de vida ceremonial y doméstica de las sociedades dispersas, no urbanas y sin liderazgo hereditario ni agricultura intensiva que los construyeron. Los pobladores se reunían allí entre magníficos templos de madera para las celebraciones, los entierros y la renovación del mundo. Instalaron artefactos rituales exquisitos, fabricados con materiales exóticos obtenidos en lugares lejanos de América del Norte. Superpusieron suelos multicolores en recintos espaciales vastos y elaborados, que constituyeron nuevas formas de entender tanto la tierra como el cielo. En este artículo, se enfatiza la sofisticación y complejidad destacable de esta arquitectura de tierra como tal: principios y técnicas de planificación geométrica, calibraciones del conocimiento celestial, saberes dimensionales compartidos en una amplia región, patrones de preparación del terreno y selección del suelo, métodos de construcción, diseño de elementos especiales que incluyen piedra y agua, así como los efectos y desafíos de su vasta espacialidad.*

Keywords: earthworks, Hopewell, geometry, archaeoastronomy

Introduction

The Hopewell Ceremonial Earthworks are a series of eight monumental earthen enclosure complexes recently inscribed on the UNESCO World Heritage List. They were built along the central tributaries of the Ohio River in east-central North America between 2000 and 1600 years ago. Their enclosed spaces range in size from 5 to 51 ha; most are formed by precise geometric figures, such as the Great Circle Earthworks in Newark, Ohio (fig. 1) and the Seip Earthworks (see fig. 5). Fort Ancient, near Lebanon, Ohio, is a set of vast, level plazas formed by the undulating, sculpted rims of connected hilltops (see fig. 7).

These immense earthen monuments were conceived and designed as ceremonial centers. People gathered here for feasts, mortuary rituals, world renewal rites, and (as will be argued in a companion paper, Lepper, this volume) pilgrimages. They are the finest and most representative surviving expressions of the cultural flowering and distinctive genius of an Indigenous people now referred to as the Hopewell culture. Most significant in this ceremonial context are the Hopewell Mound Group (the largest and the source of many beautiful artifacts crafted from rare materials) and Mound City (a thoroughly studied, carefully restored necropolis; fig. 2).

These ancient American Indians developed sophisticated knowledge of geometry, astronomy, and monumental earthen construction, yet without urban centers, intensive agriculture, or hierarchical leadership. Southern Ohio was their heartland, but their socioreligious movement's influence spread across much of the continent; their material artistry is wrought in materials brought here from as far away as Lake Superior, the Gulf Coast, and what is now Yellowstone National Park. Their ritual remains include giant blades of obsidian, abstract and figurative cutouts in Lake Superior copper, mica mirrors, seashell vessels, animal-effigy smoking pipes, and much more.



FIGURE 1 Great Circle Earthworks, Newark, Ohio (Ohio History Connection), showing its earthen ring and inner ditch; the monumental, northeast-facing gateway is at upper left. Photo: Bradley T. Lepper.



FIGURE 2 Mound City, Chillicothe, Ohio (Hopewell Culture National Historical Park). View from the west with the enclosing wall and pit (former water feature) in the foreground; the hills of the eastern horizon are visible through the trees. Photo: John E. Hancock.

The Hopewell Earthworks are a distinctive type of earthen architecture, not "buildings made from earth" but undulating, swelling surfaces of the earth itself, formed into monuments of great formal sophistication. They appear to be unique in the world—the most nearly comparable sites are the earthen rings and lines of Wiltshire, England—but their precision of form and intent was probably unequaled globally until the modern landforms of artist Michael Heizer or landscape architect George Hargreaves (both of whom were inspired by ancient Ohio Valley architecture).

Hopewell earthen architecture deployed squares, circles, and octagons, executed with an astonishing precision of form, technique, and dimension and duplicated with variations across a wide geographic region. Their geometries align not only with the sun's cycles but also with the far more complex rising and setting patterns of the moon. Their builders devised ever more precise and elaborate ways of fashioning the earth and its gifts (soil, clay, stone, water) into spatial conceptions that were also monuments to the temporal domains of sky and time (moon, sun, the calendar).

Geometry

The Octagon Earthworks in Newark, Ohio, exhibit an astonishing formal precision and dimensional unity (figs. 3, 4). The Observatory Circle, with its diameter of 321 m, is within 0.6 m of the ideal circumference of a perfect circle. The distance from the Observatory Mound to the center of the Octagon, along the site's principal axis, is equal to exactly two times that dimension. The sides of a square touching the Octagon's primary axial and cross-axial gateways equal the Observatory Circle Diameter (OCD). Rotated 45 degrees, it locates the mounds inside the other four gateways. This same OCD dimension is found at all but one of the other eight earthworks in the series—an apparent multiple of some still-unknown Hopewell unit of measure used across the region.



FIGURE 3 Octagon Earthworks, Newark, Ohio (Ohio History Connection). One of the Octagon's eight perfectly straight, eye-level walls, viewed from the interior. Photo: John E. Hancock.



FIGURE 4 View of the Octagon Earthworks, showing the axial position of the moonrise at its northern extreme every 18.6 years. Video still from the Ancient Ohio Trail archive, John E. Hancock.

Shapes and sizes were also shared across multiple sites. The three geometric figures composing the Seip Earthworks (fig. 5) occur, with the same sizes but differing arrangements, at four other earthworks within in a 30 km radius (DeBoer 1997). At each of these five "tripartite" complexes, the square was one OCD on a side (enclosing 11 ha), and the large circle measured 1.5 OCD in diameter. At Seip, lines connecting the centers of the three large geometric figures are of equal length and form an angle exactly bisected by the axis of the large circle's northeastern gateway.

These repeated dimensions and areas required precise techniques of design and execution. Laying out such geometries at a scale of hundreds of meters, and at locations separated by as much as 200 km, would have required some very long "sticks and strings." The creation of perfect squares requires the mastery of either equalizing diagonals or the 3:4:5 triangle principle, or both. Evidence at the Newark Earthworks suggests they also matched perimeters and areas of unlike figures—requiring even more esoteric mathematical or empirical methods about which we can only speculate.

Astronomy

Alignments among the Octagon Earthworks' principal walls, axes, and corners encode knowledge of six of the moon's eight extreme rise and set points along the eastern and western horizons, as observable from this specific latitude (Hively and Horn 1982). The remaining two are also present in less prominent features of the design. The site's main, central axis points to the northern maximum moonrise—observable over a few consecutive months every 18.6 years (see fig. 4). The maximum southern moonrise, also within less than 1 degree of Azimuth, aligns along the southwestern wall of the Octagon.

At High Bank Works, 100 km southwest of the Octagon, a circle (of the same diameter) and adjoining octagon are configured to mark not only the key lunar rises and sets but the four solar extremes as well. Again, some are marked by clear axial and linear wall positions; others are defined by features (such as a strangely offset gateway) that otherwise appear to be anomalies, having only these remaining alignments to explain their existence.

At Mound City (see fig. 2), the profile of a distinctively symmetrical range of hills (6 km away) forms the eastern horizon. From the position of the Central Mound, the most prominent within the enclosure, the visual width of this mass from

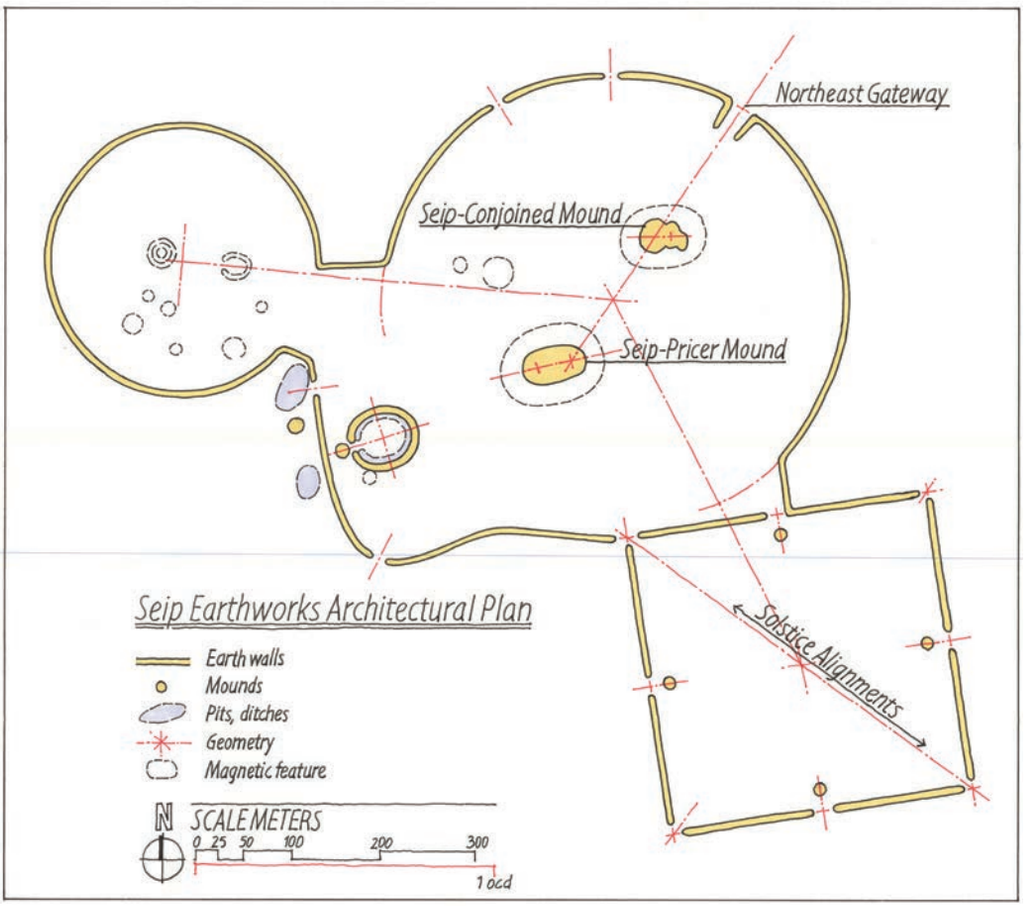


FIGURE 5 Seip Earthworks, Bainbridge, Ohio (Hopewell Culture National Historical Park). Architectural plan based on recent geophysical surveys, showing geometric derivations. John E. Hancock, delineator.

one peak to the other defines the 48.5 degree range between the minimum extreme northern and southern lunar rise points every 18.6 years. Its width from the outer base points of those same peaks marks, with equivalent precision, the two solstice sunrises (Hively and Horn 2010).

The observational knowledge needed to correctly position and design these earthworks to capture lunar as well as solar standstills would have taken generations. The moon is elusive in its rising and setting, due to its phases and to weather conditions, and its full movement cycle repeats only once in a generation. Other than Stonehenge, almost no other ancient site captures the complexity of this long lunar cycle—and none as thoroughly as these Hopewell earthworks.

Materials and Construction

The Hopeton Earthworks are the most thoroughly studied in the Hopewell series (Lynott 2008). They combine a square with a circle, both dimensioned to the OCD and having identical, 8 ha areas. Targeted excavations since 2002 have revealed the complex procedures of ground preparations, wall construction, and soil selections. Like all of the major Hopewell geometric earthworks, Hopeton is built on a large, level upper-river terrace, over well-drained, gravel-rich subsoils, beyond the reach of floods. Huge clearings in the native hardwood forest were found or created and then maintained to facilitate construction and provide open alignment horizons.

Wall building began with the removal of the topsoil to create a uniform surface, on which small fires were kindled and then buried as earth wall construction began (fig. 6). Remarkably consistent, intentional, cross-sectional patterns were deployed and distinct boundaries maintained between two (or sometimes three) homogeneous soil types. Most often, yellow-brown soils were placed first to form the core and the interior aspect of the wall. Then reddish-brown clay loam soils were laid up along the exterior surface. The contrasting soil types required quarrying material at some distance from the site.

Similar red and yellow soil combinations were used at Great Circle, High Bank, and Seip. Presenting and maintaining

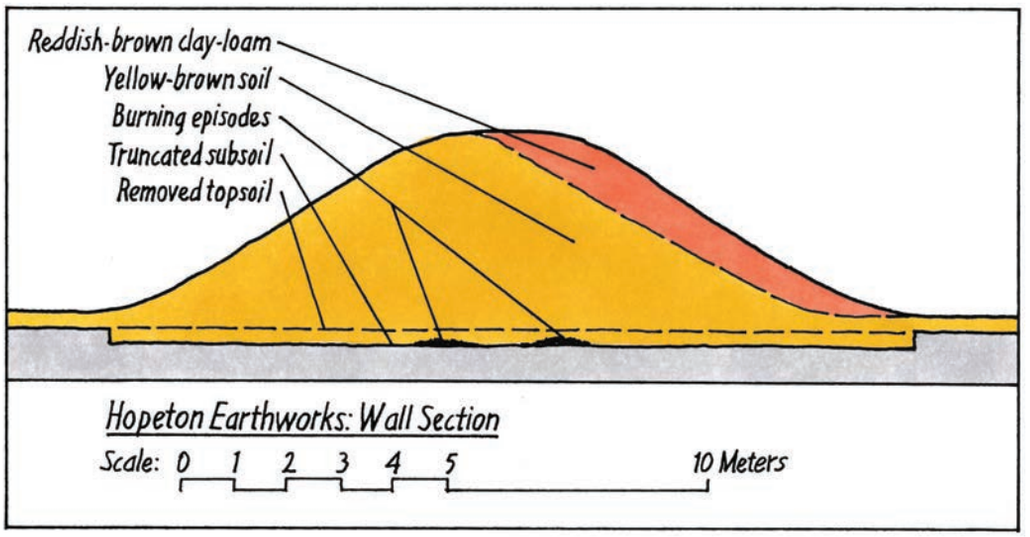


FIGURE 6 Hopeton Earthworks, Chillicothe, Ohio (Hopewell Culture National Historical Park). Wall section as built, showing construction layers and colors. John E. Hancock, delineator.

these patterns against the regrowth of ground-covering vegetation would have been a challenge. Other soil types, especially clays (and often stone), were used on erosion-prone embankments or to line water features (fig. 7). At Mound City, thin layers of sand were laid down between bands of colored soil to form the conical or spherical mound profiles.

The builders' detailed mastery of earthen architecture meant understanding multiple soil types of varying texture, color, and permeability and deploying them with great precision according to their technical and symbolic properties. To achieve these effects, materials were quarried as far as 2 km from the construction site; they were then carried in shallow



FIGURE 7 Fort Ancient Earthworks, near Lebanon, Ohio (Ohio History Connection), showing the South Fort (foreground), Middle Fort, and North Fort, with interior ponds. Video still from the Ancient Ohio Trail archive, John E. Hancock.

baskets and carefully stacked to create the desired profile and to ensure their durability against erosion.

Precursor Buildings

Earthwork building generally followed directly after the dismantling of wooden architecture. The ceremonies took place in elaborate timber temples: giant open woodhenges, charnel houses, and multichambered covered buildings. Arrangements of standing posts undoubtedly served generations of observers during their calibrations of the astronomical cycles. Beneath most of Mound City's twenty-five mounds are the remains of timber-framed buildings whose rounded-corner shapes reflect the fire-hardened clay basins on their floors and the outline of the enclosing earthwork.

Most spectacularly, the large mound at the Seip Earthworks was built over the remains of a 20 × 50 m structure: three rooms, along an axis, with a clay and sand floor. Crematory basins, burial platforms, and artifact deposits accompanied the remains of at least 125 people. When this building was dismantled, a complex mounding process began. Three feet of clay were laid over the shrine's most elaborate burial, topped by five large effigy pipes. Much higher, on the primary stage of mounding, a printed fabric canopy was pegged down over the tomb's location with more than 100 hundred deer-bone skewers. The mound's final layer more than doubled its height, encircled it with a 3.5 m thick stone-slab retaining wall, and capped it with a deep mantle of small stones.

Stone and Water

Fort Ancient is the largest and most elaborate of the Hopewell hilltop enclosures. Its eighty-four segmented embankment walls total 5.6 km in length, enclose 40 ha, and range in height from 1.5 to 7 m (see fig. 7). Construction required moving more than 420,000 m^3 of earth and stone. And, although these were named "forts" by nineteenth-century settlers, all evidence now indicates they had ceremonial and not military functions.

The outside faces of many of the walls were extensively paved with white limestone slabs brought up from the riverbanks far below. These could have been designed to gleam in the sunshine as well as to prevent erosion. Limestone slabs were also stacked on both sides of some of the gateway passages. In an otherwise topographically determined conception, one decisively geometric feature stands out at Fort Ancient: four stone-covered mounds in the large, level interior of the North Fort define a square that is 161 m on a side (one half of an OCD). Two of its mounds serve as back-sights to solar and lunar alignments through eastern gateways.



FIGURE 8 Fort Ancient Earthworks, showing earthen walls and reflecting pond near Gateway 14. Photo: John E. Hancock.

Interior ditches follow the encircling walls, most lined with clay and limestone to create water-filled reservoirs and reflecting ponds (fig. 8). Many continue to function today for much of the year. Other earthworks have comparable water features: the interior ditch of Newark's Great Circle was similarly lined with clay and stone to form a watery ring much of the year. At Mound City, eight pits adjacent to the enclosure wall were not merely borrow pits (the subsoil was gravel); they, too, were lined with clay, creating a series of reflecting pools.

Water has a prominent role in American Indian cosmology. Creation stories tell of animals who bring the earth up out of a watery domain. A three-layered conception involves the Above World (sun, moon, stars, weather), the Earth World (the habitable zone for human life), and the watery Beneath World (Reilly 2004). The animals featured in Hopewell iconography are often the liminal creatures who can move from one of these worlds to another. The ditches and ponds at the earthworks present an experience of these worlds; we see into the "watery beneath world," where the earthen wall and the sky beyond are reflected.

Form and Experience

The unity of architecture and religious iconography across much of eastern North America suggests that congregants came here from far and wide. What they experienced in this

enigmatic architecture is impossible to know, but certain themes are likely: the enormity and complexity of their combined geometries, the integration of both preexisting and constructed water features, and the calibration of key turning points in the solar and lunar cycles. Together, these characteristics suggest the earthworks were more than earth-walled, open-air "cathedrals." Their vast, subtle spaces were more like complex, ritual machines: drawing upon the energies of the Beneath World through their connections to water and the Above World through their alignments to the cosmos. They attracted large numbers of people (more than the local communities could provide) who gathered when the cosmic rhythms altered in ways that may have made those energies more vivid and available (Lepper 2010).

For us today, the vast spatiality and subtlety of these Hopewell Ceremonial Earthworks render them almost incomprehensible as works of architecture or as landscape experiences. Some are covered by forests and some are degraded by agriculture, some are both. But even those that survive well and in the open, like the sites in Newark, present us with a spatial conception that is fundamentally beyond the reach of the modern Western imagination (Hancock 2004). We are left to wonder: How were they grasped in the imaginations of their builders? From nearby hilltops? With pristine "fresh dirt" contrast (see figs. 4, 7)? The beautiful nineteenth-century engravings have been helpful over the years, though now our on-the-ground perceptions are being enhanced with new, digital media and augmented reality, as described in the companion paper to follow (Ruby et al., this volume).

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Conservation and Management of Ohio's Ancient Earthworks

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Abstract: *This paper explores the unique conservation and management challenges posed by the magnificent earthen monuments built by American Indians along the tributaries of the central Ohio Valley between 1600 and 2000 years ago, known today as the Hopewell Ceremonial Earthworks. Surviving largely intact for centuries after their reforestation and stewarded by later Indigenous nations, these architectural landscapes astonished the earliest non-Native settlers in the Ohio Country. Yet their degradation since then, especially by agriculture, has been challenging for traditional archaeological documentation and compromises their legibility and impact for visitors today. We need new archaeological methods capable of documenting these vast, yet degraded, architectural landscapes. We also need to visualize and interpret these works in ways that engage passion and care among a variety of audiences, including visitors, community members, and contemporary American Indian nations. In this paper we describe our efforts to overcome these challenges in three ways. First, our unprecedented high-resolution, landscape-scale geomagnetic surveys have allowed us to detect and document richly detailed, buried archaeological landscapes in and around these earthen monuments; this paper shares several startling examples. Second, we have deployed innovative vegetation management to offer visitors an on-site experience of these now otherwise indistinct landscape monuments. Third, we have deployed digital visualization tools to create memorable, iconic images and immersive experiences of these monuments, in video and augmented reality. In each of these categories, we emphasize the specificity of solutions given the unique attributes of this earthen architecture.*

Resumen: *En este artículo, se analizan los desafíos de conservación y gestión que suponen los magníficos monumentos de tierra construidos por los indígenas americanos a lo largo de los afluentes del valle central de Ohio, con 1600 a 2000 años de antigüedad, que son conocidos hoy en día como "Terraplenes ceremoniales de Hopewell". Estos paisajes arquitectónicos que, en muchos casos, sobrevivieron intactos durante siglos después de su reforestación y estuvieron bajo la protección de las naciones indígenas posteriores, asombraron a los primeros colonos no nativos de la región de Ohio. Sin embargo, la degradación sufrida desde entonces, sobre todo como consecuencia de la agricultura, constituye un desafío para la documentación arqueológica tradicional y compromete su legibilidad e impacto para los visitantes. En primer lugar, se necesitan métodos arqueológicos nuevos que permitan documentar estos vastos (aunque degradados) paisajes arquitectónicos. En segundo lugar, es necesario visualizar e interpretar estas obras de manera que despierten la pasión y el interés de diversas audiencias, incluidos los visitantes, los integrantes de la comunidad y las naciones indígenas americanas contemporáneas. En este artículo, se describen tres tipos de esfuerzos tendientes a superar estos desafíos. Primero, se realizaron estudios geomagnéticos sin precedentes, de alta resolución y a escala del paisaje, que permitieron detectar y documentar, de manera muy detallada, vestigios arqueológicos enterrados dentro de estos monumentos y en sus alrededores; en el artículo se incluyen varios ejemplos sorprendentes. Segundo, se implementó una gestión innovadora de la vegetación para ofrecer a los visitantes una experiencia en el lugar de estos monumentos paisajísticos que, de otro modo, pasarían inadvertidos. Tercero, se implementaron herramientas de visualización digital en video y realidad aumentada para crear imágenes memorables y emblemáticas, así como experiencias inmersivas en estos monumentos. En cada una de estas categorías, se destaca la especificidad de las soluciones debido a las características únicas de esta arquitectura de tierra.*

Keywords: heritage management, magnetometry, 3D visualization, augmented reality (AR)

Ohio's Ancient Earthworks

Nearly 2000 years ago, American Indians built dozens of huge earthen enclosures in the American Midcontinent, centered in present-day southern Ohio. Masterpieces of earthen architecture, these monuments were ceremonial centers associated with an Indigenous religious movement whose influence spread to hundreds of communities across half the continent. As earthen architecture, these works embody remarkable sophistication and intricacy: principles and techniques of geometric planning, astronomical alignment, dimensional consistencies shared across a wide region, patterns of ground preparation and soil selection, techniques of construction, design of special features involving stone and water, and the effects and challenges of their vast spatiality (Hancock and Lepper, this volume; Lepper, this volume).

This paper explores the unique conservation and management challenges posed by these Indigenous architectural landscapes. These challenges arise from several sources, foremost being their immense spatial scale and, in some cases, their degraded state of conservation. Even when well preserved, their sheer size confounds our ability to perceive and comprehend their form, and our traditional archaeological methods of exploration and documentation fall short.

In this paper, we describe our efforts to overcome these challenges in three ways. First, our unprecedented high-resolution, landscape-scale magnetic surveys have allowed us to detect and document richly detailed archaeological landscapes in and around these earthen monuments. Second, we have used these surveys to guide innovative vegetation management that offers visitors an on-site experience of these now otherwise indistinct landscape monuments. Third, we have deployed digital visualization tools to create memorable, iconic images and immersive experiences of these monuments, in video and augmented reality. Our solutions are tailored to the unique attributes of this earthen architecture and have proven to be effective tools to engage care, passion, and connection among our audiences, including visitors, community members, and contemporary American Indian nations.

Conservation and Management Challenges

Despite their grandeur, most of these vast, Indigenous architectural landscapes suffered for more than 200 years under the indifference or active erasure of settler colonists. The era of earthwork construction and use largely ended about 400 CE, when Indigenous ceremonial life shifted away from the earthworks and toward less visible forms of expression. With diminished human management, ecological succession favored reestablishment of deciduous hardwood forests. When non-Native settlers took possession of the Ohio Valley by force, culminating in the 1795 Treaty of Greenville, most of the earthworks were intact and covered with old-growth forest. Within fifty years, however, contemporary observers already lamented their state of conservation: "The operations of the elements, the shifting channels of the streams, the levelling hand of public improvement, and the most efficient of all, the slow but constant encroachments of agriculture, are fast destroying these monuments of ancient labor, breaking in upon their symmetry and obliterating their outlines. Thousands have already disappeared, or retain but slight and doubtful traces of their former proportions" (Squier and Davis 1848, xxxix).

Within our serial nomination, only the Newark Octagon and Great Circle Earthworks, and Fort Ancient near Lebanon, escaped extensive damage from agricultural plowing. The Mound City Group suffered widespread plow damage in the nineteenth century and development as a military training camp in World War I. But its visibility was restored when an accurate reconstruction based on archaeological and archival sources was undertaken in the 1920s and refined in the 1960s and 1970s. The High Bank Works, Hopewell Mound Group, Hopeton Earthworks, and Seip Earthworks were all plowed down to the point that most of the mounds, ditches, and enclosure walls are difficult or impossible to see on the ground today. The rate of earthwork erosion increased markedly after 1955, when farmers switched from simple horse-drawn scratch plows and moldboard plows to much more powerful diesel-powered tractors. These pulled multi-bottomed chisel plows that cut deeper and tended to level topographic irregularities (Blank 1985).

The invisibility of these earthworks poses several conservation and management challenges. From the visitor's perspective, it is difficult to appreciate the monumental scale of the architectural achievement. They cannot see the miles of 3 to 12 ft. tall embankments and equally deep ditches that formed the enclosures. They cannot trace the elegant geometry of the circles, squares, and octagons. They cannot experience the precise alignment of walls and gateways to horizon points where the sun and moon stand still on annual and generational cycles. From the site manager's perspective, the invisibility of the earthworks poses a risk of inadvertently damaging associated archaeological deposits with infrastructure associated with essential visitor services, including trails,

wayside exhibits, parking areas, restrooms, and maintenance facilities. From the archaeologist's perspective, earthwork invisibility limits access to key data points bearing on long-standing questions about the economic, social, and religious means and motivations driving these remarkable investments in monumentality. And for Indigenous peoples, the invisibility of the earthworks contributes to the erasure of their ancestral ties to the land and extends the social and spiritual trauma of dispossession into the present.

Responses to Earthwork Erasure and Invisibility

Erasure and invisibility stand at the heart of these conservation and management challenges. Here, we focus on several creative ways of restoring the earthworks to view. In the early twentieth century, physical reconstruction and restoration[1] work was undertaken at all but three of the nominated sites. In most cases the work was limited in scope, but at Mound City the reconstruction was near total. By the time of the Venice Charter in 1964, this sort of direct intervention into the historic (archaeological) fabric was viewed with considerable skepticism (ICOMOS 2004). But recently, reconstruction and restoration have found justification in international conservation under limited conditions, especially where local cultural identity has been threatened by the destruction of monuments through natural disaster, accident, or deliberate destruction in war. In some instances, reconstructions can assume new significance as symbols of renewal and reconciliation (Australia ICOMOS 2013; Historic England 2016; ICOMOS 1994). The destruction of Indigenous earthworks under colonial regimes in the nineteenth and twentieth centuries may constitute one of these cases where reconstruction or restoration may be justified in the interest of the revitalization and reassertion of cultural identity in former homelands on the part of descendant communities today.

Nevertheless, a conservative principle still guides practice today, and "softer" approaches are always favored over direct physical intervention into historic fabric. And in any case, complete and detailed documentation of the original state is necessary to assure the authenticity of any visualization, restoration, reconstruction, or re-creation (ICOMOS-ICAHM 1990).

Landscape-Scale Geophysical Surveys

Archaeological applications of geophysical remote sensing constitute one of the most significant advances in the investigation of Hopewell earthen architecture. Magnetometers have long proved useful in archaeology because they can detect subtle disturbances in the earth's magnetic field caused by ancient pits, ditches, and berms, as well as burned features such as hearths and kilns. But until now, only small areas could be practically surveyed. European approaches to archaeological heritage have long stressed landscape-level planning and management and non-destructive methods of investigation (Council of Europe 1992), spurring research and development intended to expand the spatial scale of archaeological remote sensing. Recently, a partnership between the German Archaeological Institute (GAI) and the US National Park Service (NPS)—stimulated by the prospect of World Heritage listing—applied state-of-the-art equipment and know-how to conduct magnetic surveys on a scale commensurate with these monumental earthworks (Komp et al. 2019). The GAI/NPS team used a SENSYS Magneto MXV3 magnetometer system consisting of a vehicle-towed array of 16 fluxgate gradiometers spaced at 25 cm intervals, integrated with a Global Navigation Satellite System (GNSS) (fig. 1). The team was able to survey up to 10 ha/day over three short field seasons, covering more than 485 ha in and around the nominated property, the largest archaeomagnetic dataset ever collected in North America.

Figure 2 shows an interpreted magnetogram covering 51 ha at the Hopeton Works. Despite its plowed-down condition, the main geometric enclosures are clearly detected and can be accurately measured and positioned. A host of previously undocumented features are also mapped: possible postholes



FIGURE 1 The German Archaeological Institute/National Park Service team used a SENSYS Magneto MXV3 magnetometer system integrated with a Global Navigation Satellite System (GNSS). Newark Earthworks is shown in the background. Photo: Ohio History Connection.

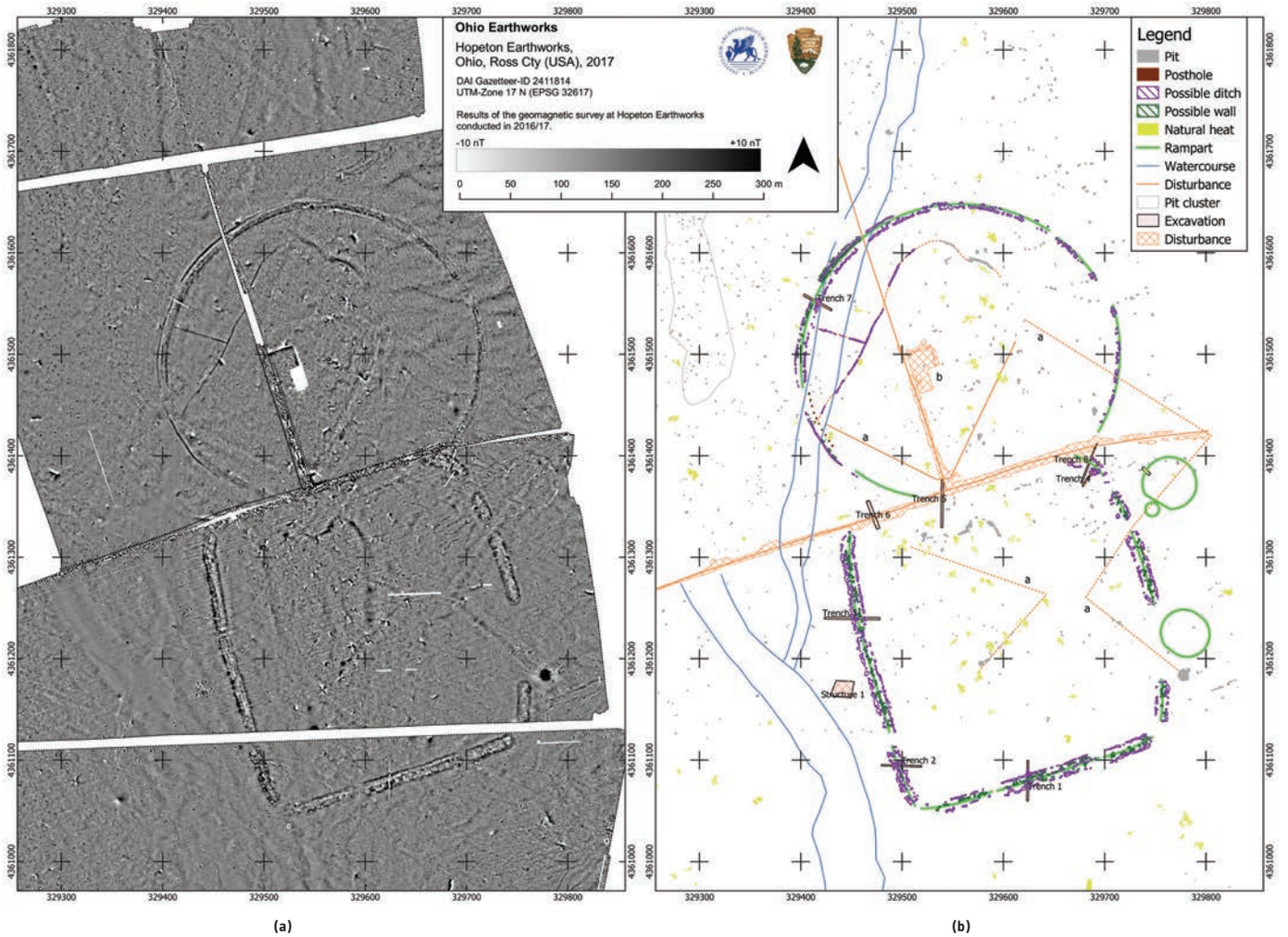
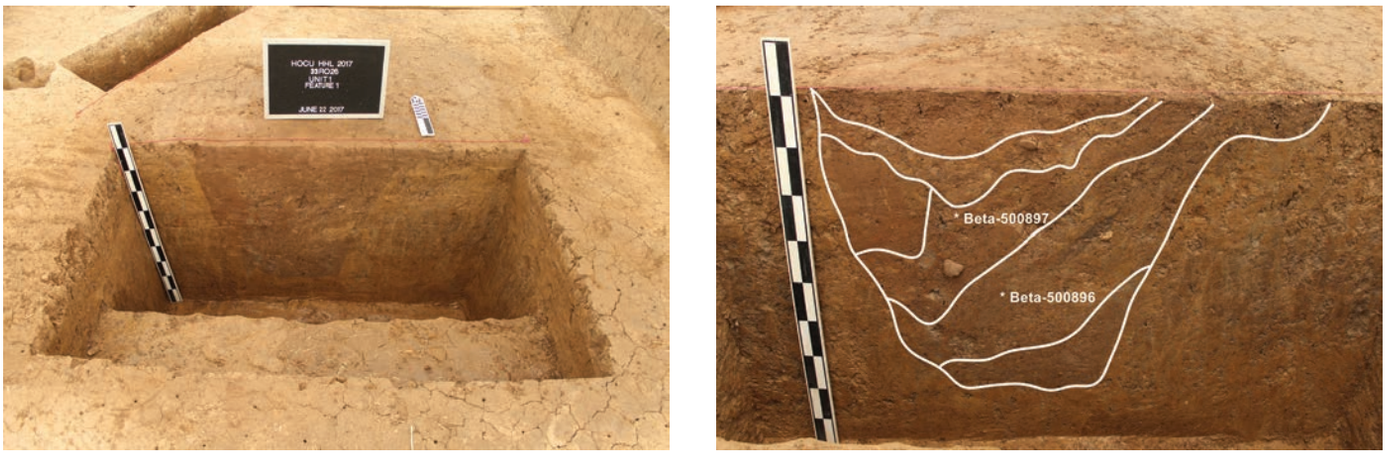


FIGURE 2 (a) Results of the geomagnetic survey conducted at Hopeton Earthworks in 2016–2017, approximately 51 ha shown, and (b) data interpretation. Illustration: © Deutsches Archäologisches Institut 2017.

and timber post structures, ditches, cooking and storage pits, and modern and natural disturbances. Of particular interest is a set of anomalies spaced at about 6 m intervals, ringing the inside edge of the southwestern arc of the large circle. Targeted ground-truth excavations in 2017 demonstrated that these are enormous post pits, each almost 1 m in diameter and more than 1 m deep, evidence of a monumental timber post circle or "woodhenge" more than 1000 m in circumference (fig. 3).

Figure 4 shows one of the most important results—we were able to use the magnetogram as a guide to plant and lay out an accurate mowing pattern in the turf grass. This authentic "soft" reconstruction of the plow-damaged earthen architecture allows visitors to see and interact with the ancient cultural landscape without any destructive intervention into the historic fabric. Native warm-season grasses are planted in the surrounding fields to promote biodiversity and habitat for threatened and endangered grassland nesting birds and pollinators.

Future management and treatment plans for the NPS earthworks are outlined in a cultural landscape report developed with public input and in consultation with American Indian tribes (Bishop et al. 2016). More "assertive" treatment alternatives including earthen reconstructions are considered, but it is recognized that those interventions are justifiable only with full and credible information about original materials, form, and design, and should be held in abeyance until



(a) (b)

FIGURE 3 (a) Excavated cross section of a post pit discovered as a magnetic anomaly underneath the large circular enclosure at Hopeton Earthworks. The pit is 96 cm in diameter, 1.13 m deep below ground surface, and likely held a monumental timber post; and (b) close-up of post pit showing stratified fills. These indicate the timber post was eventually dismantled and the post pit refilled. Two radiocarbon age determinations place the fill event near AD 100 (Beta-500897, 1930 ± 20 rcybp; Beta-500896, 1920 ± 30 rcybp). Photos: Timothy Everhart, National Park Service.



FIGURE 4 Aerial photograph of the Hopeton Earthworks, showing turf grasses mowed to create a "soft" reconstruction of the plow-damaged earthen architecture, guided by a landscape-scale magnetic survey to ensure authenticity (view to the southeast). Photo: Tim Anderson, Jr., First Capital Aerial Media.

sufficient archaeological research is completed. The GAI/NPS surveys are the first step toward a more precise delineation of earthwork geometry and are a comprehensive understanding of form (ditches vs. ramparts vs. post structures) and materials (gravels vs. organic soils vs. mineral soils).

Earthwork Visualization

Two decades before these large-scale surveys, in the mid-1990s, the "virtual heritage" field was new and we were experimenting with digital tools to help audiences visualize these

sites. Their vast scope and physical (as well as cultural) obscurity presented unique challenges. As architectural experiences, they stretch our modern spatial-perceptual skills—unfathomably large and subtle in form, or degraded by agriculture, or covered by obscuring forest, or all these things at once, it is no wonder they remain so little known outside of specialized circles. To persuade public audiences that southern Ohio was home to a brilliant civilization required that we bring their monuments to light, and to life, in new ways (Hancock 2016). All well-known ancient cultures capture and hold their place in the public imagination primarily through iconic architectural images; for example, the Parthenon in Athens, the Great Wall of China, and the Pyramids of Giza.

Visualization was our first area of emphasis—converting digital restorations into vivid images of the monuments with emotional impact and memorable meanings. Our early computer reconstructions led to several outcomes. First, a poster-size image of the Newark Octagon, cleared of trees and aligned to its axial moonrise on a beautiful fall evening, delivered on the promise of the iconic—vivid, meaningful, and memorable—and is now circulating widely (Hancock and Lepper, this volume, fig. 4). Second, animated flyovers of now-invisible sites like High Bank Works (fig. 5) were featured in our interactive video exhibits and publications, their visual treatments and vantage points evoking the spectacular effect of these vast landscapes. Third, for our Ancient Ohio Trail website, we developed a type of animation to help on-site visitors better visualize the site (with portable screens): "fly-ups" transform the actual view from a certain spot (e.g., a signage location) into an ascending animation over the entire restored site. Resembling an imaginary balloon launch, they connect the perceptual with the conceptual—the visible fragment in its current state, with the overall earthwork design in its ideal, imaginative form.

The second, and current, emphasis of our "virtual heritage" work involves interactivity. In early exhibits, we featured visual interfaces linking content topics with place locations among the virtual sites. Recently, we have expanded this "stories in places" method to an on-site experience, linking physical signage with an app for handheld devices (fig. 6). GPS tracking shows visitors their position relative to five numbered sign locations. At each trail stop, "deep signage" content in the app includes three interactive engagements with the restored virtual earthworks: (1) as animated, narrated video tours, (2) as 360 degree, real-time panoramas from that sign location in the phone's "window," and (3) as an augmented reality



FIGURE 5 Computer reconstruction showing an animated flyover of the now-invisible High Bank Works, Chillicothe, Ohio (Hopewell Culture National Historical Park). Video still from the Ancient Ohio Trail archive, John E. Hancock.



FIGURE 6 App for handheld devices linking physical signage at earthwork sites with "deep signage" content to give visitors interactive engagements with the restored virtual earthworks. Junction Earthworks, Chillicothe, Ohio (Arc of Appalachia). App and image by Virtual Grounds Interactive, LLC.



FIGURE 7 App for handheld devices allowing visitors to engage with the earthworks as an AR 3D scale model of the restored site, positioned virtually in front of them. Junction Earthworks, Chillicothe, Ohio (Arc of Appalachia). App and image by Virtual Grounds Interactive, LLC.

(AR) 3D scale model of the restored site, positioned virtually in front of them (fig. 7). By moving their device around the AR model, visitors can move to any vantage point, perceive its scale and form, and link to more content. Now ubiquitous and stable, AR technology offers new opportunities that make this earthen architecture more vividly and memorably visible, more deeply and widely understood, and more actively and passionately appreciated.

Conclusion

Ohio's ancient Hopewell Ceremonial Earthworks are in many ways unique in the fields of earthen architecture and archaeology. Their scale, form, design, and materials stand as eloquent testimony to the creative genius of their Indigenous builders. Yet, these same attributes challenge our traditional means and methods of conservation and management. We hope this paper and its companions will inspire wider interest and collaboration to foster respect and stewardship of this remarkable American Indian heritage.

Note

1 Following the definitions in the Australia ICOMOS *Burra Charter* (2013): Reconstruction (known earlier state, new material); Restoration (known earlier state, re-assembly or anastylosis); Recreation (deduced earlier state, new materials).

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Cultural Routes among the Hopewell Ceremonial Earthworks

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Abstract: *The ancient American Indian Hopewell culture was a regional florescence of monumental architecture, art, and ceremony that reached its fullest expression in southern Ohio between 1 and 400 CE. A common feature at many of the earthworks was wide avenues defined by low, parallel earthen walls that channeled the movement of large numbers of celebrants into and through the various ceremonial spaces. This paper reviews the evidence for these formal cultural routes and considers their purpose. The preeminent example of such a Hopewell avenue is the Great Hopewell Road, which consisted of parallel walls of earth 58 m apart. It extended from Newark's Octagon Earthworks at least 10 km in the direction of the largest concentration of geometric earthworks in the Hopewell world located along the Scioto River nearly 100 km to the southwest. One of these sites, High Bank Works, is the only other Hopewell circular enclosure linked to an octagon, and its architecture mirrors that of the Octagon, with identical dimensions and complementary astronomical alignments. Identifying the extent and purpose(s) of these formal Hopewell cultural routes is challenging due to the lack of attention often given to such cultural resources and the extent to which they have been erased by decades or even centuries of agriculture and development. Evidence suggests that the wide and generally straight Hopewell roads served as routes of pilgrimage to monumental earthworks linked to celestial phenomena.*

Resumen: *A nivel regional, la antigua cultura indígena americana de Hopewell generó un gran caudal de arquitectura monumental, arte y ceremonias que alcanzó su máxima expresión en el sur de Ohio entre el año 1 y 400 de nuestra era. Una característica común de muchos de los terraplenes ceremoniales consistió en las amplias avenidas delimitadas con muros de tierra bajos y paralelos, que canalizaban el movimiento de una gran cantidad de personas que participaban en las celebraciones, en sus desplazamientos de ida y vuelta a los diferentes espacios ceremoniales. En este artículo, se revisan las pruebas de estas rutas culturales formales y se analiza su propósito. El ejemplo más importante de una de estas avenidas Hopewell es la Great Hopewell Road, que consistía en muros paralelos de tierra con 58 metros de separación. Se extendía desde los terraplenes octogonales de Newark al menos 10 kilómetros hacia la mayor concentración de terraplenes geométricos del mundo Hopewell, ubicados a lo largo del río Scioto, a casi 100 kilómetros al suroeste. Uno de estos sitios, High Bank Works, es el único recinto circular de Hopewell vinculado a un octógono; y su arquitectura es un reflejo de la de Newark, con dimensiones idénticas y alineaciones astronómicas complementarias. Resulta todo un desafío identificar la extensión y los objetivos de estas rutas culturales y formales de Hopewell debido a la falta de atención que, por lo general, se presta a estos recursos culturales y a la manera en la que décadas o siglos de agricultura y desarrollo los dejaron fuera de escena. Las pruebas demuestran que los caminos anchos y casi siempre rectos de Hopewell servían como rutas de peregrinación hacia los terraplenes monumentales relacionados con los fenómenos celestes.*

Keywords: Hopewell culture, earthworks, roads, pilgrimage

Introduction

The ancient American Indian Hopewell culture was a regional florescence of monumental architecture, art, and ceremony that reached its fullest expression in southern Ohio between 1 and 400 CE (Lepper 2018), yet its interaction sphere extended as far west as the Rocky Mountains and as far south as the Gulf of Mexico (fig. 1). The architecture consists of earthen enclosures of two main types: geometric earthworks and enclosures that conformed to the shapes of the hilltops on which they were situated (Hancock and Lepper, this volume). Some enclosures are more or less isolated, whereas others are grouped together in complex cultural landscapes.

Avenues framed by parallel earthen walls are an important element of the Ohio Hopewell ceremonial landscape (fig. 2). They can be components of the largest earthwork complexes, such as those at Newark and Portsmouth, as well as components of much smaller earthworks (table 1). They are associated primarily with geometric earthworks and most commonly lead from one enclosure to another or from an enclosure to a nearby stream. They served to channel movement into and through the earthworks along predetermined routes.

Great Hopewell Road

At the Newark Earthworks, one set of parallel walls that were originally approximately 1 m in height and 58 m apart extended from a large octagonal enclosure for an as yet undetermined distance to the southwest (fig. 3). In one of the earliest studies of these earthworks, Caleb Atwater (1820, 129) noted the walls extended "for ten or twelve miles [16–19 km] at least" and possibly 30 miles (48 km).

These observations were corroborated by James and Charles Salisbury (1862, 15), who traced the walls for 6 miles (10 km) along an "undeviating course." They did not follow it to its terminus but observed that if it continued along its straight course, it could lead to Chillicothe, nearly 100 km distant.

Aerial reconnaissance, Light Detection and Ranging (LiDAR) imaging, limited surface surveys, and archival research have identified only one still-discernable remnant of the road. It is preserved on private property in a woodlot about 2 km southwest of the Octagon Earthworks. Possible subsurface remnants have been identified by archaeological excavations at a site approximately 1.8 km southwest of the surviving road remnant, including a layer that contained



FIGURE 1 Map showing the extent of the Hopewell Interaction Sphere along with examples of Hopewell regalia. There was no comparable corresponding export of material from the Hopewell area, which supports the interpretation that pilgrims brought offerings to the Hopewell ceremonial centers in exchange for the spiritual benefits accrued from their experiences at these special places. Courtesy of Ohio History Connection.



FIGURE 2 View along the parallel-walled avenue connecting Newark's octagonal enclosure with the large, circular enclosure. The avenue defines the main axis of the Octagon Earthworks, which is aligned to the northernmost rising of the Moon. A small platform mound partially blocks the entrance to the octagonal enclosure. Photo: Bradley T. Lepper.

"flecks of white decaying limestone," suggesting the possibility that it was "Hopewell pavement or top dressing for the road" (Schwarz 2016, 22).

Timothy Price (2004) conducted a Geographic Information System (GIS) analysis of the projected route of the Great Hopewell Road and established that, in spite of maintaining a straight trajectory for 100 km, it closely matched a least-cost route between Newark and Chillicothe (fig. 4). Moreover, Price's analysis demonstrated that the projected route between these two concentrations of Hopewell earthworks does not approach any comparable points of potential interest (fig. 5), supporting the conclusion that the cluster of earthworks around Chillicothe was the road's intended destination.

Hopewellian Newark and Chillicothe had a special connection apart from the Great Hopewell Road. High Bank Works (fig. 6), one of the several large earthworks in the vicinity of Chillicothe, and Newark's Octagon Earthworks are the only circle and octagon combinations built by the Hopewell culture; the circular enclosures at both sites are nearly perfect circles with identical diameters of 321 m. In addition, both

TABLE 1 Parallel Earthen Walled Roads Associated with Ohio Hopewell Earthworks

	Type of earthwork	Walls end at stream	Walls end in cul-de-sac	Walls lead from one enclosure to another	Wall are of unde-termined length	Source
Newark Earthworks[1]	Geometric; multiple large enclosures with extensive network of parallel-walled avenues	X		X	X	Squier and Davis 1848:67–72; Plate XXV; Salisbury and Salisbury 1862
Portsmouth Earthworks	Geometric; multiple large enclosures with extensive network of parallel-walled avenues	X	X		X	Squier and Davis 1848:77–82; Plate XXVII
Hopeton Earthworks[1]	Geometric; large circle connected to large square	X				Squier and Davis 1848:51–52; Plate XVII
Marietta Earthworks	Geometric; two large irregular squares	X				Squier and Davis 1848:73–77; Plate XXVI
Dunlaps Earthworks	Geometric; large quadrilateral connected to small circle		X	X		Squier and Davis 1848:63–64; Plate XXIII, No. 1
Fort Ancient Earthworks[1]	Hilltop enclosure		X			Squier and Davis 1848:18–21; Plate VII
Ancient Work near Bainbridge	Geometric; small circle connected to small, multilobed enclosure			X		Squier and Davis 1848:92; Plate XXXII, No. 5
Milford Work No. 1	Geometric; square and large irregular circle combination connected to a small circle			X		Squier and Davis 1848:94–95; Plate XXXIV, No. 1
Milford Work No. 2A	Geometric; square connected to a small circle			X		Squier and Davis 1848:95; Plate XXXIV, No. 2A
Seal Township Works	Geometric; large circle connected to large square			X		Squier and Davis 1848:66; Plate XXIV

[1] Site is included in the Hopewell Ceremonial Earthworks UNESCO World Heritage Site.

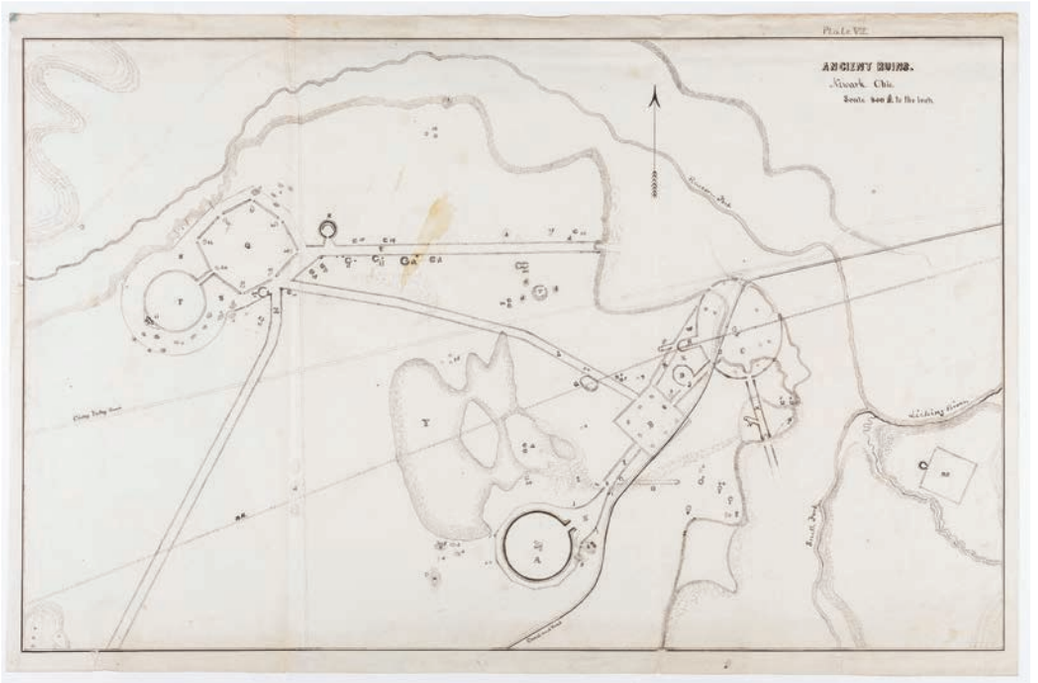


FIGURE 3 James and Charles Salisbury map of the Newark Earthworks, 1862. The Great Hopewell Road is the set of parallel walls extending from the southernmost gateway of the octagonal enclosure to the southwest. Courtesy of American Antiquarian Society.

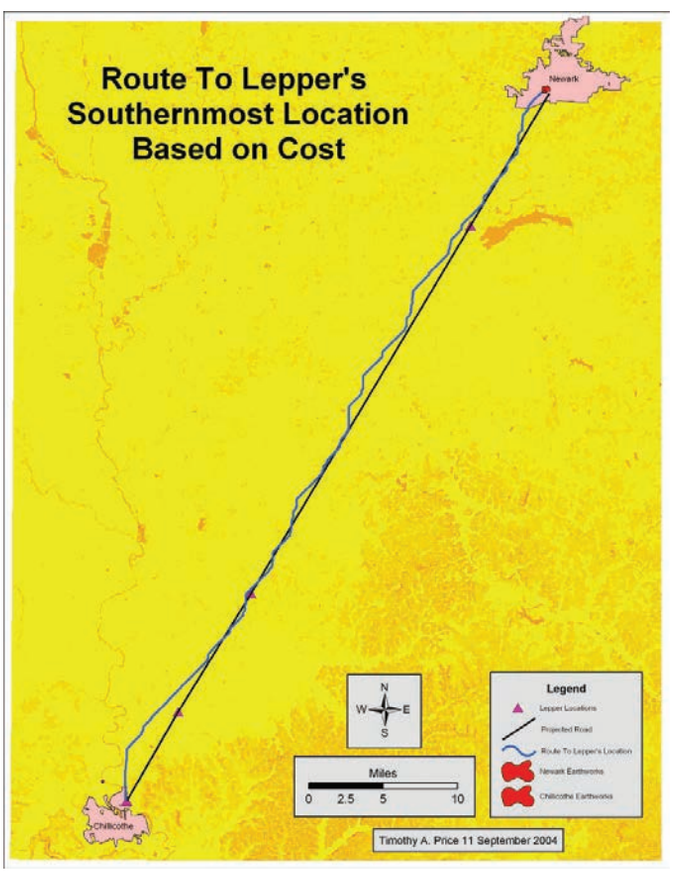


FIGURE 4 Map showing the least-cost route from Newark to Chillicothe compared to the projected route of the Great Hopewell Road. It is remarkable that such a straight corridor could so closely approximate a least-cost route. Courtesy of Timothy Price.

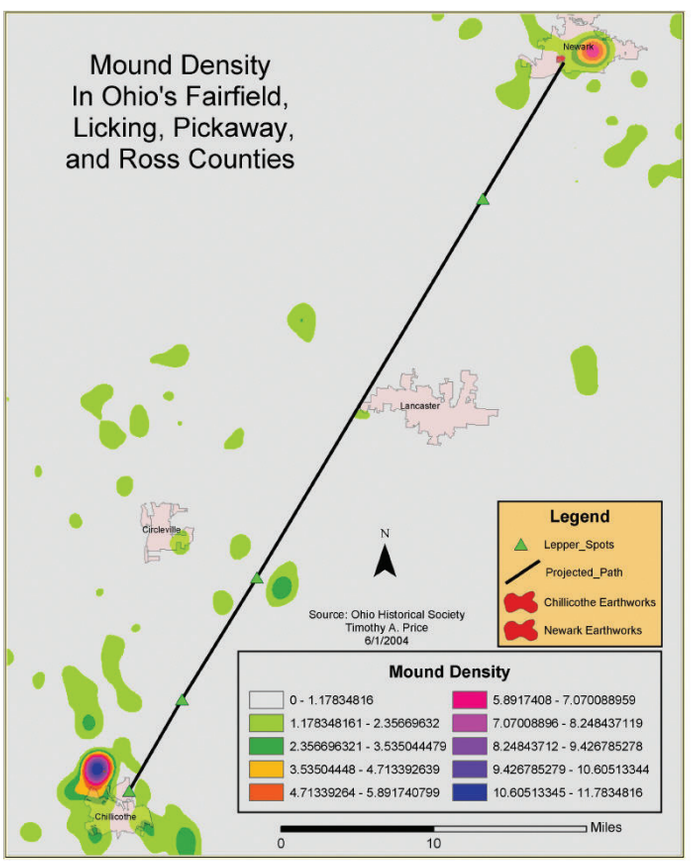


FIGURE 5 Map showing the density of mounds and earthen enclosures between Newark and Chillicothe and the absence of intermediate possible destinations for the Great Hopewell Road. This supports the proposition that the road connected these two major centers of Hopewell ceremonial activity. Alternatively, if the road did not extend the full distance between them, then the builders of the Newark Earthworks were at least using the alignment of the Great Hopewell Road to point in the direction of the center of the Hopewell world. Courtesy of Timothy Price.

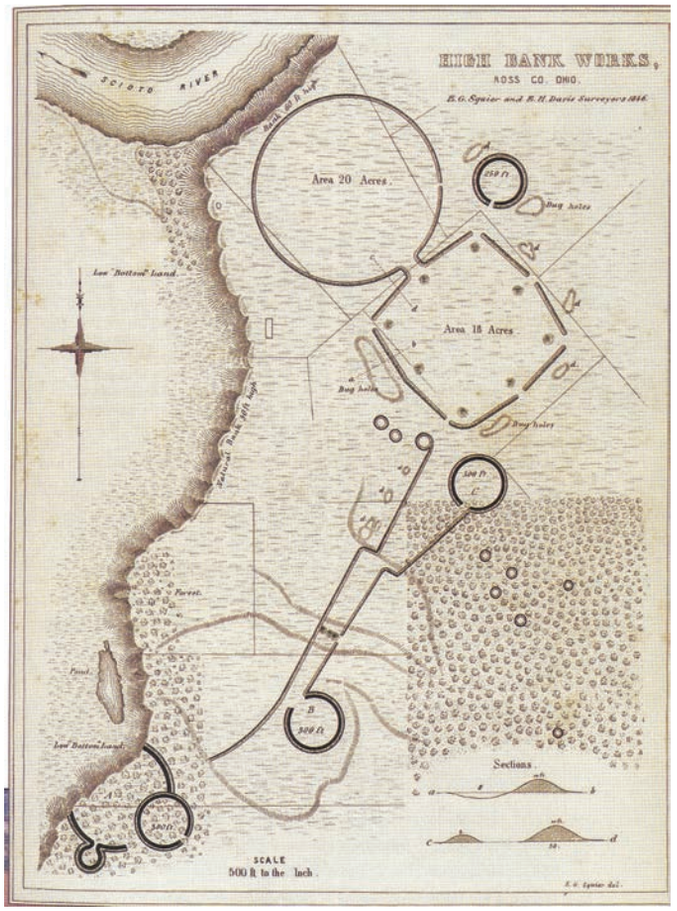


FIGURE 6 Ephraim Squier and Edwin Davis's 1848 map of High Bank Works. The circular enclosure has the same diameter as the large circle at Newark's Octagon Earthworks; both sites encode alignments to the 18.6-year-long lunar cycle. Courtesy of Ohio History Connection.

earthworks encode within their architecture precise alignments to the eight points on the horizon that mark the maximum and minimum limits of the 18.6-year-long lunar cycle (Hively and Horn 1982, 1984). These ceremonial centers, therefore, shared an architectural canon that incorporated a sophisticated knowledge of geometry and astronomy (Hancock and Lepper, this volume).

Insights from Similar Indigenous American Cultural Routes

I have argued elsewhere (Lepper 2006) that the Newark Earthworks was a pilgrimage center and that the Great Hopewell Road was used principally by pilgrims coming to both the earthworks to present offerings and engage in ceremonies associated with the awe-inspiring architecture. This activity may have been focused on the dates when the moon rose at its northernmost point on the eastern horizon in perfect alignment with the principal axis of the Octagon Earthworks, which occurred once every 18.6 years, or roughly once a generation (Hancock and Lepper, this volume, fig. 4).

The Maya built long, straight *sacbeob* (white roads), which were said to have been used by pilgrims on their journeys to ceremonial landscapes in furtherance of "a remarkable variety of goals," including "maintaining cosmic balance, upholding covenants with gods, [and] reinforcing group identity" (Hudson and Welch 2021, 6). Martti Pärssinen and Alceu Ranzi (2020) proposed that parallel-walled avenues leading into the monumental geometric earthworks in Acre and Amazonas, Brazil, which are remarkably similar to those at the Hopewell earthworks, were paths to prestige and political power for nascent chiefs. Brian Bauer and Charles Stanish (2001, 22), based on their work in the Andean highlands, asserted that "the development of multiregional pilgrimage complexes . . . only occurs in the context of state levels of organization." Helaine Silverman (2016, 103), while recognizing that "pilgrimage is an arena of personal competition as well as religious devotion," does not agree that building monumental pilgrimage centers required the political apparatus of the state. She acknowledges, however, that the "lack of intent to achieve political integration" in both the early Nasca and Hopewell cultures could have made it difficult for them to deal with the demands and pressures within their societies, especially over the long term, and this may have contributed to the eventual collapse of their respective ritual systems (Silverman 2016, 107).

American Indian Oral Traditions Possibly Relating to Hopewell Cultural Routes

The recorded traditions of American Indian tribes unfortunately do not shed much light on the meaning and purpose of the ancient Hopewell earthworks (Lepper 2014). There are, however, a few surviving traditions and stories that may offer valuable insights (Lepper 2010; see also Barnes and Lepper 2018).

The late Vine Deloria Jr., a Standing Rock Sioux and noted scholar, wrote, "Much Indian knowledge involved the technique of reproducing the cosmos in miniature. . . . Wherever possible the larger cosmos was represented and reproduced to provide a context in which ceremonies could occur. Thus, people did not feel alone; they participated in

cosmic rhythms" (2001, 25–26). I believe this captures much of what the major Hopewell earthwork centers likely represented and offered to pilgrims who journeyed there (Lepper 2016).

Regarding the parallel-walled Hopewell roads, there are two stories from Delaware (Lenape) traditions that hint at possible cultural memories of their purpose. The Moravian missionary David Zeisberger recorded in 1780 how, when the chiefs would "lay out a trail several hundred miles through the woods," they would clear the path of trees and rocks, "cut through the hills, level up the track and strew it with white sand, so they may easily go from one nation to another" (Hulbert and Schwarze 1910, 35). A long "white road" also is mentioned in a story recounted by the Reverend Albert Seqaqknind Anthony: "In the good old times," before any European had landed on their shores, the Delaware had "a string of white wampum beads . . . which stretched from the Atlantic to the Pacific, and on this white road their envoys traveled from one great ocean to the other, safe from attack" (Brinton 1890, 188).

These stories may speak to a time when the ancestors of the Delaware and many other tribal nations could travel across half a continent on spiritual journeys to breathtakingly enormous earthen cathedrals bearing offerings of exotic raw materials obtained from the ends of their world (see fig. 1). The "white road" in the Delaware story may conceivably refer to the white sand strewn across the paths laid out by Delaware chiefs and the white limestone paving that Schwarz (2016, 22) found at a possible buried remnant of the Great Hopewell Road. The Creek Indians of the southeastern US have oral traditions that explicitly refer to traveling northward on seasonal pilgrimages to "special mounds" (Chaudhuri and Chaudhuri 2001, 9, 135), which were important for "ritual interactions with the cosmos" (6). It is not known whether those special mounds were as far north as the Ohio Valley, but the Hopewell earthworks, with their astronomical alignments, certainly could have facilitated ritual interactions with the cosmos.

Challenges to Studying Hopewell Cultural Routes

The Great Hopewell Road is the most extensively studied example of a Hopewell cultural route, but there are others (see table 1). The Portsmouth Earthworks had numerous parallel-walled avenues that extended farther than is recorded on any early map (fig. 7). Ephraim Squier and Edwin Davis (1848, 78) remarked that one segment extended "north-west for a considerable distance" and "may have communicated with other works in that direction, which have been obliterated by time or, most likely, were destroyed in the manifest changes which the plain in that direction has undergone within a few centuries." And there are references to other roads associated with various Hopewell earthworks (Lepper 2006). For example, in 1894, Lindesay Brine reported that, in addition to a parallel-walled road documented at the Fort Ancient Earthworks by Squier and Davis (1848, 20; Hancock and Lepper, this volume, fig. 7), there also "once existed other parallel banks connected with the fort which could be traced for several miles, but that these had been destroyed." These formal cultural routes are important elements of the Hopewell ceremonial landscape and offer insights into how people came to and experienced their places of worship. As such, they warrant further investigation.

There are, however, significant challenges to studying Hopewell cultural routes. Few early archaeologists paid much attention to the parallel earthen walls that sometimes extended beyond the margins of their maps of the enclosures. Moreover, plowing rapidly leveled nearly all surface traces of these low embankments. Fortunately, imagery from aerial surveys conducted in previous decades can reveal portions of ancient roads as crop marks (Lepper 2006); even today, if the season and soil conditions are right, segments of these roads sometimes can be observed on Google Maps aerial imagery. Geophysical prospecting and the use of LiDAR, followed by limited excavations to provide ground truth for possible road remnants, appear to offer our best hope for identifying the vanishing traces of Hopewell roads (Romain and Burks 2008; Ruby et al., this volume; Schwarz 2016).

Hopewell Cultural Routes as Pilgrimage Paths

The monumental scale and extreme straightness of the Hopewell cultural routes indicate they were not merely routes of socioeconomic intercourse. The vast size of many of the Hopewell ceremonial enclosures is a clear indication that they were gathering places for more than the local population. The cryptic geometry and astronomical alignments combined with the mortuary focus of many of the earthworks indicate these places were devoted to ceremonies with formal liturgies, rituals, and regalia. Therefore, the data and arguments presented here and elsewhere (Lepper 2006, 2016) support the idea that the large earthwork complexes were pilgrimage centers for a religious movement that spanned much of eastern North America. The formal Hopewell cultural routes, such as the

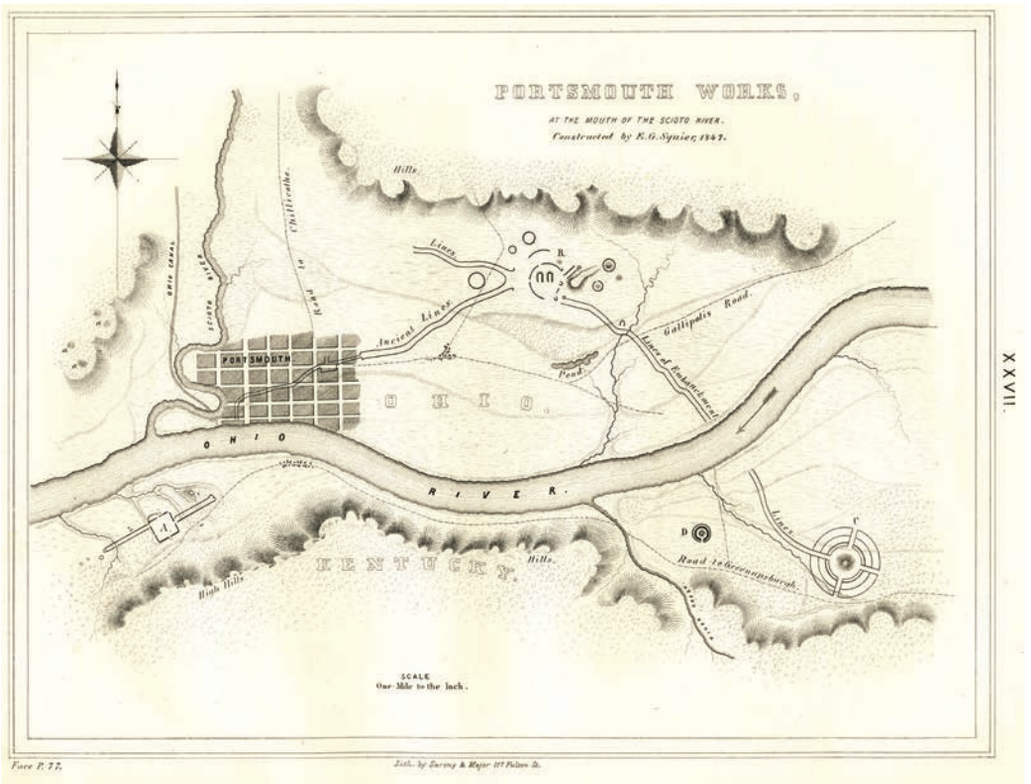


FIGURE 7 Ephraim Squier and Edwin Davis's map of the Portsmouth Works, 1848. Two avenues framed by parallel walls lead to earthworks on the opposite side of the Ohio River. A third extends to the northwest and originally may have extended much farther, linking the site to another earthwork along the Scioto River. Courtesy of Ohio History Connection.

Great Hopewell Road, were sacred avenues used by pilgrims to approach, enter, and move through a vast ceremonial landscape in choreographed processions. It would be naive to suppose that their construction and use had no political implications, but, given the relatively low level of sociocultural complexity documented for the Hopewell, these must have been subsidiary to the overwhelmingly ceremonial and religious purposes.

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Conclusions

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The following conclusions, delivered at the meeting, are based on reports submitted by a group of colleagues who acted as rapporteurs for each of the keynote, plenary, and roundtable talks, as well as for the parallel poster and video sessions at Terra 2022: 13th World Congress on Earthen Architectural Heritage in Santa Fe, New Mexico. This text does not intend to detail the congress presentations but, instead, to summarize the recent trends, gaps, and areas for future work to advance the field of earthen conservation.

General Impressions of the Congress

Over the last fifty years, we have had thirteen official, international meetings, colloquia, and congresses on the conservation of earthen heritage. Each of these gatherings created synergies that promoted and improved the practice of the conservation of earthen sites, both in the regions where they were organized and in the field in general. Some examples of these improvements include the decision by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), after the second meeting in Iran in 1976, to start a series of laboratory testing programs to better understand earth as a building material, using some sites as case studies (Jokilehto 2011; Torraca 1970). These testing programs were carried out between 1976 and 1980 at the archaeological site of Chan Chan, Peru, and the Spanish colonial mission of Tumacácori, Arizona (Crosby 1980). Similarly, following Adobe 90, a series of research projects were launched in the southwestern US and other parts of the world and, after Lima 2012, several Peruvian universities began teaching earthen construction and conservation in architecture and engineering schools. We hope that the 13th Congress energizes new initiatives again in the southwestern US and abroad.

The involvement of the local community in keynote addresses and follow-up discussions proved to be an extremely positive aspect of the 13th Congress. We sincerely thank the community members who joined us and shared their wisdom and insights with our international audience. The congress organizers hope you enjoyed being part of the Terra family and that we were able to make you feel welcome. The organizers endeavored to demonstrate the value of partnering with local communities, and we hope this was achieved. It allows us, as guests, to fully experience these places and to meet the people who are involved in their care. We urge future congresses to continue this approach.

The conclusions are related to the conservation of earthen archaeological sites, historic buildings, urban settlements, and cultural landscapes:

- History of the conservation of earthen sites;
- Identified threats;
- Community-based approaches;
- Conservation education and training;
- Research and implementation.

This paper will conclude with some additional comments about Terra 2022 and recommendations for future congresses.

History of the Conservation of Earthen Sites

The Terra 2022 keynote presentation addressed the history of our field over the last fifty years, acknowledging those

colleagues and professional leaders integral in advancing the field and identifying groundbreaking research, training initiatives, and model projects, both past and present. Learning from our past will help us to shape a better future. We must develop critical thinking and learn from our own failures. We must find the time to pause, reflect, and redesign our activities. The need to see more research and papers in future congresses that focus on evaluating the lessons learned from projects and/or initiatives was identified as a priority in moving the field forward.

The Terra congresses are opportunities to do that, but local or regional colloquia and gatherings are also encouraged. The COVID-19 pandemic taught us a new way to work virtually and, although not ideal, virtual video calls and webinars allow us to communicate more often. We urge the continuance of regular communications in advance of the next congress and encourage recognition of the importance of self-evaluation for those projects already in development.

Part of this idea to pause and reflect is the concept of evaluation. There is a series of scientific methodologies that are useful for evaluating projects by identifying clear objectives and measurable indicators. During Terra 2022 we heard about a number of implementation projects as well as research and training initiatives, some of which are new and others that have been ongoing for decades. Do we know what the impacts of these initiatives are and which efforts are working? We must find the time and the funds to objectively evaluate their results. It has been recommended that in the oral presentations of the next congresses, we find opportunities to evaluate the treatments, research, capacity-building activities, or scientific testing performed on projects. This way, we can look forward by looking back and will be able to reflect on our work as a foundation for future successes.

Research and projects carried out over the past fifty years have taught us that in order to understand the relationship between all the parts of a project as a whole, the conservation of earthen architecture should be approached holistically. The keynotes, plenary sessions, and roundtables made it clear that there is a need to look at a problem from all angles and consider the roles of all players.

The International Scientific Committee on Earthen Architectural Heritage (ISCEAH) has been investigating the development of an "Earthen Charter" that could better target a methodology for the conservation of earthen sites. There are existing methodologies, such as the Burra Charter, that we can borrow from to help identify needs, determine ways to involve all key stakeholders, holistically approach a problem, and evaluate a project's results for the next phases (Australia ICOMOS 1999).

Identified Threats

Threats identified during the congress as particularly detrimental to earthen architecture and its conservation are climate change, natural disasters, abandonment and neglect, and incompatible human interventions.

Several presentations addressed the impact of climate change (and its accompanying extreme weather events including drought, fires, flooding, and earthquakes) on earthen architecture. However, few papers offered possible solutions to minimize the impact on earthen sites created by these disasters. This could be because we—the professional community working on the conservation of earthen sites—are still in the exploratory and research phase of developing methodologies to identify, quantify, and qualify these risks. Existing documents from organizations like the International Council on Monuments and Sites (ICOMOS) can guide us in more in-depth research into the important topic of climate change (ICOMOS 2019; Potts 2021).

Several presenters mentioned that there is a need to prioritize the vulnerability of earthen architecture over its resilience. This means understanding how climate change affects the performance of the material and the preservation of a site. However, it is equally important to study how some sites confronted climate change in the past, making use of empirical and traditional knowledge. In the same way seismic strengthening solutions are based on actual data and modeling of a building's seismic performance, protective interventions against climate change should be developed from data-based climate models. In situ data acquisition methods, as well as protocols and testing procedures to map risks regarding climate change, were presented for archaeological sites. More research on the implementation of appropriate solutions for climate change remains a priority for upcoming congresses.

Monitoring and maintenance were also presented as activities that could be implemented to mitigate damage over time. Environmental and structural monitoring allows us to understand the behavior of a site and to design appropriate data-based solutions. Periodic maintenance is traditionally the best way to preserve an earthen site and should be encouraged in all projects. The impact of climate change, however, demands a reexamination of current maintenance approaches, and clear and reproducible methodologies for both maintenance and monitoring of earthen sites were presented in this congress, where the impact of climate change was considered.

Similarly, the issues of abandonment and neglect were addressed as threats to earthen urban settlements that have lost their inhabitants and, equally devastating, the know-how to regularly maintain their sites. The complex issue of bringing back original inhabitants involves the re-creation of the economic system that prompted the settlement in the first place. Unfortunately, those mechanisms turn out to be extremely challenging or impossible to replicate. When earthen settlements become archaeological remains of not-so-distant inhabitants who left the area looking for a more modern way of living, the general knowledge of how to properly repair unique and, in some cases complex, constructions is also gone. The congress presenters encouraged the creation of capacity-building activities in order to recover these traditions and pass them on to new generations.

This kind of cultural continuity will also help to stop incompatible interventions on earthen sites. Teaching traditional construction techniques, with compatible modern materials when needed, is encouraged for the preservation of urban settlements and historic sites to a new generation of architects, engineers, conservators, and craftspeople to enter the workforce with the appropriate knowledge.

Community-Based Approaches

As mentioned earlier, the representation of local communities in the 13th Congress was exceptional, and we urge a continuation of this approach in the future. The participation by local communities in plenary and roundtable sessions enhanced discussion and exchange. Community members are the main actors and best allies to advance the preservation of earthen sites. Their experience, knowledge, and opinions are invaluable. Heritage preservation should celebrate the sense of place and bring pertinence, social empowerment, and economic benefits to these communities.

The involvement of local communities needs to follow inclusive and appropriate decision-making processes—those that are established, emerging, or already practiced within communities. The field can learn from existing procedures to involve communities in all-inclusive and long-term projects. The Burra Charter and other internationally accepted methodologies have proven to be successful at involving local communities or, better still, empowering them to lead their own projects (Australia ICOMOS 1999). Some papers presented in the Care by and for Communities track detailed their successful experiences, many of which also included a multidisciplinary approach.

Finally, there is the need to promote an exchange of knowledge between communities and practitioners. It is not a question of "educating" the inhabitants of a site or ignoring the expertise that a professional can bring to its preservation. The community, in collaboration with other stakeholders, can provide different but complementary understanding of a site. Successful solutions for a conservation project consider all empirical, historic, technical, and scientific knowledge.

Conservation Education and Training

A series of training initiatives for different regions and target audiences has been developed over the past decades, with alumni from PAT (Preservación de Arquitectura de Tierra) courses, CRAterre DSA, Columbia University, and University of Pennsylvania master's degree programs, among others. Some of these programs have carried out short- and long-term evaluations of their roles in the advancement of the conservation of earthen sites. It is important to periodically evaluate the impact of these post-graduate courses on the development of the field in order to improve and update their curricula and pedagogical strategies when needed.

Earthen conservation should be taught in schools of architecture, engineering, and archaeology. Additionally, courses on archaeology, engineering, and architecture should be included in the curricula of conservation programs. The field has been trying to do this for decades and, as presented in this congress, there has been some progress at the university level in several countries. The field should also investigate the teaching of courses on anthropology and sociology, particularly as a means to address community-based participation. Earthen conservation education is at a juncture where a strategic and multidisciplinary approach to address the conservation of earthen heritage can and must be implemented. Capacity-building of masons (as well as support for their participation in future congresses) should be encouraged to ensure the preservation of traditional earthen construction techniques. Earthen conservation pedagogy, teaching materials, and evaluations of past courses need to be shared within the field. Established training centers can benefit from didactic materials already developed by similar institutions.

Research and Implementation

This congress witnessed a demonstrable advancement in the number of papers that foregrounded research and implementation—few papers or posters featured descriptions of a single

site or its problems. Most papers presented a proposal and results of research or methods for the implementation of case studies. A fair number of papers, posters, and videos presented research on material characterization, traditional techniques, documentation, moisture content, permeability of treatments, and consolidation.

This congress also presented a series of case studies for reconstruction with the ultimate objective of preserving a site. This is a different approach considering that minimal intervention was a favorable tactic in the past. However, in some cases, reconstruction is needed either to make proper use of a site or to stop the further deterioration of some of its components. The Historic Buildings and Structures track presented a range of sound methodologies to properly address reconstruction when required.

Regarding rehabilitation of urban settlements, there was a symposium on the conservation project of AlUla Old Town and Oasis, in the Kingdom of Saudi Arabia. The presentation of a thorough survey of the material assets of the site was a valuable contribution to the congress. The topic of urban rehabilitation should address the management of sustainable tourism as well as encourage the development of proper policies for urban regeneration and the ongoing maintenance of these sites.

The conservation of earthen archaeological sites is a topic that has been addressed since the first colloquium in Iran in 1972. At Terra 2022, there was a symposium on the conservation of the Hopewell Ceremonial Earthworks in Ohio that addressed the complex issue of preserving the material and, most importantly, the surrounding landscape while engaging the local community. Other research and implementation case studies were presented that addressed the identification, monitoring, and management of site vulnerabilities against climate change.

The last plenary session addressed the benefits and challenges faced by earthen World Heritage Sites. In this session, the point was made that with the latest update, carried out in 2022, there are 203 earthen sites on the World Heritage List, with 18 earthen sites on the List of World Heritage in Danger. It is interesting to note that in the first set of sites nominated and declared World Heritage Sites were the City of Quito, Ecuador, and Mesa Verde National Park, US, both inscribed in 1978, and both considered earthen heritage. Since 1978, the number of earthen sites on the World Heritage List has increased substantially, showing the growing recognition of the significance of earthen architecture.

The Earthen World Heritage session was very productive, and we recommend that it continue in the future by focusing on different aspects, including how to manage expectations of applicants to World Heritage status, how to engage local communities in the nomination for sustainability purposes, and how—specifically in areas of armed conflict—the international community can support local partners to protect these sites. Additionally, it would be interesting to understand the evolution of the nominations by considering their current states of conservation and identifying their specific needs.

Organization of the Congress

The design of the congress program was dynamic, beginning each morning with plenary presentations and roundtables that then broke out into parallel sessions. The organizers encourage the continuation of similarly innovative formats to advance discussions and the exchange of ideas at future meetings.

Including roundtables in the plenary sessions proved to be a unique and inventive format that prompted a series of interesting discussions. Our roundtable discussions first covered the history and evolution of our field, followed by regional perspectives, the experiences of the National Park Service (NPS), and the challenges faced by earthen World Heritage Sites. The roundtables allowed a series of groups with similar interests to have the floor and exchange ideas with the audience. The inclusion of emerging professionals in a similar format could be a great addition to future events. Congresses are moving away from individually led presentations to more discussion-based formats that provide opportunities to engage more voices, exchange experiences, and advance the field. Additionally, the video and poster sessions provided a stimulating and diverse pool of topics and ways to disseminate projects.

The series of virtual lead-up events to Terra 2022, organized over the course of the year prior to the congress, was a success. This idea was a result of the pandemic and taught us a new way to be in close contact despite not being able to meet in person. The next congress organizers are encouraged to consider this as part of their program and to maintain regular communications between now and when we meet again in Cuenca, Ecuador, in 2025.

The three pre-congress workshops were very inspiring. Other professional congresses and gatherings organize similar ones as part of their programs and we should continue to do so as well. Such workshops allow colleagues to experience

hands-on activities and contribute to the dissemination of new techniques and approaches within our professional community.

Finally, the 13th Congress provided the opportunity to meet in person for the first time after years of isolation—undoubtedly a source of relief and happiness for all participants. Terra 2022 assembled an extraordinary group of professionals and underscored yet again how these gatherings mark important moments in time when new initiatives are born. We cannot wait to see what comes next.

Acknowledgments

These conclusions represent the contributions of a group of colleagues who acted as rapporteurs for the sessions and met to discuss their sessions during the congress. These discussions were extremely inspiring considering the high level of engagement of the rapporteurs, and I am grateful to each and every one of them for their valuable opinions and insights.

I am a proud staff member of the Getty Conservation Institute, organizational partner of this event, and manager of the GCI Earthen Architecture Initiative—of which the Terra 2022 World Congress is a component. However, credit for the organization of this event should go to Jeanne Marie Teutonico, associate director of the GCI; Frank Matero, chair of the Graduate Program in Historic Preservation at the University of Pennsylvania Stuart Weitzman School of Design; Lauren Meyer, program manager, Intermountain Historic Preservation Services (Vanishing Treasures, Historic Structures, Cultural Landscapes and History); and my dear friend and colleague—in that order—Leslie Rainer, senior project specialist at the Getty Conservation Institute.

This congress is a testament to the professionalism and passion of everyone who contributed to the organization of Terra 2022 for the field.

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Conclusiones

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Las conclusiones que a continuación se describen fueron igualmente presentadas en el congreso. Estas se basan en los informes enviados por un grupo de colegas que asistieron a las charlas magistrales, las sesiones plenarias y las mesas redondas, así como a las sesiones de ponencias, pósteres y videos paralelas del evento Terra 2022: XIII Congreso Mundial del Patrimonio Arquitectónico de Tierra en Santa Fe, Nuevo México. En esta sección de las actas, no se pretende detallar las ponencias del congreso, sino resumir las últimas tendencias, las brechas actuales y los temas a profundizar a futuro para avanzar en el campo de la conservación de los sitios de tierra.

Impresiones generales del congreso

Durante los últimos cincuenta años, la comunidad internacional ha organizado trece reuniones, coloquios y congresos sobre la conservación del patrimonio de tierra. En cada reunión, se crearon sinergias que promovieron y mejoraron la práctica de la conservación de sitios de tierra, tanto en las regiones donde se organizaron como a nivel internacional. Algunos ejemplos incluyen la decisión por parte del Centro Internacional de Estudios de Conservación y Restauración de los Bienes Culturales (ICCROM), luego de la segunda reunión en Irán en 1976, de iniciar una serie de programas de ensayos de laboratorio para mejorar el entendimiento que tenemos sobre la tierra como material de construcción, usando algunos sitios como casos de estudio (Jokilehto 2011; Torraca 1970). Estos programas de ensayo se llevaron a cabo entre 1976 y 1980 en el sitio arqueológico de Chan-Chan, Perú, y en la misión colonial española de Tumacácori, EE. UU. (Crosby 1980). De forma similar, luego de Adobe 90, se lanzó una serie de proyectos de investigación en el suroeste de EE. UU. y otras partes del mundo; luego de Lima 2012, muchas universidades peruanas comenzaron a enseñar construcción y conservación de la arquitectura de tierra en escuelas de arquitectura e ingeniería. Esperamos que el XIII Congreso impulse nuevas iniciativas en el suroeste de EE.UU. y otras partes del mundo.

La participación de la comunidad local en las charlas magistrales y los debates surgidas de las mismas son un resultado sumamente positivo del XIII Congreso. Nuestro más sincero agradecimiento a los miembros de la comunidad que se sumaron y compartieron su sabiduría y conocimiento con nuestra audiencia internacional. Los organizadores del congreso esperan que hayan disfrutado ser parte de la familia de Terra y que hayamos podido hacerlos sentir bienvenidos. Los organizadores se esforzaron por demostrar el valor de trabajar con comunidades locales, y esperamos haberlo logrado. Esto nos permite, como invitados, experimentar estos lugares completamente y conocer las personas involucradas en su cuidado. Alentamos la continuidad de este enfoque participativo en congresos futuros.

Las conclusiones que a continuación se presentan están relacionadas a la conservación de sitios arqueológicos, edificaciones históricas, asentamientos urbanos y paisajes culturales de tierra, y cubren:

- Historia de la conservación de los sitios de tierra
- Amenazas identificadas en perjuicio a sitios de tierra
- Enfoques basados en la inclusión de la comunidad
- Educación y capacitación en conservación
- Investigación e implementación

Este documento concluye con algunos comentarios adicionales sobre Terra 2022, así como recomendaciones para congresos venideros.

Historia de la conservación de los sitios de tierra

La presentación principal de Terra 2022 abordó la historia de la profesión en los últimos cincuenta años, y reconoció a los colegas y líderes profesionales que formaron parte integral de su evolución, a la vez que identificó exitosas investigaciones innovadoras, iniciativas de capacitación y proyectos modelo, tanto del pasado como del presente. Aprender de nuestro pasado nos ayudará a forjar un mejor futuro. Debemos desarrollar el pensamiento crítico y aprender de nuestros errores, así como encontrar momentos para detenernos, reflexionar y rediseñar nuestras actividades. Necesitamos que, en los próximos congresos, se priorize la presentación de investigaciones y estudios que se enfoquen en evaluar lo aprendido de los proyectos y las iniciativas *desarrolladas* para seguir adelante.

Los congresos Terra son una oportunidad para eso, pero también se fomenta hacer lo mismo en encuentros, reuniones y coloquios locales o regionales. La pandemia de la covid-19 nos enseñó una nueva manera de trabajar de forma virtual y, si bien no es la ideal, las videollamadas y los seminarios web permiten comunicarnos con más frecuencia. Fomentamos la continuación de las comunicaciones con regularidad de cara al próximo congreso y alentamos el reconocimiento de la importancia de la autoevaluación de aquellos proyectos que ya estén en desarrollo.

Evaluar significa detenerse y reflexionar. Existe una serie de metodologías científicas que son útiles para evaluar proyectos a través de la identificación de objetivos claros e indicadores medibles. Durante Terra 2022, escuchamos sobre diversos proyectos de implementación, investigación e iniciativas de capacitación, algunas nuevas y otras que están en marcha desde hace décadas. ¿Conocemos el impacto de estas iniciativas y cuáles están funcionando? Debemos encontrar el tiempo y los fondos para evaluar de manera objetiva los resultados. Se recomienda que, en las presentaciones orales de los congresos venideros, encontremos oportunidades para evaluar las intervenciones, la investigación y las actividades de desarrollo de capacidades o ensayos científicos realizados en los proyectos. De esta manera, podemos mirar hacia adelante al evaluar el pasado y reflexionar sobre nuestro trabajo como pilar fundamental para el éxito en el futuro.

La investigación y los proyectos que se llevaron a cabo los últimos cincuenta años nos han enseñado que, para comprender la relación entre todas las partes de un proyecto en su conjunto, la conservación de la arquitectura de tierra debe abordarse de forma integral. Las conferencias principales, las sesiones plenarias y las mesas redondas ponen de manifiesto que hay una necesidad de analizar el problema desde todos sus ángulos y considerar las funciones de todos los participantes.

El Comité Científico Internacional del Patrimonio Arquitectónico de Tierra (ISCEAH) ha investigado el desarrollo de la "Carta de la Tierra," que puede abordar mejor una metodología para la conservación de los sitios de tierra. Existen metodologías, como la Carta de Burra, que podemos usar como modelo para ayudar a identificar las necesidades, determinar las formas de incluir a todas las entidades y personas clave interesadas, abordar de forma integral un problema y evaluar los resultados de un proyecto para las fases siguientes (Australia ICOMOS 1999).

Amenazas identificadas

Las amenazas identificadas durante el congreso como perjudiciales para la arquitectura de tierra y su conservación son el cambio climático, los desastres naturales, el abandono, la negligencia y las intervenciones humanas incompatibles.

Muchas presentaciones abordaron el impacto del cambio climático (y los eventos climáticos extremos relacionados, incluídos sequías, incendios e inundaciones) en la arquitectura de tierra. Sin embargo, en pocos trabajos se abordaron las posibles soluciones para minimizar el impacto generado por estos desastres en los sitios de tierra. Esto puede deberse a que todavía nuestro campo está en una fase exploratoria y de investigación de las metodologías para identificar, cuantificar y calificar estos riesgos. Los documentos existentes de organizaciones como el Consejo Internacional de Monumentos y Sitios (ICOMOS) pueden guiarnos hacia una investigación más profunda sobre el importante tema del cambio climático (ICOMOS 2019; Potts 2021).

Muchos presentadores mencionaron que es necesario priorizar la vulnerabilidad de la arquitectura de tierra por sobre su resiliencia. Esto implica entender cómo el cambio climático afecta el comportamiento del material y la preservación del sitio. Sin embargo, es igualmente importante estudiar cómo algunos sitios afrontaron el cambio climático en el pasado, haciendo uso del conocimiento empírico y tradicional. De la misma manera en que las soluciones de reforzamiento sísmico se basan en datos reales y modelos de vulnerabilidad sísmica de edificios, se deben desarrollar intervenciones que protejan contra el cambio climático, con base en modelos de datos climatológicos. Se presentaron métodos de adquisición de datos *in situ*, al igual que

protocolos y procedimientos de ensayos para mapear riesgos relacionados con el cambio climático en sitios arqueológicos. Sigue siendo prioritario para los congresos venideros que haya una mayor investigación en la implementación de soluciones apropiadas para el cambio climático.

El monitoreo y el mantenimiento también se presentaron como actividades que pueden implementarse para mitigar daños a traves del tiempo. El monitoreo ambiental y estructural nos permite comprender el comportamiento del sitio y diseñar soluciones apropiadas basadas en datos. Tradicionalmente, el mantenimiento periódico es la mejor manera de preservar los sitios de tierra y es algo que debe promoverse en todos los proyectos. No obstante, el cambio climático exige el reexamen de los enfoques actuales de mantenimiento y, en este congreso, se presentaron metodologías claras y reproducibles tanto para el mantenimiento como para el monitoreo de sitios de tierra, donde el impacto del cambio climático es considerado.

De manera similar, se abordaron los problemas del abandono y la negligencia como amenazas a los asentamientos urbanos de tierra que perdieron no solo su población, sino también las técnicas para dar mantenimiento periódico a esos sitios. La complejidad del problema de reinstalar a la población original involucra la recreación del sistema económico que originó el asentamiento en primer lugar. Lamentablemente, esos mecanismos resultaron ser extremadamente desafiantes o imposibles de replicar. Cuando los asentamientos de tierra se transformaron en restos arqueológicos de poblaciones que los abandonaron en busca de una forma de vida más moderna no muy lejos de su asentamiento original, el conocimiento general de cómo reparar adecuadamente construcciones únicas, y en algunos casos complejas, también desapareció. Los presentadores del congreso alentaron la creación de actividades de desarrollo de capacidades para recuperar esas tradiciones y transmitirlas a las nuevas generaciones.

Este tipo de continuidad cultural también ayudará a detener las intervenciones incompatibles en los sitios de tierra. Es fundamental la enseñanza de técnicas tradicionales de construcción (con materiales modernos compatibles cuando sea necesario), para preservar los asentamientos urbanos y los sitios históricos a través del desarrollo de una generación nueva de arquitectos, ingenieros, conservadores y artesanos que ingresen a la fuerza laboral con los conocimientos adecuados.

Enfoques basados en la comunidad

Tal como se mencionó anteriormente, la representación de las comunidades locales en el XIII Congreso fue excepcional, y alentamos a que este enfoque continúe en el futuro. La participación de las comunidades locales en la sesión plenaria y la mesa redonda enriqueció el debate y el intercambio de ideas. Los participantes de la comunidad son los actores principales y los mejores aliados para avanzar en la preservación de los sitios de tierra. Su experiencia, conocimiento y opiniones son invaluables. La preservación del patrimonio debe celebrar el sentido de lugar y de pertenencia, promover el empoderamiento social y traer beneficios económicos para esas comunidades.

La participación de las comunidades locales debe seguir procesos incluyentes y apropiados para la toma de decisiones: sean los establecidos, los emergentes o los ya practicados dentro de las comunidades. El sector puede aprender de los procedimientos existentes para involucrar a las comunidades en proyectos inclusivos y de largo plazo. La Carta de Burra y otras metodologías aceptadas internacionalmente son ejemplos exitosos de la participación de las comunidades locales o, mejor aún, su empoderamiento, para llevar adelante proyectos propios (Australia ICOMOS 1999). Algunos trabajos presentados en "Cuidado por y para las comunidades" detallan notables experiencias, muchas de las cuales también incluyen un enfoque multidisciplinario.

Por último, es necesario promover el intercambio de conocimientos entre las comunidades locales y los profesionales. No es una cuestión de "educar" a la población del sitio o ignorar la experiencia que un profesional puede aportar a su preservación. La comunidad, en conjunto con las partes interesadas, pueden ofrecer conocimientos diferentes pero complementarios de un sitio. Las soluciones exitosoa para la preservación de la construcción tienen en cuenta todo el conocimiento empírico, histórico, técnico y científico.

Educación y capacitación en conservación

A lo largo de las últimas décadas, se ha desarrollado una serie de iniciativas de capacitación para diferentes regiones y público objetivo, con exalumnos pertenecientes a los cursos PAT, del Diplomado de Especialización y Profundización en Arquitectura (Diplôme de spécialisation et d'approfondissement, DSA) de CRAterre y de programas de maestría de la Universidad de Columbia y de la Universidad de Pensilvania, entre otros. En algunos de estos programas, se han planteado evaluaciones de su desempeño, a corto y largo plazo, en el avance de la conservación de los sitios de tierra. Es importante que se hagan evaluaciones periódicas del impacto de estos cursos de posgrado en el desarrollo del sector, para mejorar y actualizar, de ser necesario, los planes de estudio y enfoques pedagógicos.

La conservación de los sitios de tierra debe enseñarse en escuelas de arquitectura, ingeniería y arqueología. De igual

manera, se deben incluir cursos de arqueología, ingeniería y arquitectura en los planes de estudio de programas de conservación. El sector ha intentado hacer esto por décadas y, tal como se indica en este congreso, se ha tenido cierto progreso a nivel universitario en diversos países. Asimismo, el sector debe investigar la enseñanza de cursos de Antropología y Sociología, especialmente para incluir la participación de la comunidad. La educación en conservación de sitios de tierra se encuentra en un momento crítico en el que puede y debe implementarse un enfoque estratégico y multidisciplinario para abordar la conservación del patrimonio de tierra. Debe alentarse el desarrollo de capacidades constructivas de los albañiles (así como fomentar su participación en futuros congresos) para asegurar la preservación de las técnicas tradicionales de construcción con tierra. Es necesario compartir la pedagogía referente a la conservación de componentes de tierra, la enseñanza de ciencias de materiales y sus métodos de evaluación. Los centros de capacitación establecidos pueden beneficiarse de los recursos didácticos ya desarrollados por instituciones similares.

Investigación e implementación

Este congreso fue testigo de un aumento considerable en la cantidad de trabajos enfocados en la investigación y la implementación de proyectos: solo algunas ponencias y pósteres se dedicaron a describir un sitio o sus problemas. En la mayoría de los trabajos, se presentó una propuesta y resultados o métodos de implementación en casos de estudio. Una buena cantidad de ponencias, pósteres y videos expusieron investigaciones sobre caracterización de materiales, técnicas tradicionales, documentación, contenido de humedad, permeabilidad de los tratamientos y consolidación.

En este congreso, también se presentó una serie de casos de estudio referentes a la reconstrucción integral como medida extrema para preservar un sitio. Éste es un enfoque novedoso si se tiene en cuenta que la llamada "mínima intervención" ha sido la táctica promovida regularmente. En algunos casos, la reconstrucción es necesaria tanto para hacer uso apropiado de un sitio como para frenar el deterioro de algunos de sus componentes. El rubro "Edificios y estructuras históricos" presentó una variedad de metodologías sólidas para abordar adecuadamente la reconstrucción cuando sea necesaria.

En referencia a la rehabilitación de asentamientos urbanos, hubo un simposio sobre un proyecto de conservación de AlUla Old Town and Oasis, en el Reino de Arabia Saudita. La presentación de una encuesta exhaustiva sobre los recursos materiales del sitio fue una valiosa contribución para el congreso. El tema de la rehabilitación urbana debe abordar la gestión del turismo sustentable, así como fomentar el desarrollo de políticas apropiadas para la regeneración urbana y el mantenimiento continuo de estos sitios.

La conservación de sitios arqueológicos de tierra es un tema que se trató desde el primer coloquio en Irán en 1972. En Terra 2022, se llevó a cabo un simposio sobre la conservación del Hopewell Ceremonial Earthworks en Ohio, que se enfocó en la compleja problemática de preservar el material y, lo que es más importante, el paisaje circundante, involucrando además a la comunidad local. Se presentaron otros casos de estudio de investigación e implementación que abordaron la identificación, el monitoreo y la gestión de las vulnerabilidades de zonas arqueológicas ante el cambio climático.

En la última sesión plenaria, se trataron los beneficios y desafíos que enfrentan los sitios de tierra declarados Patrimonio de la Humanidad. En esta sesión, se indicó que, luego de la última actualización realizada en 2021, de los 203 sitios de tierra que son parte de la Lista del Patrimonio Mundial, 18 están en la Lista del Patrimonio Mundial en Peligro. Es interesante notar que el primer conjunto de los sitios nominados y declarados Patrimonio de la Humanidad fueron la ciudad de Quito, en Ecuador, y el Parque Nacional Mesa Verde, en EE. UU., ambos inscritos en 1978 y ambos considerados Patrimonio de tierra. Desde 1978, la cantidad de sitios de tierra en la Lista del Patrimonio Mundial aumentó considerablemente, lo que muestra un reconocimiento creciente de la importancia de la arquitectura de tierra.

La sesión sobre sitios de tierra declarados Patrimonio de la Humanidad fue muy productiva, y recomendamos que, en el futuro, continúe enfocándose en distintos aspectos, que incluyan la manera de gestionar las expectativas de los postulantes al estatus de Patrimonio Mundial, cómo involucrar a las comunidades locales en la nominación para fines de la sustentabilidad, y cómo –en el caso específico de la presencia de conflicto armado en estos sitios– la comunidad internacional puede apoyar a los profesionales locales para protegerlos. Asimismo, sería interesante comprender la evolución de las nominaciones, considerando el estado de conservación luego de cada nominación e identificando sus necesidades especiales.

Organización del congreso

El diseño del programa del congreso fue vigoroso: la mañana comenzaba con presentaciones plenarias y mesas redondas que después se dividían en sesiones paralelas. Los organizadores

alientan la continuación de formatos innovadores similares para avanzar en los debates y el intercambio de ideas en reuniones futuras.

La inclusión de las mesas redondas en las sesiones plenarias resultó ser un formato único y creativo que motivó una serie de debates interesantes. En las discusiones en mesas redondas, se trató primero la historia y la evolución del sector, luego se abordaron las perspectivas regionales, las experiencias del Servicio de Parques Nacionales (NPS) y los desafíos que enfrentan los sitios de tierra declarados Patrimonio de la Humanidad. Las mesas redondas permiten que los distintos grupos con intereses similares tengan un espacio para intercambiar ideas con los participantes. La inclusión de profesionales emergentes en un formato similar puede ser una gran incorporación para eventos futuros. Los congresos están cambiando de presentaciones individuales a formatos tipo debate, que brindan oportunidades para conocer más opiniones, intercambiar experiencias y avanzar en el sector. Además, las sesiones de videos y pósteres proporcionaron un grupo estimulante y diverso de temas y formas de difundir proyectos.

La serie de eventos virtuales organizados previo al congreso a lo largo de un año fue exitosa. Esta idea fue el resultado de la pandemia y nos enseñó nuevas maneras de estar en contacto cercano a pesar de no poder encontrarnos en persona. Se alienta a los organizadores del próximo congreso a considerar estas actividades como parte de su programa, y a mantener comunicaciones regulares desde ahora hasta que nos volvamos a encontrar en Cuenca, Ecuador, en 2025.

Los tres talleres previos al congreso fueron muy inspiradores. Otros congresos y reuniones profesionales organizan talleres similares como parte de sus programas, y deberíamos continuar con ellos. Dichos talleres permiten que los colegas experimenten actividades prácticas y contribuyan a la difusión de nuevas técnicas y enfoques dentro de nuestra comunidad de profesionales.

Por último, el XIII Congreso nos brindó la oportunidad de encontrarnos en persona por primera vez luego de años de aislamiento: sin duda, un alivio y una felicidad para todos los participantes. Terra 2022 juntó a un grupo extraordinario de profesionales y nos hizo ver nuevamente cómo estas reuniones son hitos importantes en momentos en los que nacen nuevas iniciativas. No podemos esperar para ver lo que vendrá.

Agradecimientos

Estas conclusiones representan las contribuciones de un grupo de colegas que asistieron a las sesiones y se reunieron durante el congreso para debatir sobre las mismas. Estos debates fueron muy inspiradores si se tiene en cuenta el alto nivel de participación de los colegas, y agradezco a cada una de esas personas por sus valiosas opiniones e ideas.

Estoy orgullosa de ser miembro del personal del Getty Conservation Institute, socio organizador de este evento, y líder de la Iniciativa de Arquitectura en Tierra del GCI, programa del cual forma parte el Congreso Mundial Terra 2022. Sin embargo, el reconocimiento por la organización de este evento es para Jeanne Marie Teutonico, directora adjunta de GCI; Frank Matero, titular de cátedra del programa de posgrado en Preservación Histórica de la Escuela de Diseño Stuart Weitzman de la Universidad de Pensilvania; Lauren Meyer, líder del programa Intermountain Historic Preservation Services (Vanishing Treasures, Historic Structures, Cultural Landscapes and History); y a mi querida amiga y colega, en ese orden, Leslie Rainer, especialista sénior de proyectos, Getty Conservation Institute.

Este congreso es un testimonio del profesionalismo y pasión de todos los que contribuyeron a la organización de Terra 2022.

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John E. Hancock is professor emeritus of architecture at the University of Cincinnati, where he taught architectural theory and design for forty years. In addition to authoring academic publications on the phenomenology of architecture, he has created exhibits and digital publications on ancient Ohio. As an author and photographer, he helps lead the UNESCO World Heritage nomination effort for the Hopewell Ceremonial Earthworks.

Sharlot Hart is an archaeologist with the National Park Service, Southern Arizona Office. In this capacity she aids parks with on-the-ground archaeology and historic preservation endeavors, assists with federal compliance, and manages projects. She holds an MA in anthropology, with a specialization in applied archaeology, from the University of Arizona.

Pamela W. Hawkes, a principal with Scattergood Design, has directed a wide variety of award-winning design projects and led multidisciplinary teams to create strategies for landmarks owned by the National Park Service and the National Trust for Historic Preservation, as well as museums, historic sites, and other institutions. She is professor of practice in historic preservation at the University of Pennsylvania Stuart Weitzman School of Design.

Susanne von der Heide is a cultural scientist and conservation specialist. She was curator for education at the Museum of East Asian Art in Cologne from 1988 to 1995. She was employed at UNESCO Headquarters in Paris, where she was appointed director in 2001. In 2008 she became chair of the HimalAsia Foundation. In addition, she teaches at various universities.

Michael C. Henry is principal engineer-architect at Watson & Henry Associates, where he has been consultant to institutions, cultural heritage stewards, and architects/engineers throughout the US and in India, Cuba, Mexico, Brazil, and Tunisia. As adjunct professor of architecture at the University of Pennsylvania, he teaches courses on pathologies of buildings and their systems and on diagnostic methodologies and monitoring.

John Hinchman graduated from the University of Pennsylvania with an MS in historic preservation. A lecturer at the University of Pennsylvania, he teaches the course Applications of Digital Media in Preservation, which focuses on developing a comprehensive understanding of the use of diverse software packages as single integrated tools in historic preservation.

Yutaka Hirako is an architect specializing in conservation and is program director of the Tibet Heritage Fund (THF) and the Leh Old Town Initiative (LOTI). Since 1998 he has worked with THF on conservation projects in Lhasa and other Tibetan regions, Beijing, Mongolia, and, since 2012, the Himalayan regions of Sikkim and Ladakh. His projects have won UNESCO awards.

Tobias Hofstetter holds a bachelor's degree in archaeology and anthropology (University of Neuchâtel) and master's degrees in bioanthropology and archaeology (University of Geneva) and in history, English, and American literature (University of Neuchâtel). He works as a bioanthropologist and archaeologist on various projects in Europe and the Middle East. He is currently assistant to the head of the architectural survey of the AlUla Cultural Oasis Project (UCOP), within Archaïos.

Mounsif Ibnoussina is a university professor and a researcher specializing in the earth sciences, stratigraphy,

and paleontology. He believes that architecture must meet the challenge of being authentic, harmoniously reflecting its historical, artistic, social, cultural, and spiritual contexts while maintaining an awareness of environmental issues.

Pamela Jerome, FAIA, LEED AP, is a preservation architect with forty years of experience. She is president of Architectural Preservation Studio, DPC, a New York–based architecture and preservation firm. She is treasurer for the international board of ICOMOS and secretary general of ICOMOS-ISCEAH. She has consulted on cultural properties in the US, the Mediterranean, the Black Sea region, the Middle East, and the Far East.

Concepción Jiménez-López is associate professor in the Department of Microbiology at the University of Granada (UGR). She holds a BS and a PhD in physics from UGR. Her research is focused on bacterial biomineralization processes and biomimetic magnetic nanoparticle production. She is the inventor of two patents in this area for bacterial stone consolidation and magnetosome-like magnetic nanoparticle formation.

Thierry Joffroy is an architect specializing in earthen architecture. After his involvement in numerous projects and programs around the world, he is currently director of the CRAterre team, AE&CC Research Unit at ENSAG. In that framework, he directs PhD students in the preparation of their theses in architecture that explore the possibilities of linking heritage to development and alleviation of poverty.

Michael Jones is manager of cultural heritage conservation at the Royal Commission for AlUla, which he joined in 2018. He has participated in numerous projects related to the excavation, documentation, preservation, and presentation of archaeological sites and historic buildings in Egypt and the Near East. His interests include the impact of local cultural dynamics on the conservation of built heritage and how landscape-based sites can play a role in changing heritage values in contemporary societies.

Jharna Joshi, PhD, is visiting professor at Kathmandu University, Nepal. She is an architect with a master's degree in historic preservation and cultural landscapes and a PhD in tourism management. Her areas of specialization include architecture, conservation, cultural landscapes, cultural tourism, and sustainable development. She is currently involved in designing and restoring traditional buildings as well as teaching at architectural institutions.

Fadwa Jroundi is a postdoctoral researcher in the Department of Microbiology at the University of Granada (UGR), examining molecular biology as applied to building materials to explore the microorganisms responsible for biomineralization and consolidation as a response to conservation treatments. She holds a degree in biology from Mohamed V University, Rabat, Morocco, and a PhD in microbiology from UGR.

Xu Kanda, a master planner and national registered planner, received his master's degree in urban planning and urban-rural heritage conservation from Tongji University. He has seven years of experience in heritage conservation and is engaged in thirty projects in Guizhou, Guangzhou, Dali, Pingyao, and other regions in China. His research focuses on urban and rural heritage conservation, with particular attention to heritage regeneration in historic centers.

Yasmin Kanhoush holds a PhD in archaeology and history of ancient civilizations from the University of Lyon. She is a buildings archaeologist specializing in Near Eastern earthen architecture, and is currently field director and head of the archaeological survey of the AlUla Cultural Oasis Project (UCOP), within Archaïos. She is also a research associate in the Archéorient laboratory (UMR 5133).

Steven Karacic received his PhD in classical and Near Eastern archaeology from Bryn Mawr College in 2014. He is currently an office principal at PaleoWest, a cultural resource management firm in the US. Karacic has worked throughout the UAE on numerous prehistoric sites, with a special focus on sites from the Iron Age.

Rachida Kasimi is a university professor and researcher and has participated in many national and international research projects. Kasimi is committed to the preservation, protection, and enhancement of historical, prehistoric, and archaeological heritage.

Marilyn Kelly-Buccellati has been excavating and conducting research on the ancient city of Urkesh for the past thirty years. She is professor emerita at California State University, Los Angeles, where she taught archaeology and art history, and is now visiting professor at the Cotsen Institute of Archaeology, UCLA.

Jonathan Kemp has over thirty years of experience as a sculpture conservator on heritage made of stone and allied materials. He was a senior sculpture conservator at the V&A Museum, London, and a consultant on projects in Brazil, Canada, Iran, Iraq, Spain, Ukraine, the UK, and Taiwan. He is a lecturer in conservation at the Grimwade Centre for Cultural Materials Conservation at the University of Melbourne and editor of the *Journal of the Institute of Conservation*.

Alireza Khaksar is a consultant and expert in the restoration of historical buildings and a member of the technical office of the Āsbād Cultural Heritage Site of Iran. Khaksar graduated from the Jundishapur Industrial University in Dezful and has a diploma in mathematics and physics. Khaksar is active in painting and night-sky photography.

Mohammed Khalifa graduated from the University of Ain Shams in Cairo and has worked as an archaeologist with the Department of Culture and Tourism–Abu Dhabi since 2007. He has more than twenty years of experience in rescue archaeology, buildings archaeology, conservation of earthen structures, and management of cultural landscapes in Egypt and the UAE.

Zohreh Khezri is an expert in the restoration of historical buildings. She graduated from Tehran Cultural Heritage University and holds a degree in the restoration of historical relics from Tehran University of Arts. She has collaborated on the Toos and Abyane projects and has taught courses related to the field of restoration at the universities of Birjand and Torbat Heydariyeh.

Rainer Komp studied classical archaeology and received his MA from the Free University Berlin. Since 1999 he has been a research assistant at the German Archaeological Institute, with a focus on geophysical surveys, computer applications in archaeology, and research data management. Previously, he was a researcher on the project Remote Access to Museum Archives (RAMA) at the Collection of Antiquities Berlin as well as an information technology professional.

Dale Kronkright has been head of conservation at the Georgia O'Keeffe Museum, Santa Fe, New Mexico, since its inception in 1997. His current research focuses on vibration-induced damage to art in transit and quantitative imaging and remote sensing to detect and monitor deterioration.

Ambrantonella Lattanzio is an architect with a master's degree in architecture. She has collaborated with Terrae Onlus since 2015, leading the activities of CEDTerra. In 2019 she participated in the National Civil Service, where she analyzed aspects related to education, environmental consciousness, and rural landscape design. She is passionate about natural architecture, and in 2020 she obtained a master's degree in bioarchitecture from CasaClima Agency, Bolzano.

Malo Le Guern is a researcher and teacher in the Civil Engineering Laboratory at ESITC Caen. He has published original research related to earthen buildings, including a hybrid walling technique combining mechanical and thermal performance, and civil engineering topics such as the implementation and experimental monitoring of a subgrade road layer based on treated marine sediments.

Bradley T. Lepper is curator of archaeology for the Ohio History Connection in Columbus. He has written extensively on the Ohio Hopewell culture in general and the Newark Earthworks in particular for both academic and general audiences. He is the principal author of *Ohio Archaeology: An Illustrated Chronicle of Ohio's Ancient American Indian Cultures*.

Nicola Lercari is a professor and chair of digital cultural heritage studies at the Ludwig Maximilian University of Munich. His scholarship exposes the fundamental role that digital and geospatial technologies play in the investigation and protection of sites of cultural significance, archaeological and museum collections, and data and information that describe and document the cultural diversity of our planet. He edited the volume *Preserving Cultural Heritage in a Digital Age: Sending Out an S.O.S.*

Alick Leslie was, until summer of 2021, head of the Built Heritage Research team at the Getty Conservation Institute, which focuses on the development and application of scientific skills to improve the conservation of the world's built heritage. He previously worked for Historic Environment Scotland and Historic England and is currently carrying out consultancy for the latter.

Ashley M. Lingle is a lecturer in conservation at Cardiff University. She was head of conservation for the Çatalhöyük Research Project from 2012 to 2020. Her PhD from Cardiff University focused on the use of aqueous polymers on archaeological earthen substrates. She holds an MA and an MSc in conservation from University College London.

Isa Loo is currently a PhD candidate at the Grimwade Centre for Cultural Materials Conservation at the University of

Melbourne, where she also completed an MA in cultural materials conservation. Prior to her current research, she worked as an archaeological/objects conservator at many of the major collecting institutions in Australia and overseas.

Friedrich Lüth is director and professor at the German Archaeological Institute. His research interests include the Mesolithic and Neolithic periods in Europe and the Near East, including paleogenetics and submerged landscapes, and the development of conservation and management tools for global archaeological heritage. Previously, he was head of archaeological heritage management for the state of Hamburg and state archaeologist and conservator for Mecklenburg–Western Pomerania. He holds a DPhil and PhD from the University of Hamburg.

Benjamin Marcus is a project specialist at the Getty Conservation Institute (GCI) and project manager for the International Course on the Conservation of Earthen Architecture. He holds a master's degree in historic preservation from Columbia University. Before joining the GCI, he was a building conservator with the Abu Dhabi Authority for Culture and Heritage and a conservator at Page & Turnbull Inc.

Frank Matero is Gonick Family Professor of Historic Preservation Architecture and chair of the Graduate Program in Historic Preservation at the University of Pennsylvania and director of the Center for Architectural Conservation. He is also editor in chief of *Change over Time*. He is one of the partners for the organization of Terra 2022 and a volume editor for these proceedings.

Jerome Mayaud is honorary research associate at the School of Geography and the Environment, University of Oxford. He completed his DPhil in geography at the University of Oxford before undertaking a postdoctoral research fellowship at the University of British Columbia, Vancouver. He is currently a lead data scientist at a company aiming to improve transit networks.

Karima Mazirh is an architect and PhD student at Cadi Ayyad University, Marrakech. She is passionate about sustainable entrepreneurship. She approaches architecture from a socio-environmental perspective, which has been refined over the years by professional and personal experiences that are as rich as they are varied.

Sebastian Messal is a research assistant at the German Archaeological Institute. His work focuses on geophysical surveys and early historical archaeology of northern and eastern Europe. Previously, he conducted studies of prehistory and early history, geology, and anthropology in Kiel, Germany, and Lund, Sweden, and was a research assistant at the State Office for Cultural Heritage, Mecklenburg–Western Pomerania. He holds a DPhil from the University of Rostock.

Lauren Meyer oversees the National Park Service's (NPS) Intermountain Historic Preservation Services Group, including the Vanishing Treasures Program. In this role, she guides and provides support to parks and partners in the conservation of the significant yet fragile architectural heritage of the American West. Having been with the NPS for twenty years, her focus areas include the conservation of archaeological sites in the American Southwest, the development of tools for evaluating and addressing climate change risks and vulnerabilities for cultural heritage, and the implementation of multidisciplinary approaches to cultural resource management. She has a BA in archaeological studies from Boston University, an MS in historic preservation from the University of Pennsylvania, and an advanced certificate in architectural conservation and site management from the University of Pennsylvania. She is one of the partners for the organization of Terra 2022 and a volume editor for these proceedings.

Sébastien Moriset, architect, has been involved in teaching activities and applied research on issues of heritage conservation for CRAterre-ENSAG since 1993. He has contributed to sixty-eight projects in Africa, Central Asia, and the Arab region and prepared several World Heritage nominations, management plans, and conservation programs. He also lectures in the postgraduate course DSA-Terre in Grenoble.

Tom Morton is an architect, project officer, and member of EBUKI. He has expertise in ecological construction, conservation, and the reuse of old buildings. He has managed a wide variety of projects for private and community clients and leads Arc's research activities. Morton is RIAS accredited in both conservation and sustainable design.

Jeremy Moss is an archaeologist and preservation specialist with the National Park Service (NPS) and is currently chief of science and resource stewardship at Pecos National Historical Park. He earned an MA in anthropology from the University of Wyoming and has worked for the NPS for twenty-four years.

Salman Muhammad holds an MSc in conservation of monuments and sites from the University of Leuven. He has over

twenty years of experience in heritage conservation. He is currently working with Conrad Gargett in Australia. Previously, he worked with the Department of Culture and Tourism–Abu Dhabi and the Aga Khan Trust for Culture.

Wendel C. Navenma is an archaeologist at Montezuma Castle and Tuzigoot National Monuments. He is a member of the Hopi tribe and is from the village of Old Oraibi. He belongs to the Rabbit/Tobacco clan. Navenma has a BA in anthropology from Northern Arizona University.

Anca Nicolaescu has a degree in wall paintings conservation from the National University of Arts in Bucharest and a Master 2 Professionnel Conservation Restauration des Biens Culturels from Université Paris I Sorbonne. Since 2005, she has been a member of the Tibet Heritage Fund as head of conservation for Buddhist wall paintings in the Himalayas.

Larry Nordby worked for the National Park Service (NPS) from 1975 to 2005. In his last assignment, at Mesa Verde National Park, he led the Archaeological Site Conservation and Vanishing Treasures Programs with a professional focus on preserving the scientific and heritage values of ancient Indigenous buildings of the Southwest, especially cliff dwellings. Nordby continues to collaborate on similar studies with academic and NPS colleagues.

Ishanlosen Odiaua is senior social development specialist at the World Bank. She is a trained architect specializing in earthen architectural heritage and is vice president of ICOMOS-Nigeria. She is a current board member of ISCEAH and was chair of the landscape theme from 2018 to 2020.

Moses O. Oladele is an architect and urbanist with a passion for low-carbon designs and technologies as well as infrastructure planning and maintenance. He has presented papers at national and international conferences in his specialty areas. Oladele is currently in private practice and the principal of a leading architectural practice, Iconic Consult, in Abuja, Nigeria.

Daniel V. Oliveira has bachelor's and master's degrees in civil engineering from the University of Porto and a PhD in civil engineering from the University of Minho. He is associate professor in the Department of Civil Engineering at the University of Minho. His main research interests relate to the experimental and numerical analysis of traditional masonry structures, earthquake engineering, strengthening of masonry structures with innovative composite materials, earthen construction, risk assessment, and durability. Oliveira is widely published and has worked on four RILEM committees dealing with strengthening masonry and earthen constructions.

Evan Oskierko-Jeznacki is the National Park Service Vanishing Treasures Program Historical Architect and a PhD candidate at the University of Pennsylvania, where he completed his master's degree in historic preservation and environmental building design. His research includes a vulnerability assessment protocol for climate-sensitive historic structures in the arid west and the use of RFID technology as a minimally destructive moisture monitoring technique.

Fabio Paparazzo, architect, is a graduate of Università degli Studi di Firenze. While at the Universidad Santo Tomás of Bucaramanga Colombia, he carried out a study on earthen architecture and historic construction techniques in the Chicamocha Canyon.

Michele Paradiso is associate professor of strength of materials. His professional interests include the collapse mechanisms of arches, vaults, and masonry domes and the structural restoration of historical monuments, bamboo constructions, and earthen constructions. He is an expert member of ICOMOS-Cuba, as well as the International Scientific Committees of ICOMOS: ICOFORT and ISCARSAH.

Ingrid Périsse-Valéro is head of archaeological and cultural heritage projects at the French Agency for the Development of AlUla (AFALULA). She specializes in building archaeology and religious life of the Middle East in antiquity. She has led several excavations in Lebanon and Syria and was director of the department of archaeology and art history at the Sorbonne University Abu Dhabi.

Giovanni Pianigiani currently works as an architect in Florence. Fascinated by ancestral construction techniques and sustainable architecture, he graduated with a dissertation developed in the Department of Santander, Colombia, on building local cultural identity and the vulnerability of a rammed earth village in the Chicamocha Canyon.

Douglas Porter is an architectural conservator who directs research focused on the investigation, stabilization, and repair of culturally significant historic/prehistoric sites and structures in cooperation with academic, federal, and nonprofit partners. Porter holds a research faculty position in the School of Engineering, University of Vermont, where he is exploring

the roles of engineering in conservation. He is an expert member of ISCEAH and ISCARSAH.

Graham Price is an honorary fellow at the Grimwade Centre for Cultural Materials Conservation at the University of Melbourne and has a background as a geologist with many years of experience in the deformation behavior of granular materials. He is the inventor and developer of the CIPS cementation system and conducted the initial CIPS treatment of the archaeological remains of the miners' huts near Castlemaine in Victoria, Australia.

Jamie Quartermaine is an experienced archaeological surveyor and senior manager with Oxford Archaeology who has been developing archaeological strategies for recording landscapes and buildings since the early 1980s. He is project director for a major archaeological landscape survey that has been recording the heritage of AlUla on behalf of the Royal Commission for AlUla, utilizing LiDAR and photogrammetric techniques.

Leslie Rainer is a conservator of mural paintings and senior project specialist in the Buildings and Sites Department at the Getty Conservation Institute. She has worked on the conservation of decorated surfaces in Africa, Europe, China, Central and South America, and the US. She received a master's degree in conservation of architectural finishes (Antioch University), earned a certificate in the conservation of mural paintings (ICCROM), and participated in the Preservación de Arquitectura de Tierra course (PAT). She was a partner for the organization of the 2004 colloquium on the Conservation of Decorated Surfaces on Earthen Architecture at Mesa Verde and of Terra 2008, in Bamako, Mali, and was a volume editor for both of those proceedings. She is one of the organizing partners of Terra 2022 and is a volume editor for these proceedings.

Bakonirina Rakotomamonjy is an architect and a researcher at CRAterre-AE&CC ENSAG. She has carried out more than eighty missions as consultant for UNESCO, ICOMOS, and ICCROM. She is chair of CRAterre and coordinator of the UNESCO Chair for Earthen Architecture's UNITWIN network. She was pedagogical coordinator of the DSA-Terre from 2009 to 2020.

Kara Raymond is a hydrologist with the National Park Service's Southern Arizona Office, where she specializes in surface water and groundwater dynamics, aquatic ecology, climate, erosion, and general natural resource support. She holds an MS in water resources science from the University of Minnesota–Twin Cities.

Michael T. Reynolds serves as deputy director for external affairs for the National Park Service (NPS). The third generation of his family to work for the NPS, Reynolds grew up in Yosemite National Park, where he later became the superintendent. He previously served as regional director for the Legacy Intermountain Region of the NPS and, before that, as deputy director of operations, where he spent the majority of his tenure serving as acting director for the NPS, leading more than 20,000 employees who protect and preserve more than 400 national parks. He also served as associate director for NPS Workforce, Relevancy and Inclusion, as regional director of the Midwest Region, and in numerous other positions throughout parks during his thirty-six years of federal service.

Telma Ribeiro has a master's degree in stone conservation and a PhD in conservation science from Nova University of Lisbon. She is assistant professor at Portucalense University. She aims to draw attention to the importance of earthen heritage preservation and contribute to the advancement of scientific knowledge. Her research interests include analysis of the interaction between consolidation and water-repellent products (natural and synthetic) and earthen material, as well as in situ nondestructive analysis.

Jenny Richards is a supernumerary teaching fellow at St John's College, University of Oxford, and a researcher at the School of Geography and the Environment, University of Oxford. She received a BA in geography at the University of Oxford before completing an MRes at University College London, and a DPhil at the University of Oxford. She is interested in environmental interactions with earthen heritage sites.

Satwant Rihal is professor emeritus in architectural engineering at California Polytechnic State University, San Luis Obispo. He is an expert member of ISCARSAH and CIPA, ICOMOS-ISC. He serves on the board of the Structural Engineering World Congress (SEWC). He has extensive experience in earthquake hazard mitigation of buildings, especially heritage structures and earthen buildings.

Carlos Rodriguez-Navarro is professor in the Department of Mineralogy and Petrology at the University of Granada (UGR). He received a BS and a PhD in geology and an MS in conservation science from UGR. He was a research fellow at the Getty Conservation Institute from 1995 to 1998. His research focuses on heritage conservation and materials science.

Bret J. Ruby is an archaeologist with the National Park Service at Hopewell Culture National Historical Park. He earned a bachelor's degree from Kent State University and a doctorate from Indiana University, both in anthropology. His research interests include the ancient and modern histories of American Indian nations; Hopewell archaeology, community organization, craft production, and interregional interaction; heritage management; and archaeological remote sensing.

Encarnación Ruiz Agudo is associate professor in the Department of Mineralogy and Petrology at the University of Granada (UGR). She received a BS in chemical engineering and a PhD in earth science from UGR. Her research focuses on heritage conservation and materials science.

Chamsia Sadozaï is an archaeologist specializing in earthen architecture preservation. She holds a post-master's degree from CRAterre-ENSAG in France and, since 2012, has been a freelance researcher and consultant on World Heritage Sites such as Qalhat (Sultanate of Oman) and Hili in Al Ain (UAE), as well as archaeological sites in the Near East (Armenia, Bangladesh, India, Kurdistan, Tajikistan, and Turkmenistan).

María Paz Sáez Pérez is associate professor at the University of Granada. She has participated in various research projects related to materials characterization, participated in several international conferences, and published in prestigious journals. She provides expert reports on the pathology and rehabilitation of buildings and conducts research on the protection and conservation of monuments and cultural heritage.

Nuria Sánchez Muñoz is an architect and researcher. After nine years working for European firms and NGOs, she joined CRAterre-AE&CC-ENSAG in 2012. She has developed architectural projects, studies of the values and preservation of vernacular architecture, and the production of earthen materials adapted to sustainable contemporary needs in Europe, Africa, and Arab countries.

Katherine Scott is an archaeologist with the National Park Service (NPS) at Pecos National Historical Park. She has worked in the Southwest with the NPS and in cultural resource management for eleven years and specializes in archaeology and historic preservation. She holds a BA in anthropology from the University of Minnesota–Twin Cities.

Peter Sheehan has been head of Historic Buildings and Landscapes with the Department of Culture and Tourism–Abu Dhabi since 2007, a role that includes site management, conservation, and presentation of historic buildings and cultural landscapes. He has published extensively on his work in Old Cairo and the historic oasis landscape of Al Ain, UAE.

Theophilus A. Shittu is an architect and researcher with an interest in sustainable built environments. His research areas include sustainable architecture and planning, earthen architecture, vernacular architecture and conservation, and digitally enhanced low-carbon design and technologies. Shittu is currently senior lecturer and program leader for architectural technology at the University of Northampton.

Mariana de Souza Rolim, architect, is professor at Anhembi Morumbi University, Brazil, leading the Cultural Heritage Research Laboratory (Preserva). She has been a member of ICOMOS-Brazil since 2019. As a researcher and teacher, her specialties are cultural heritage and the history of architecture and urbanism, in particular, heritage management and preservation, historical research, and related public policies.

Ione R. Stiegler, FAIA, is principal historic preservation architect for IS Architecture. Her studio specializes in applying the Secretary of the Interior's *Standards for the Treatment of Historic Properties* and has rehabilitated/restored over 200 historic structures: institutional, adobe, and residential. Stiegler lectures locally and internationally, prepares desk reviews for World Heritage nominations, and has been a mission expert for UNESCO/ICOMOS.

François Streiff is an architect and is responsible for ecomaterials and eco-construction at Parc naturel régional des Marais du Cotentin et du Bessin. He has been designing and building earthen buildings for twenty years, developing training schemes for earth builders, and lecturing both at the University of Normandy and at international conferences on building with earth.

Michael Romero Taylor has worked for the last forty-seven years in historic site management, architectural conservation, and management of cultural routes, museum/visitor center management, and archaeological site preservation. He participated in the Architectural Conservation Course through ICCROM in Rome in 1987, and has been active with ICOMOS for the past thirty years. He retired in 2019 from the National

Park Service after working as a cultural resource specialist for nine congressionally designated historic trails in the US.

Jeanne Marie Teutonico is an architectural conservator with over forty years of experience in the conservation of buildings and sites. Over the course of her career, she has held positions at the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) in Rome, English Heritage in London, and, most recently, the Getty Conservation Institute (GCI) in Los Angeles, where she served as associate director for more than twenty years. Jeanne Marie received an AB in art history from Princeton University and an MSc in historic preservation from Columbia University, Graduate School of Architecture, Planning and Preservation. She is a fellow of the Association for Preservation Technology, the Society of Antiquaries of London, and the International Institute for Conservation of Historic and Artistic Works (IIC).

Jorge Tomasi, architect, is senior researcher at the National Scientific and Technical Research Council, Argentina (CONICET), working at the Laboratorio de Arquitecturas Andinas y Construcción con Tierra (LAAyCT). He is a member of Red Iberoamericana PROTERRA, an expert member of ISCEAH and CIAV-ICOMOS, and section editor of the *Encyclopedia of Vernacular Architecture of the World*. Tomasi holds a master's degree in social anthropology and a PhD in geography.

Karim Touati is a lecturer and researcher at ESITC. His research focuses on heat transfer, heat storage, and the phase change mechanisms in materials. He also has investigated energy conversions and the impact of thermoelectric effects.

Heather Viles is professor of biogeomorphology and heritage conservation at the University of Oxford. She is codirector of the EPSRC Centre for Doctoral Training in Science and Engineering in Art, Heritage and Archaeology and director of the Oxford Resilient Buildings and Landscapes Lab. Her major interests are in geomorphology and heritage science, particularly the application of science to heritage conservation.

Xudong Wang is director of the Palace Museum, China. He is the principal scientist for a key national research and development program.

Shao Yong is professor in the College of Architecture and Urban Planning at Tongji University, National Research Center of Historic Cities, and director of the Urban-Rural Heritage Conservation Department of Shanghai Tongji Urban Planning and Design Institute. She is vice president of ICOMOS-CIAV, an expert member of ICOMOS-ISCEAH, and a member of the editorial committee of the journal *Built Heritage*.

Christof Ziegert, Prof. Dr.-Ing., is a German structural engineer specializing in contemporary and historic earthen buildings. He is managing and scientific director of ZRS Ingenieure, based in Berlin. His office has been working for the Department of Culture and Tourism–Abu Dhabi at UAE Heritage since 2007. He has also been working for the German Archaeological Institute on the earthen remains of the World Heritage Site of Uruk, Iraq, since 2016. Since 2009 he has an honorary professorship in the conservation of earthen architecture at the University of Potsdam, Germany.

Colaboradores

Aquí se enumeran los autores de artículos en español; para autores de artículos en inglés, véanse las págs. 543–55.

Cristian Abad es arquitecto egresado de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca, Ecuador, formado en la Opción de Conservación del Patrimonio Edificado. Ha participado en eventos nacionales e internacionales sobre patrimonio edificado y arquitectura popular en México y Ecuador. Actualmente, se desempeña como diseñador, constructor y restaurador de muebles.

María Cecilia Achig Balarezo es docente de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca, Ecuador; investigadora del proyecto Ciudad Patrimonio Mundial en el área de mantenimiento y conservación preventiva de la arquitectura patrimonial vernácula; miembro de la Red Iberoamericana PROTERRA; candidata a PhD en la Universidad de Valladolid, España. Ha publicado artículos en revistas científicas y participado en conferencias en México, Cuba, Paraguay, Ecuador, Bolivia, Canadá, Perú y España.

Rosa Liliana Alfaro es licenciada en Restauración de Bienes Muebles con maestría en Conservación de Monumentos Construidos y doctora en Administración con especialidad en Gestión. Tiene más de 10 años de experiencia en conservación de monumentos arqueológicos. Actualmente, trabaja en la Zona arqueológica de Teotihuacán del Instituto Nacional de Antropología e Historia, México, donde coordina y dirige proyectos de conservación de pintura mural y estructuras arqueológicas.

Cristian Allaico es arquitecto egresado de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca, Ecuador, formado en la Opción de Conservación del Patrimonio Edificado. Ha participado en eventos del patrimonio edificado y arquitectura popular en Cuba, México, Perú y Ecuador y presentado ponencias nacionales. Ha colaborado de proyectos arquitectónicos y concursos a diferentes escalas. Es socio-creador de la red de plataformas digitales "AC Arquitectura y Ciudad".

Josué Álvarez es estudiante de la licenciatura en Arqueología de la Universidad de San Carlos de Guatemala. Es miembro de la Comisión Organizadora del 18 SIACOT-PROTERRA y del equipo de investigación del Proyecto Zona Arqueológica Kaminaljuyu. Participó en el Taller para la Conservación de la Escultura Maya LACEM en Copán, Honduras, en 2019, organizado por la Universidad de Harvard.

Giorgia Amoruso es arquitecta y magíster *cum laude* en Arquitectura por la Università degli Studi di Roma "La Sapienza" (2009). Estudiante de doctorado en la Universitat Politècnica de València con tesis en cotutela con la Pontificia Universidad Católica de Chile que lleva por título "Preservación y revitalización del patrimonio material e inmaterial de los centros históricos para la mitigación del riesgo sísmico".

Bárbara Arroyo es arqueóloga por la Universidad de San Carlos de Guatemala y Ph.D. en antropología por la Vanderbilt University, Nashville, Tennessee. Fue directora del proyecto Zona Arqueológica Kaminaljuyu del Instituto de Antropología e Historia, Guatemala (2010–18), y directora del proyecto de investigación Kaminaljuyu (2019–21); es miembro de la red PROTERRA Guatemala. Ha realizado investigaciones en sitios de la Costa del Pacífico de Chiapas (México), Guatemala y El Salvador.

Gabriela Barsallo es arquitecta, con formación en la Universidad de Cuenca, Ecuador. Obtuvo su grado de maestría en Conservación y Gestión del Patrimonio Cultural Edificado en el año 2019. Ha trabajado en varias instituciones públicas. Es investigadora en el proyecto Ciudad Patrimonio Mundial. Su trabajo se enmarca en el ámbito de la conservación del patrimonio cultural, específicamente en el mantenimiento y conservación preventiva.

Claudia Cancino es especialista sénior de proyectos del Departamento de Edificios y Sitios del Getty Conservation Institute, donde dirige la Iniciativa de Arquitectura de Tierra, la que incluye el Proyecto de Estabilización Sismorresistente en Perú. Es arquitecta colegiada en Perú, cuenta con un certificado en Conservación (ARC 95 ICCROM), y tiene maestrías en Administración de Empresas (ESAN) y Preservación Histórica, así como un certificado avanzado en Conservación (University of Pennsylvania).

Raúl Cárdenas Fuentes fue alcalde y gobernador del distrito de Rondocan, Perú, donde se ubica la comunidad de Kuñotambo. Fungió como presidente del Comité de Restauración del Templo de Santiago Apóstol de Kuñotambo, habiendo facilitado todas las fases del proyecto de conservación y estabilización sismorresistente; fue secretario del Comité de Salvaguardia y Protección del Templo.

Fausto Adrián Cardoso Martínez es graduado en la Facultad de Arquitectura de la Universidad de Cuenca, Ecuador, y es doctor por la Università degli Studi di Roma "La Sapienza". Dirigió el equipo técnico para la formulación del expediente para la inclusión de Cuenca en la Lista del Patrimonio de la Humanidad. Es director del proyecto Ciudad Patrimonio Mundial y profesor principal de la Universidad de Cuenca.

Andrea Cordero Zorrilla es restauradora de Bienes Muebles y trabaja para el Instituto Nacional de Antropología e Historia, México. Ha colaborado en diversos proyectos de conservación de patrimonio histórico, paleontológico y arqueológico, en vinculación con organismos institucionales, gubernamentales y académicos, para facilitar la conservación del extenso patrimonio de la región de Puebla, México.

Annick Daneels es investigadora sénior en el Instituto de Investigación Antropológica de la Universidad Nacional Autónoma de México (UNAM). Trabaja activamente en la arqueología de la costa del golfo desde 1981 y se enfoca en la arquitectura de tierra mesoamericana desde 2004. Ha editado tres libros; es autora de nueve artículos científicos y cuarenta y seis capítulos de libros, así como procedimientos sobre la arquitectura de tierra. Es miembro del Consejo Consultivo de la Red Iberoamericana PROTERRA. Tiene doctorados (PhD) de la Universidad de Gante, Bélgica (1987), y de la UNAM (2002).

Hugo Fernández Ramírez es pasante de la licenciatura de Arqueología en la Universidad Autónoma de Zacatecas, México, y becario adscrito a los estudios micromorfológicos de las muestras constructivas prehispánicas del proyecto CONACyT CB2015-254328.

Lidia García-Soriano es arquitecta (2010), máster en Conservación del Patrimonio Arquitectónico (2013) y doctora en Arquitectura (2015). Actualmente, es profesora asociada en el Departamento de Composición Arquitectónica de la Universidad Politécnica de València (España). e investigadora en el Centro de Investigación PEGASO de la UPV. Su actividad profesional e investigadora se desarrolla en torno al patrimonio arquitectónico en general y a la arquitectura de tierra y técnicas constructivas tradicionales, así como a los criterios y las técnicas de restauración, con varias publicaciones relativas a estos temas.

Dulce María Grimaldi Sierra es licenciada en Restauración de Bienes Muebles por la ENCRyM-INAH, México, con una maestría en Ciencia Aplicada a la Conservación por la Universidad de Queen's, Canadá. Es restaurador-perito de la Coordinación Nacional de Conservación del INAH, donde coordina proyectos de conservación *in situ* de pintura mural, así como elementos decorativos en piedra y tierra, en diversos estados de la República Mexicana.

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Anaïs Guéguen Perrin es licenciada en Arquitectura (Grenoble/São Paulo) y especializada en Arquitectura en Francia. Actualmente, desarrolla una investigación de doctorado en Arquitectura (AE&CC/ENSAG/UGA y HABIS/IAU/USP) sobre el hábitat indígena en Brasil y participativo en Francia. Como arquitecta y constructora, trabaja en proyectos con fines sociales y ecológicos. Es miembro de la red profesional brasileña de construcción con tierra TerraBrasil y de la Red Iberoamericana PROTERRA.

Luis Fernando Guerrero Baca es arquitecto, maestro en Restauración y doctor en Diseño. Es profesor e investigador de la Universidad Autónoma Metropolitana, Xochimilco, México, donde además se desempeña como Coordinador del Cuerpo Académico en Conservación y Reutilización del Patrimonio Edificado. Es miembro de la Red Iberoamericana PROTERRA y de la Cátedra UNESCO "Arquitecturas de tierra, culturas constructivas y desarrollo sostenible". Es coeditor del volumen de estas Actas.

Cristian Heinsen Planella es licenciado en Letras, máster en Documental Creativo y MBA en Chile. Exredactor creativo y realizador de películas, es fundador, expresidente y actual director ejecutivo de Fundación Altiplano. Consultor, profesor invitado y autor de publicaciones y ponencias del modelo Conservación Sostenible en Comunidad, ha cocreado y dirige la iniciativa Plan de Conservación Templos Andinos de Arica y Parinacota / Ruta de las Misiones-Saraña.

Giorgos Karanikoloudis es ingeniero de estructuras, especializado en la evaluación estructural de monumentos con análisis numéricos y ensayos no destructivos. Desde 2015 es asesor del GCI en proyectos de evaluación y reforzamiento estructural en Perú y Myanmar, y está realizando su doctorado sobre el efecto de los asentamientos y las vibraciones en monumentos en la Universidad del Minho en Portugal.

Claudia López López es graduada de la Escuela de Conservación y Restauración de Occidente (ECRO), Guadalajara, México, con experiencia en la gestión de proyectos, desde la concepción al desarrollo. Actualmente colabora con el Proyecto de Conservación de Bienes Culturales Muebles Asociados a Inmuebles en la Región Centro-Sur-Golfo de México.

Paulo B. Lourenço es doctor en Ingeniería de Estructuras y catedrático en la Universidad del Minho, Portugal. Tiene experiencia en los temas de ensayos no destructivos, técnicas avanzadas experimentales y numéricas, técnicas de reparación y refuerzo, e ingeniería sísmica. Es coordinador del máster internacional en Análisis Estructural de Monumentos y Construcciones Históricas y editor de la *International Journal of Architectural Heritage.*

Elena Macchioni es arquitecta, especialista en Patrimonio Arquitectónico y Paisajístico (Università degli Studi di Genova) y doctora en Conservación del Patrimonio Arquitectónico (Politecnico di Milano). Ha trabajado en proyectos de conservación de patrimonio arquitectónico y arqueológico. Desde 2019 es especialista asociada de proyectos del Departamento de Edificios y Sitios del Getty Conservation Institute, y colabora con el Proyecto de Estabilización Sismorresistente liderando el proyecto de monitoreo y mantenimiento del templo de Kuñotambo.

Marta Mateu Sagués es micromorfóloga, arqueóloga e historiadora, doctora en Arqueología por la Universidad de Barcelona (España). Ha sido beneficiaria del programa de becas posdoctorales 2019–2021 de la Universidad Nacional Autónoma de México (UNAM) en el Instituto de Investigaciones Antropológicas, con la asesoría de la Dra. Annick Daneels. Es miembro del Grupo de Investigaciones Arqueológicas Protohistóricas (GRAP-UB) y codirectora de las excavaciones e investigaciones del sitio arqueológico de Sant Jaume (Alcanar, España).

Juan Carlos Mellado es arquitecto por la Universidad San Antonio Abad de Cusco, Perú. Trabajó en la Municipalidad de Cusco para desarrollar el Plan Maestro del Centro Histórico de la ciudad. Desde 2007 trabaja en la Dirección Desconcentrada de Cultura de Cusco como residente de obra de varios proyectos de conservación dentro de la región, incluido el proyecto del templo de Kuñotambo.

Camilla Mileto es doctora arquitecta y profesora de Conservación Arquitectónica en cursos de grado, posgrado y doctorado en la Universitat Politècnica de València (España). Es directora del Centro de Investigación PEGASO de la misma Universidad. Ha sido profesora invitada en diferentes universidades como Venecia y Florencia (Italia), Córdoba (Argentina) y la Universidad de Pensilvania (Filadelfia, Estados Unidos). Ha recibido varios premios internacionales por su investigación, proyectos y obra construida sobre conservación arquitectónica y por su docencia en conservación. Es directora de la revista científica internacional *Loggia* y ha publicado extensamente sobre conservación arquitectónica en libros, artículos y actas de congresos.

Ana Bertha Miramontes es directora de Conservación y Restauración de la Coordinación Nacional de Conservación del Patrimonio Cultural (INAH), México, y directora del Proyecto "Altar a Mictlantecuhtli: Estudio y Conservación". Colaboró con la Universidad de Bonn, Alemania, en el Proyecto Arqueológico Uxul, Campeche. Es jefa de campo del Proyecto de Conservación Integral de la Zona Arqueológica

Ek Balam, Yucatán, y coordinadora del Área de Conservación del Proyecto Templo Mayor en su séptima temporada.

Claudia Miranda Sotomayor es arquitecta por la Universidad Peruana de Ciencias Aplicadas (UPC) en Lima, Perú. De 2002 a 2007 trabajó como arquitecta de conservación en varios proyectos en Lima y Cusco. Tiene a su cargo la Subdirección de Patrimonio Cultural y Defensa del Patrimonio Cultural de la Dirección Desconcentrada de Cultura de Cusco, donde supervisa y gestiona todos los proyectos de conservación.

Violeta Socorro Paliza Flores es arquitecta con especialización en Conservación y Restauración. Actualmente, trabaja en el Arzobispado de Cusco, donde es responsable del equipo técnico y está a cargo de los proyectos de rehabilitación del palacio del arzobispado y de la casa parroquial de San Pedro, así como la consolidación del proyecto de restauración de la capilla de Parara, entre otros.

Magdalena Pereira es doctora y magíster en Historia del Arte por la Universidad de Sevilla, España, y licenciada en Historia por la Pontificia Universidad Católica de Chile. Es profesora e investigadora de la Universidad Adolfo Ibáñez, directora del Centro de Investigación del Patrimonio Cultural de la misma Universidad y presidenta del Patronato de la Fundación Altiplano. Ha publicado artículos y libros sobre el patrimonio artístico andino y trabajado en el plan de conservación de iglesias de Arica y la región de Parinacota, en el desierto de Chile.

Anna Pérez es arquitecta (2015), máster en Conservación del Patrimonio Arquitectónico (2017). Es investigadora del Centro de Investigación PEGASO de la Universitat Politècnica de València (España). Actualmente, se encuentra desarrollando su tesis doctoral sobre metodología de levantamientos enfocados al patrimonio arquitectónico. Su actividad profesional e investigadora se centra en los levantamientos de edificios patrimoniales y el estudio de las técnicas constructivas tradicionales, con diversas publicaciones relacionadas con estos temas.

Salvador Piña Guido es licenciado en Arqueología por la Escuela Nacional de Antropología e Historia de México. Becario CONACyT CB2015-254328, está a cargo de los análisis micromorfológicos de las muestras constructivas prehispánicas del sitio arqueológico de La Joya, Veracruz, México.

Leslie Rainer es conservadora de pinturas murales y especialista sénior de proyectos del Departamento de Edificios y Sitios del Getty Conservation Institute. Ha trabajado en proyectos de conservación de superficies decoradas en África, Europa, China, Centroamérica, Sudamérica y Estados Unidos. Cuenta con una maestría en conservación de superficies arquitectónicas decoradas (Antioch University), un certificado en conservación de pinturas murales (ICCROM), y participó en el curso CRAterre sobre Arquitectura en Tierra (PAT). Fue socia en la organización del coloquio de 2004 sobre la conservación de superficies decoradas en la arquitectura de tierra en Mesa Verde y Terra 2008, en Bamako, Malí, y fue editora del volumen de ambas Actas. Es una de las socias para la organización de Terra 2022 y coeditora del volumen de estas Actas.

Miquel Reina Ortiz es profesor asociado y estudiante de doctorado en la Universidad de Carleton, Canadá. Colabora con Carleton Immersive Media Studio en el desarrollo de nuevas metodologías de trabajo digital aplicadas a la conservación del patrimonio histórico. Es arquitecto por la ETSA Barcelona, donde también obtuvo una maestría en restauración y rehabilitación.

Michael T. Reynolds se desempeña como Director Adjunto de Asuntos Externos del Servicio de Parques Nacionales de los Estados Unidos. Mike pertenece a la tercera generación de su familia que ha trabajado para el Servicio de Parques Nacionales; creció en el Parque Nacional Yosemite, del que luego se convirtió en superintendente. Anteriormente fue Director Regional para la Región del Legado Intermontañoso del Servicio de Parques Nacionales y, antes de eso, Director Adjunto de Operaciones, donde pasó la mayor parte de su servicio como Director Interino del Servicio de Parques Nacionales dirigiendo a más de 20,000 empleados que protegen y preservan más de 400 Parques Nacionales. Asimismo, se desempeñó como Director Asociado de Fuerza Laboral, Relevancia e Inclusión, supervisando los programas de capital humano, capacitación, relevancia, jóvenes y reclutamiento del Servicio de Parques Nacionales en todo el país. También ocupó el cargo de Director Regional de la Región del Medio Oeste y numerosos puestos en parques durante sus 36 años de servicio federal.

Mario Santana Quintero es profesor de la Universidad de Carleton, Canadá, y director del programa NSERC Create con sede en Carleton Immersive Media Studio. Tiene una licenciatura en Arquitectura, una maestría en Conservación y un doctorado en Ingeniería por la Universidad de Lovaina, Bélgica. Es secretario general del Comité Internacional de

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Mirna Roxanna Soto Medina es arquitecta y actualmente se desempeña como docente de la Facultad de Arquitectura de la Universidad Peruana de Ciencias Aplicadas (UPC) de Lima, Perú, en los cursos Obras Preliminares, Arquitectura Peruana y Conservación del Patrimonio Inmueble. Realizó estudios de maestría en Conservación del Patrimonio Edificado en la Universidad Nacional de Ingeniería y ha participado en cursos de especialización en restauración de monumentos y protección de centros históricos y zonas arqueológicas en España e Italia.

Alicia Margarita Tenze es arquitecta con estudios en Investigación y Planificación Participativa; es experta en procesos participativos sobre desarrollo local, integral y sustentable. Desde 2006 colabora con la Facultad de Ciencias Políticas y Sociología de la Universidad Complutense de Madrid (España) y con la Red CIMAS para la formación en metodologías participativas. Actualmente, es investigadora en la Universidad de Cuenca (Ecuador) en participación y gestión cultural.

Mónica Vargas Ramos es licenciada en Restauración de Bienes Muebles con maestría en Estudios Mesoamericanos por la Universidad Nacional Autónoma de México. Trabaja en la Coordinación Nacional de Conservación del Patrimonio Cultural del Instituto Nacional de Antropología e Historia. Tiene más de 10 años de experiencia en conservación arqueológica, donde ha coordinado proyectos de conservación *in situ* de pintura mural y elementos decorativos en piedra y tierra en diversos estados del país.

Fernando Vegas es doctor arquitecto y profesor de la Universitat Politècnica de València (España); imparte clases de conservación y composición arquitectónicas. Ha sido profesor invitado en las universidades de Venecia y Milán (Italia), Córdoba (Argentina) y la Universidad de Pensilvania (Filadelfia, EE. UU.). Es director de la revista científica internacional *Loggia* y ha publicado extensamente sobre conservación arquitectónica. Ha recibido varios premios internacionales por sus investigaciones, proyectos y trabajos construidos de conservación arquitectónica. Ha realizado varios estudios, proyectos e intervenciones para la conservación de la Alhambra de Granada, entre otros monumentos en España.

Clemencia Vernaza es restauradora especialista en la conservación de pintura mural con amplia experiencia en América Latina y Europa. Estudió conservación en Colombia, conservación de pintura mural y de piedra en Roma y Venecia, y también participó en el curso CRATerre sobre arquitectura en tierra. Trabaja como asesora del Getty Conservation Institute en varios proyectos de arquitectura en tierra.

Luis Andrés Villacorta Santamato es arquitecto por la Universidad Nacional de Ingeniería de Lima, Perú; ha realizado estudios de posgrado en temas de historia de la arquitectura y de gestión de patrimonio. Actualmente es docente de cursos de Historia del Arte y de la Arquitectura en la Universidad Peruana de Ciencias Aplicadas (UPC) de Lima, Perú.

Silvana Vintimilla es arquitecta graduada en la Universidad de Cuenca, Ecuador, y magíster en Conservación y Gestión del Patrimonio Cultural Edificado. Su trabajo se vincula con la identificación y valoración de visuales relevantes en el paisaje urbano histórico de Cuenca. Es parte del equipo del proyecto Ciudad Patrimonio Mundial. Posee experiencia profesional en diferentes oficinas privadas de arquitectura y en consultorías.

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Cisse	Lassana	ICOMOS Mali	Mali
Civelek	Keturah	Department of Engineering, Durham University	United Kingdom
Colas	Elsoit	Institut de Sauvegarde du Patrimoine National	Haiti
Cole	Amy	US National Park Service	United States
Cooeyate	Kevin	Ancestral Lands Conservation Corps, Zuni	United States
Cooper	Catherine	NCPTT, NPS	United States
Correia	Mariana	UPT-Portucalense University, ISCEAH, PROTERRA	Portugal
Crooks	Steve	US National Park Service	United States
Crosby	Anthony	Architectural Conservation LLC	United States
Cruz Garay	Paola Lizette	Independiente	Mexico
Daneels	Annick Jo Elvire	Universidad Nacional Autónoma de México	Mexico
Dass	Rhonda	New Mexico Historic Sites	United States
Dempsey Alves	Anna	Bandelier National Monument	United States
DeMuynck	Ellyn	US National Park Service	United States
Devan	Sarah	Architectural Resources Group	United States
Dhar	Sanjay	Indira Gandhi National Center for Arts, New Delhi	India
Diop	Hamet Alpha	Atelier d'Architecture Aldi	Mali
Dipasquale	Letizia	University of Florence	Italy
Dixon	Neil	The Front Standard Photography	United States
Dodge	Patricia	University of New Mexico	United States
Dorame	Anthony	Tesuque Pueblo	United States
Dorr	Roger	US National Park Service	United States
Drown	Lauran	Wiss, Janney, Elstner Associates, Inc.	United States
Druc	Bill	Druc Engineering	United States
Duran	Anthony	Taos Pueblo Historic Preservation Office	United States
Eddy	Samantha	University of Utah	United States
Elkin	Robin	Refuge Industrial Hemp Building	United States
Elsheshtawy	Shaimaa	Ministry of Antiquities and Tourism	Egypt

Last Name	First Name	Organization	Country
Emami	Nader	ALH Foundation for Art & Architecture	Iran
Emery	Virginia	US National Park Service–Fort Union National Monument	United States
Enab	Mohamed	Faculty of Archaeology, Fayoum University	Egypt
Esquivel Morales	Maria Bernadette	ICOMOS CR-ISCEAH-CIAV, Red Iberoamericana PROTERRA	Costa Rica
Éssesse	Amelie	Batir et Developper	France
Evans	Shawn	MASS Design Group	United States
Fidler	John	John Fidler Preservation Technology Inc.	United States
Fogler	Jennifer	SCA/NPS	United States
Fong	Kecia	University of Pennsylvania	United States
Foote	Rebecca	Royal Commission for AlUla	United Kingdom
Fortuné	Isabelle	École Nationale d'Architecture de Toulouse	France
Fox	Kristen	National Park Service	United States
Fox	Matthew	University of Plymouth	United Kingdom
Fragua	Dakota	Designer	United States
Francis	Angela	Cornerstones Community Partnerships	United States
Freire Castro	Ursula Anna	Universidad Central del Ecuador	Ecuador
Fuchs	Katharina	Institute of Conservation, University of Applied Arts Vienna	Austria
Funston	Vanessa	Hartman+Majewski Design Group	United States
Gandreau	David	CRAterre	France
Garcia Velez	Gabriela	Universidad de Cuenca	Ecuador
Garrett	Billy	New Mexico History Museum	United States
Gilbert	Douglas	Douglas Gilbert Architect, Inc	United States
Glanville	Julia	Tenderloin National Forest	United States
Godlewski	Cynthia	Getty Conservation Institute	United States
Goldman	Mark	University of New Mexico, Taos	United States
Gonzales	Derrick	Arizona Conservation Corps	United States
Gonzales	Myron	US National Park Service	United States
Gonzales	Vidal	Bandelier National Monument	United States
Gonzalez	Frida Itzel Mateos	INAH	Mexico
Goodhew	Steve	University of Plymouth	United Kingdom
Graz	Christophe	HYDEA	Belgium
Greene	Joseph	Harvard University	United States
Guéguen Perrin	Anaïs	CRAterre/AE&CC/ENSAG/UGA (France) and HABIS/IAU/USP (Brazil)	France
Guerrero Baca	Luis Fernando	Universidad Autónoma Metropolitana Xochimilco	Mexico
Guessoum	Riyadh Nour	University of Montreal	Canada
Gulotta	Davide	Getty Conservation Institute	United States
Guo	Huazhan	Beijing Jiaotong University	China
Gutierrez	Felipe	Department of Culture and Tourism–Abu Dhabi	United Arab Emirates
Gutierrez	Belsy	Universidad Privada Antenor Orrego	Peru
Habib	Sarah	Historic Santa Fe Foundation	United States
Hamblett	Johanna	Santa Fe Community College	United States
Hancock	John	University of Cincinnati	United States
Hanson	Kelsey	School of Anthropology	United States
Harding	David	US National Park Service	United States
Hart	Sharlot	US National Park Service	United States
Hawkes	Pamela	Scattergood Design	United States
Hegde	Gayathri	Independent	Germany
Heinsen	Cristian	Fundacion Altiplano	Chile
Hengst	Christy	iron-to-live-with	United States
Henry	Dominic	US National Park Service	United States
Hernández	Gerardo Antonio Román	El Pueblo de Sonora	Mexico
Higbee	Kirk		United States
Hill	Joshua	Getty Conservation Institute	United States
Hillenkamp	Helmut	iron-to-live-with	United States
Hillenkamp	Oliver	iron-to-live-with	United States

Last Name	First Name	Organization	Country
Hoedl	Lucas	US National Park Service	United States
Hood-Cree	Karen	University of Plymouth	United Kingdom
Hoover	Robert L.	California Mission Foundation	United States
Horn	Amy	National Park Service	United States
Hornung	Tara	Artifact Conservation Services	United States
Hough	Ian	US National Park Service	United States
Hudson	Anthony	Hudson Architects Ltd	United Kingdom
Hylton III	Morris	US National Park Service	United States
Imen	Zaghez		France
Jackson	Kayla	Dine College	United States
Jean	Butoto Nsanabandi	Umuseke Organization	Rwanda
Jeffery	R. Brooks	University of Arizona	United States
Jerome	Pamela	Architectural Preservation Studio, DPC	United States
Jofré Troncoso	Maria Graciela	Profesional independiente	Spain
Johnson	Marcia	Author	United States
Jones	Michael	Royal Commission for AlUla	Saudi Arabia
Kager	Nicholas	Coeur d 'Alene Tribe	United States
Kaneko Reynolds	Emily	Kyoto Institute of Technology	Japan
Kao	Ching-mei	Ming Shiang Art Conservation	Taiwan
Keane Lopez	Joanna	Adobe in Action	United States
Kebaili	Nourredine	Laghout University	Algeria
Keller	David	Center for Big Bend Studies	United States
Kelly	Matt	University of Oregon	United States
Kendrick	James W.	US National Park Service	United States
Key	Leesa		United States
Koziol	Christopher	University of Colorado, Denver	United States
Kuntz	Katharina	German Archaeological Institute	Germany
Kusz	Jessica	Friends of Santa Cruz State Parks	United States
Lardinois	Sara	Getty Conservation Institute	United States
Larson	Flynn	US National Park Service	United States
Laurin	Gina	Denver Art Museum	United States
Le Guern	Malo	ESITC Caen	France
Leal Cortez	David Luis	*Successful Outlaw* (documentary film)	United States
Lente	David	Pueblo of Isleta	United States
Lepper	Bradley	Ohio History Connection	United States
Lercari	Nicola	Ludwig Maximilian University of Munich	Germany
Levine	Elizabeth	Getty Conservation Institute	United States
Lewin-Reggio	Nicole	Nicole Lewin Studio	United States
Lewon	Danielle	History Colorado State Historical Fund	United States
Lidón de Miguel	María	Universitat Politècnica de València	Spain
Lidwin	Jolanta	DOM Design	United Kingdom
Ligare	Douglas	University of New Mexico	United States
Lim	Alex	US National Park Service	United States
Lindberg	James	US National Park Service	United States
Lingle	Ashley	Cardiff University	United Kingdom
Little	Terry	Ahmadu Bello University	Nigeria
Loescher	Ben	Loescher Meachem Architects	United States
Logsdon	Issac	Cornerstones Community Partnerships	United States
Loo	Isa	University of Melbourne	Australia
Lopes Aleixo Fernandes	Maria	CEAACP, Centre for the Archaeological Studies, Arts and Heritage Sciences, Unit I&D 281, University of Coimbra	Portugal
Lopez	Agapita	Georgia O'Keeffe Museum	United States
Lopez	Christopher	SCA/NPS	United States
Lorenzo	June	Dził Ditł'Ooí School of Empowerment, Action and Perseverance (Deap)	United States
Lourenço	Paulo B.	University of Minho	Portugal

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Lucero	Daryl	Pueblo Resurgents	United States
Lueth	Friedrich	Deutsches Archäologisches Institut	Germany
Macchioni	Elena	Getty Conservation Institute	United States
Macdonald	Susan	Getty Conservation Institute	United States
Maher	Joy	German University in Cairo	Egypt
Mallick	Neha	Sushant University	India
Marcolongo	Andrea	Diriyah Gate Development Authority (DGDA)	Saudi Arabia
Marcus	Benjamin	Getty Conservation Institute	United States
Mariano	James	US National Park Service	United States
Martine	Kristen	US Bureau of Land Management	United States
Martinez	Antonio	Community of Rociado Arriba	United States
Martinez	Jupiter	University of New Mexico	Mexico
Masayumptewa	Lloyd	US National Park Service	United States
Mason	James	US National Park Service, Vanishing Treasures Program	United States
Matero	Frank	Stuart Weitzman School of Design, University of Pennsylvania	United States
Mateu	Marta	GRAP, Institut d'Arqueologia Universitat de Barcelona	Spain
Mazirh	Karima	Cadi Ayyad University	Morocco
McGuire	Grace	University of Arizona	United States
McMillian	Drew	AOS Architects	United States
Mendes Vila-Chã	Ana Eduarda	Getty Conservation Institute	United States
Meyer	Lauren	US National Park Service	United States
Michèle	Chazal	CHAZAL	France
Mileto	Camilla	Universitat Politècnica de València	Spain
Mitchell	Mark	Pueblo of Tesuque	United States
Molina Soto	Maria Elena	University of San Carlos de Guatemala, Faculty of Architecture	Guatemala
Montoya	Amanda	Chamiza Foundation	United States
Montoya	Rebecca	Santa Teresita del Niño Jesus	United States
Moon	Cameron	University of Pennsylvania	United States
Moreno	Mónica	Universidad Pablo de Olavide	Spain
Morris	Hugh	University of Auckland	New Zealand
Moss	Jeremy	US National Park Service	United States
Mullen	Natalie	Coeur d'Alene Tribe	United States
Munzenrider	Claire	Self-employed	United States
Nabil	Dalia	Politecnico di Milano	Egypt
Navenma	Jeremy	US National Park Service	United States
Navenma	Wendel	US National Park Service	United States
Nicolaescu	Anca	Tibet Heritage Fund	France
Núñez	Rosa Delmy	Ing. Rosa Delmy Núñez de Hercules	El Salvador
Nuvayestewa	Valerie	Tutskwat Oqawtoynani	United States
Odiaua	Ishanlosen	World Bank Group	Canada
Olds	James	US National Park Service	United States
Olson	John	US National Park Service	United States
Orea Magaña	Blanca Haydeé	Instituto Nacional de Antropología e Historia	Mexico
Oskierko-Jeznacki	Evan	US National Park Service	United States
Owen	Kevin	University of Plymouth	United Kingdom
Owen	Michael	History Colorado State Historical Fund	United States
Parea	José Valencia	INAH	Mexico
Parker	Shane	Navajo	United States
Paul	Rosie	Masons Ink	India
Pesaresi	Paola	Diriyah Gate Development Authority (DGDA)	Saudi Arabia
Phillips	Andrew	Natural Dwelling LLC	United States
Rai	Gurmeet Sangha	CRCI India Pvt Ltd	India
Rainer	Leslie	Getty Conservation Institute	United States
Rakotomamonjy	Bakonirina	CRAterre	Madagascar
Reilly	Alison	Getty Foundation	United States
Reynolds	Michael	US National Park Service	United States

Last Name	First Name	Organization	Country
Rezende	Marco Antônio Penido	Universidade Federal de Minas Gerais	Brazil
Richards	Jennifer	University of Oxford	United Kingdom
Rihal	Satwant	California Polytechnic State University, San Luis Obispo	United States
Rivera Vidal	Amanda	ICOMOS-ISCEAH	Italy
Ro	Ha Leem	Center for Architectural Conservation	United States
Robles	Chas	Ancestral Lands Conservation Corps	United States
Rodrigues	Chenelle	Freelancer / Self-employed	France
Rogers	Shelby	Chinati Foundation	United States
Ruby	Bret	US National Park Service, Hopewell Culture National Historical Park	United States
Sadozaï	Chamsia	CRAterre	France
Salcedo Gutierrez	Zazanda	CIDES	Bolivia
Samuel	Jerome	Tesuque Pueblo	United States
Samuel	Larry	Tesuque Pueblo	United States
Sanchez	Earle	US National Park Service	United States
Sanchez	Liana	Avanyu LLC	United States
Sánchez González	Emilia	J. Paul Getty Museum	United States
Saxer	Mara	Historic Santa Fe Foundation	United States
Scales	Mary	US National Park Service	United States
Schwantes	Gesa	Shanghai University	China
Schwarzenbach	Peter	City College of San Francisco	United States
Scott	Kate	US National Park Service	United States
Segura Escobar	Juana	Proyecto Patrimonio	Colombia
Sexton	Elizabeth	Recent graduate student	United States
Shao	Yong	College of Architecture and Urban Planning, Tongji University	China
Sharifi	Sajjad	Getty Conservation Institute	United States
Sharma	Archana	Ideate Design Studio	India
Shields	Barbara	Space Dimension Services	United States
Shirley	Michaela	University of New Mexico	United States
Shittu	Theophilus	University of Northampton	United Kingdom
Siguencia	Maria	Universidad de Cuenca	Ecuador
Sikka	Sandeep	Architectural Preservation Studio, DPC	United States
Singh	Aastha	Cornerstones Community Partnerships	United States
Sirna	Angela	US National Park Service	United States
Skeirik	Randall		United States
Sprega	Alessandra	Getty Conservation Institute	United Kingdom
Stiegler	Ione	ISCEAH	United States
Stratte	Sara	US National Park Service	United States
Streiff	François	Parc naturel regional des Marais du Cotentin et du Bessin	France
Suazo	Tiana	Red Willow Center	United States
Sule Sani	Abubakar	Ahmadu Bello University, Zaria	Nigeria
Swentzell	Porter	Institute of American Indian Arts (IAIA)	United States
Swentzell	Roxanne	Contemporary Pueblo artist	United States
Sy	Mariam	ARCHITERRE	Mali
Taan	Doa'e	SCHEP and FoAH	Jordan
Tartaglia	Giulia		Italy
Taylor	Albert Patrick	Pat Taylor, Inc.	United States
Taylor	Anne	School Zone Institute and La Luz	United States
Taylor	Michael	US National Park Service (retired)	United States
Teboe	Randy	Pueblo de San Ildefonso	United States
Tejada Farfán	Andrea Giuliana	Universidad Católica Sedes Sapientiae	Peru
Teutonico	Jeanne Marie	Architectural Conservator	United States
Theodoropoulou	Stamatina	Head architecture / CASH CLT	United Kingdom
Thierry	Joffroy	CRAterre/AE&CC/ENSAG/UGA	France
Tinney	Kiona	Bureau of Indian Affairs	United States
Toledo	Zoe	Harvard University	United States
Tonetti	Charles	US NPS IMR Facilities and Lands	United States

Last Name	First Name	Organization	Country
Torra Campos	Gemma	Freelance	Spain
Torres	Elizabeth	Chinati Foundation	United States
Touati	Karim	ESITC Caen	France
Tsitsinaki	Myrto	Royal Commission for AlUla	Saudi Arabia
Uviña-Contreras	Francisco	University of New Mexico	United States
Valdo	David	Old Santa Fe Association	United States
Valencia	José Luis Medina	El Pueblo De Sonora	Mexico
Valera	Llilian	Universidad de la Habana	Cuba
Vallo	Brian	Pueblo of Acoma	United States
Van Balen	Koenraad	KU Leuven / HERKUL / RLICC	Belgium
van Damme	Henri	ESPCI-Paris	France
Van Ness	John	La Luz Foundation	United States
Varin	Claudia	FADU Udelar	Uruguay
Vavrille	Anaïs		France
Vegas	Fernando	Universitat Politècnica de València	Spain
Velázquez	Cinthya Selene	Restāurika	Mexico
Venecia	Valerie	El Paso County	United States
Ventura	Chavez	AZCC	United States
Vernaza	Clemencia	Conservator	Switzerland
Villacorta Santamato	Luis	Consultant, Getty Conservation Institute	Peru
Villarreal Catanach	Samuel	Pueblo of Pojoaque Tewa Language Department	United States
von der Heide	Susanne	HimalAsia Foundation	Germany
Wagner	Jill	Coeur d'Alene Tribe	United States
Walker	Richard	Engineering Sustainable Solutions Ltd	New Zealand
Wall	Julia	Tutskwat Oqawtoynani	United States
Wang	Yue	Beijing Jiaotong University	China
Wessel	David	Architectural Resources Group	United States
Whitley	Catrina	Office of Archaeological Studies, Museum of New Mexico	United States
Williams	Katharine	University of New Mexico	United States
Williams	Stephenie	Blanco Architecture Inc.	United States
Wong	Lori	Getty Conservation Institute	United States
Woods	Katherine	City Visions, Inc.	United States
Yeo	Arouna	Institute of Anthropological Development Sciences (ISAD)	Ivory Coast
Yepa	Garron	AOS Architects	United States
Ziegert	Christof	ZRS Ingenieure GmbH	Germany