Seismic Retrofitting Project: Assessment of Prototype Buildings

Volume 1

Research Report

Claudia Cancino, Sara Lardinois, Dina D'Ayala, Carina Fonseca Ferreira, Daniel Torrealva Dávila, Erika Vicente Meléndez, and Luis Villacorta Santamato

Los Angeles 2012

The Getty Conservation Institute

Seismic Retrofitting Project: Assessment of Prototype Buildings

Volume 1

By Claudia Cancino, Sara Lardinois,
Dina D'Ayala, Carina Fonseca Ferreira,
Daniel Torrealva Dávila, Erika Vicente Meléndez,
and Luis Villacorta Santamato

Los Angeles 2012

THE GETTY CONSERVATION INSTITUTE
LOS ANGELES

The Getty Conservation Institute
1200 Getty Center Drive, Suite 700
Los Angeles, CA 90049-1684
United States
Telephone 310 440-7325
Fax 310 440-7702
E-mail gciweb@getty.edu
www.getty.edu/conservation

The Getty Conservation Institute works to advance conservation practice in the visual arts, broadly interpreted to include objects, collections, architecture, and sites. It serves the conservation community through scientific research, education and training, model field projects, and the broad dissemination of the results of both its own work and the work of others in the field. And in all its endeavors, it focuses on the creation and dissemination of knowledge that will benefit professionals and organizations responsible for the conservation of the world's cultural heritage.

Contents

Project Participants

Dina D'Ayala	Senior Lecturer Department of Architecture and Civil Engineering University of Bath, United Kingdom
Claudia Cancino	Project Specialist Getty Conservation Institute, Los Angeles, USA
Amila Ferron	Former Associate Project Specialist Getty Conservation Institute, Los Angeles, USA
Carina Fonseca Ferreira	PhD Student Department of Architecture and Civil Engineering University of Bath, United Kingdom
Sara Lardinois	Project Specialist Getty Conservation Institute, Los Angles, USA
Susan Macdonald	Head, Field Projects Getty Conservation Institute, Los Angeles, USA
Viviana Novelli	PhD Student Department of Architecture and Civil Engineering University of Bath, United Kingdom
Daniel Torrealva Dávila	Dean, School of Engineering Pontificia Universidad Católica del Perú Lima, Peru
Erika Vicente Meléndez	Structural Engineer Pontificia Universidad Católica del Perú Lima, Peru

GCI Consultants

Mirna Soto	Architect and Architectural Conservator Lima, Peru
Luis Andes Villacorta Santamato	Architect and Architectural Historian Lima, Peru
Jabdiel Zapata	Architectural Drafter and Renderer South Pasadena, California, USA

Ministerio de Cultura del Perú

David de Lambarri Samanéz	Managing Director Lima, Peru
Juan Julio García Rivas	Former Director of the Cusco Regional Office Cusco, Peru

Project Participants

Dina D'Ayala	Senior Lecturer Department of Architecture and Civil Engineering University of Bath, United Kingdom
Claudia Cancino	Project Specialist Getty Conservation Institute, Los Angeles, USA
Amila Ferron	Former Associate Project Specialist Getty Conservation Institute, Los Angeles, USA
Carina Fonseca Ferreira	PhD Student Department of Architecture and Civil Engineering University of Bath, United Kingdom
Sara Lardinois	Project Specialist Getty Conservation Institute, Los Angles, USA
Susan Macdonald	Head, Field Projects Getty Conservation Institute, Los Angeles, USA
Viviana Novelli	PhD Student Department of Architecture and Civil Engineering University of Bath, United Kingdom
Daniel Torrealva Dávila	Dean, School of Engineering Pontificia Universidad Católica del Perú Lima, Peru
Erika Vicente Meléndez	Structural Engineer Pontificia Universidad Católica del Perú Lima, Peru

GCI Consultants

Mirna Soto	Architect and Architectural Conservator Lima, Peru
Luis Andes Villacorta Santamato	Architect and Architectural Historian Lima, Peru
Jabdiel Zapata	Architectural Drafter and Renderer South Pasadena, California, USA

Ministerio de Cultura del Perú

David de Lambarri Samanéz	Managing Director Lima, Peru
Juan Julio García Rivas	Former Director of the Cusco Regional Office Cusco, Peru

CHAPTER 1

Background

1.1 Introduction

For millennia humans have constructed buildings of earth. In places ranging from ancient archaeological sites to living cities, from the vernacular to the monumental, earth is used as both a structural and a decorative material (Figs. 1.1, 1.2). The remarkable diversity of earthen heritage presents equally complex conservation challenges. As an example, while only ten percent of the cultural sites on UNESCO's World Heritage List are earthen, fifty-seven percent of these are included on the List of World Heritage in Danger.

Earthen buildings, typically classified as unreinforced masonry structures, are vulnerable to earthquakes and subject to sudden collapse during a seismic event—especially if a building lacks proper and regular maintenance. Historic earthen sites located in seismic areas are at high risk of being heavily damaged and even destroyed.

1.2 Institutional Background and Project Partners

For nearly two decades, the Getty Conservation Institute (GCI) has been a recognized leader in developing methodologies and setting standards for the conservation of earthen architectural heritage in California and abroad. The GCI has

FIGURE 1.1
Great Mosque, Djenné, Mali. Regular maintenance of this earthen architectural masterpiece is carried out by the community at an annual festival.
Image: Françoise Descamps.

FIGURE 1.2
Mission San Luis Rey de Francia, Oceanside, California, USA. The church at San Luis Rey, ninth of the California missions, is constructed of unreinforced adobe masonry.
Image: Gail Ostergren.

generated cutting edge research, training programs, publications, and field projects that have deepened the understanding of earthen architecture and its particular vulnerabilities. All of these activities have disseminated research results and built capacity in the field through the organization of workshops and training courses for practitioners, highly-specialized experts meetings and colloquia, and major international conferences.

During the 1990s, the GCI carried out a major research and laboratory testing program—the Getty Seismic Adobe Project (GSAP)—which the GCI and the field are now building upon. The GSAP investigated the performance of historic adobe structures during earthquakes and developed cost-effective retrofit methods that substantially preserve the authenticity of these buildings. Results of this research have been disseminated in a series of publications, both in English and Spanish.

In April 2006, the GCI hosted the GSAP Colloquium at the Getty Center in Los Angeles. This meeting assembled an interdisciplinary group of sixty international specialists to assess the impact and efficacy of the GSAP seismic retrofitting recommendations and to discuss where and how GSAP guidelines have been implemented; the colloquium proceedings were published in 2009. The participants concluded that the GSAP methodology was reliable and effective, but its reliance upon high-tech materials and professional expertise was a deterrent to it being more widely implemented.

To address this, the GCI has joined forces with the Ministerio de Cultura del Perú (formerly the Instituto Nacional de Cultura), the Department of Architecture and Civil Engineering at the University of Bath in the United Kingdom, and the Escuela de Ciencias e Ingeniería (School of Engineering) at Pontificia Universidad Católica del Perú to form the Seismic Retrofitting Project (SRP). Building on the earlier work of the GSAP, the SRP will marry traditional construction techniques and materials with methodologies that have been created for use in the developing world.

1.3 Seismic Retrofitting Project

The ultimate objective of the Seismic Retrofitting Project is to adapt the GSAP guidelines in countries where equipment, materials, and technical skills are not readily available by providing low-tech seismic retrofitting techniques and easy-to-implement maintenance programs for historic earthen buildings in order to improve their seismic performance while preserving their historic fabric. Using Peruvian building prototypes as case studies, the project aims to design and test these techniques; provide guidance for those responsible for implementation, including architects, engineers, and conservators; and, work with authorities to gain acceptance of these methods, with the goal of ultimately including them as part of the *Norma Técnica de Edificación NTE E.080 Adobe (Technical Building Standard E.080 for Construction in Adobe)*[1] within the Peruvian National Building Code. Peru has been selected as the location for the work due to the current and historical knowledge and professional interest in the subject; the ongoing revision of the *NTE E.080*; the existence of potential partners for implementation of these techniques on a model conservation project; and, background work already completed by the GCI, such as the *Damage Assessment of Historic Earthen Buildings After the August 15, 2007 Pisco, Peru Earthquake* (Figs. 1.3, 1.4).

FIGURE 1.3
The earthen Church of El Carmen, Chincha, Peru. The bell tower collapsed during the 2007 Pisco earthquake.
Image: Philippe Garnier, for the GCI.

FIGURE 1.4
The earthen Capilla Virgen Concebida de Kuchuwasi, near Cusco, Peru.
Image: Claudia Cancino.

1.3.1 Project objectives

- Design low-tech seismic retrofitting techniques, using locally available materials and expertise for Peruvian historic building types that have potential for wider application in other countries;
- Validate retrofitting techniques with current scientific knowledge;
- Obtain the recognition, approval, and promotion of the techniques by local authorities in Peru;
- Develop a methodology to assess earthen historic sites, which can be used as a tool for making decisions about maintenance and interventions and has potential for wider application in other countries;
- Develop guidelines for site assessments and implementation techniques, highlighting the significance that ongoing evaluation, maintenance, and repair play in improving the seismic performance of historic earthen buildings; and
- Develop a model conservation project that demonstrates the implementation of the techniques.

1.3.2 Project phases

All project activities have been divided in four phases: (I) feasibility and research; (II) methodology; (III) testing and modeling; and, (IV) dissemination and implementation. The planned activities for each phase are described in greater detail below.

1.3.2.1 Phase I - Feasibility and research

- **Feasibility**: Test the project feasibility, goals, and outcomes by consulting with different professionals with expertise in the field of conservation and seismic retrofitting, and establish an external peer review group.
- **Modes of failure**: Gather information on modes of failures of the already-identified prototypes. This research study will analyze existing historic data regarding the way earthen buildings behave during a seismic event using the findings from the damage assessments performed after the 2007 Pisco,

Peru earthquake as well as the 1996 Northridge, California (USA) earthquake.

- **Selection and assessment of building prototypes**: Identify four building typologies that are priorities for the application of seismic retrofit techniques based upon level of significance, where solutions are most needed, and which modes of failure and their corresponding reinforcing techniques will have the most widespread application in Peru and other countries in Latin America; and perform construction assessments of the selected building prototypes.
- **Low-tech / alternative / vernacular / historic solutions for retrofitting**: Collect historic information on traditional and seismically-resistant construction materials and techniques developed over time in Peru.
- **Previous interventions already implemented in Peru**: Collect information from other professionals working in the field of conservation in Peru regarding the seismic performance of already existing/implemented repairs on earthen historic buildings in recent decades.

1.3.2.2 Phase II - Methodology

- **Proposal for numerical modeling of earthen sites**: In collaboration with the Department of Architecture and Civil Engineering at the University of Bath (BATH), develop a proposal for the numerical modeling and seismic analysis of the identified building prototypes.
- **Proposals for experimental testing of building types**: In collaboration with the School of Engineering at Pontificia Universidad Católica del Perú (PUCP), develop a proposal for static and dynamic testing of the identified building prototypes for the study of their structural performance during an earthquake, as a complementary technique to the numerical modeling and analysis.
- **Peer review meeting**: Organize a peer review group meeting to discuss the project design and methodology, the construction assessment of the selected prototype buildings, and proposals for the numerical modeling and experimental testing of the prototypes.
- **Capacity building activities**: In collaboration with national institutions, potentially develop workshops regarding the methodology used during phases I and II of the project for the construction assessment of earthen sites.

1.3.2.3 Phase III - Testing and modeling

- **Design of retrofitting solutions**: In collaboration with BATH and PUCP, propose suitable retrofitting techniques for the prototype buildings.
- **Testing and modeling of retrofitting technique**s: Verify the effectiveness of the proposed retrofitting solutions by means of numerical approaches at BATH and experimental tests at PUCP.
- **Peer review**: Seek input of peer review group on the design of the retrofitting techniques.
- **Capacity building activities**: In collaboration with national institutions, potentially develop a preliminary series of workshops to build up a national/regional assessment methodology to develop an action plan for the maintenance and repair of historic earthen sites.

1.2.3.4 Phase IV - Dissemination and implementation

- **Dissemination**:
  - Draft peer-reviewed guidelines for the implementation of retrofitting designs and techniques to be considered as a part of the *NTE E.080* and that can be more widely applied in other Latin American countries.
  - Develop guidelines for site managers that practically explain the implementation of retrofitting techniques and include principles for site maintenance that together form the basis of preventive approaches to the conservation of earthen historic buildings in seismic areas.
- **Implementation**:
  - In collaboration with national and international consultants, develop a project proposal for the retrofitting of one or two of the selected building types.
  - In collaboration with a national partner, implement retrofitting project for the site(s).
  - Document the retrofitting project(s) for further dissemination.

1.4 Introduction to Assessment Report

This assessment report has been prepared to synthesize the data obtained for the selected prototype buildings during phase I of the project and is being published during phase II.[2] It is intended to be a useful reference document for the project team as they develop the numerical modeling and seismic analyses of the buildings and the complementary experimental tests, as well as for the peer review group, site managers, and owners. The document will also be used for the dissemination of the assessment methodology to the wider conservation and engineering community.

The report provides a detailed description of the project methodology for the selection and survey (through both non-destructive techniques and limited openings) of the prototype buildings (chapter 2); a description and condition assessment of the selected prototype buildings (chapters 3–6); and, general conclusions on the survey methodology, collected structural data, and structural design and observed behavior of the prototype buildings (chapter 7). A sample of the survey form developed for the project is provided in Appendix A. Appendices B and C include the architectural and detailed prospection drawings prepared for the prototype buildings (the appendices are included in volume 2 of this report). All photographs of the prototype buildings included in the report were taken during the field survey campaigns carried out in 2010, unless otherwise noted.

It is important to note that this assessment report reflects the project team's understanding of the buildings prior to the results of the numerical modeling and seismic analyses and experimental testing. Thus, some of the preliminary findings included in this report are subject to revision upon the completion of phase III.

Notes

1 This technical norm—commonly known as *Norma del Adobe*—was created to regulate seismically-resistant new adobe construction and was added for the first time to the Peruvian National Building Code in 1987. The *NTE E.080* was originally designed by a group of architects and engineers who were members of the *Norma del Adobe* committee (NORMA), created at the Servicio Nacional de Capacitación para la Industria de la Construcción (SENCICO – National Training Service for the Construction Industry). SENCICO is a governmental agency that is part of the Ministry of Housing and Construction. Among its functions, it develops norms, standards, and regulations for building design, construction materials, and technologies in order to improve construction quality, costs, and life safety assurance. The *NTE E.080* was reviewed for the first time in 1999 and the revised edition was published in 2000. It is currently being expanded to include a section on interventions in historic earthen buildings.

2 The data collected during phase I of the project was obtained during two field survey campaigns carried out in 2010. Thus, this report reflects the condition of the four prototype buildings in 2010 and does not incorporate any subsequent changes in condition resulting from seismic activities or other environmental factors.

CHAPTER 2

Methodology

2.1 Previous Assessments

The Seismic Retrofitting Project methodology was informed by the work of earlier post-earthquake assessments, such the GCI's *Damage Assessment of Historic Earthen Buildings After the August, 15, 2007 Pisco, Peru Earthquake*. Such assessments offer an opportunity to understand why buildings fail and provide information that can serve as the basis for the improvement of their seismic performance. For centuries, lessons learned from earthquakes and other natural disasters have been used to advance construction techniques. More recently, such lessons have fostered the development of the engineering and historic preservation disciplines, as well as the testing and review of current building codes and disaster management policies and procedures.

The history of Peruvian architecture exemplifies this process. In response to their understanding of the effects of seismic activity on earthen structures, early Peruvian cultures developed reinforcement techniques to enhance their earthen construction systems. The tradition continues today with the inclusion of the *Norma Técnica de Edificación NTE E.080 Adobe (Technical Building Standard E.080 for Construction in Adobe)* in the Peruvian Building Code. This technical standard provides a series of recommendations to reduce the seismic vulnerability of new adobe construction.

On August 15, 2007, an earthquake with a moment magnitude (M_W) of 8.0 and a maximum local Modified Mercalli Intensity (MMI) of VII–VIII hit the southern coast of Peru. Preliminary reports indicated that a large number of historic earthen sites located in the communities of Cañete, Chincha, Pisco, Ica, and Huancavelica were severely damaged (Figs. 2.1, 2.2).

FIGURE 2.1 (LEFT)
Church of Guadalupe, damaged by the 2007 Pisco earthquake, 2007. Image: Claudia Cancino.

FIGURE 2.2 (RIGHT)
Church of Humay, damaged by the 2007 Pisco earthquake, 2007. Image: Claudia Cancino.

After the 2007 earthquake, a multidisciplinary team of national and international earthquake engineers, preservation architects, and conservators—convened by the GCI—visited a total of 14 historic earthen sites, rapidly documented them, and evaluated the damage to these sites. The team concentrated on recording existing conditions such as abandonment, deterioration, or structural alterations over time, with the ultimate objective of understanding the impact of such conditions on the buildings' seismic performance. The assessment, which was organized in response to a request from the former Instituto Nacional de Cultura del Perú (now the Ministerio de Cultura del Perú), is available on the GCI's website.

The lessons learned from the Pisco earthquake assessment informed the process of identifying prototype buildings to be studied as part of the Seismic Retrofitting Project, as well as the development of the methodology to survey the condition of those prototype buildings.

2.2 Selection of Prototype Buildings

As part of the first phase of the Seismic Retrofitting Project, it was a determined that up to four building typologies would be selected for study in future project phases. Each selected typology was to represent buildings that are priorities for seismic retrofitting based upon their level of historic, social, or architectural significance; the current lack of—and thus greater need for—retrofitting solutions for the particular prototype; and their demonstration of typical modes of failure, so that the reinforcing techniques developed as part of the project would be able to be more widely applied to other earthen sites in Peru, South America, and other seismic regions of the world.

At the beginning of 2010, the SRP team identified four building typologies that met these criteria. The typologies were:

- **Typology 1**: Residential structure constructed with mud brick and *quincha* (wattle and daub) walls and flat roofs; representative of colonial houses in the historic centers of coastal towns and cities.[1]
- **Typology 2**: Religious structure constructed with thick mud brick walls and quincha vaults and domes; representative of the churches built in coastal cities and preferably located in the region affected by the 2007 Pisco earthquake.
- **Typology 3**: Religious structure constructed with thick mud brick walls, normally decorated with mural paintings, and a wood truss roof; representative of the churches built in the Andes.
- **Typology 4**: Residential structure constructed with two-story mud brick walls and a wood truss roof; representative of the colonial houses built in the historic centers of Andean cities.

A total of 20 sites in Peru were pre-selected for an initial assessment by GCI and Peruvian architects, architectural historians, and engineers; and, those sites were visited in February 2010. The sites were assessed using different criteria that considered if (1) the original structural system was extant, with limited or no interventions; (2) the building was historically significant; (3) the building was representative of one of the four identified typologies; (4) the owner/manager would facilitate access to the site for study, with no further expectations for the implementation of a retrofitting or repair project; (5) the site and surrounding area would be safe for the team to survey and carry out other necessary work of the project; (6) the structure exhibited deterioration mechanisms/conditions that could impact its seismic performance; (7) the site was easily accessible by foot and/or by car with proper lodging close in the vicinity; (8) there was existing and readily available historical and architectural data for the site; and, (9) the site had visibility, or aesthetic value. Each site was given a score of 1–10, with 10 being the highest, for each of the criterion described above; and, each of the criterion was equally weighted to determine the final score. Table 2.1 provides a list of the 20 visited sites, as well as a summary of their assessment scores.

Table 2.1 Initial assessment scores for 20 preselected sites

Name of site	Original structure (no interventions)	Historical value	Significance (representative of a typology)	Availability (approachable owner)	Security (safe for project staff)	Representative pathologies	Accessibility (location)	Extant historical and architectural data	Visibility	**TOTAL**
Hospicio Ruiz Dávila, Lima	6	7	8	1	4	6	6	4	4	**46**
Quinta Heren, Lima	8	8	8	8	4	7	5	5	5	**58**
Hacienda San Juan Grande, Lima	5	7	6	2	2	6	6	4	5	**43**
Hotel El Comercio, Lima	6	8	8	10	8	8	8	9	6	**71**
Cathedral of Ica, Ica	9	7	7	6	9	10	8	6	8	**70**
Church of San Antonio, Mala	5	5	8	9	7	9	4	4	3	**54**
Church of San Juan, Ica	8	5	8	9	7	9	4	4	3	**57**
Church San Luis, Cañete	4	5	8	10	7	9	4	4	3	**54**
Church Santuario de Yauca, Ica	7	5	8	8	7	9	4	4	3	**55**
Church of Andahuaylillas, Cusco	7	10	8	7	7	3	5	7	10	**64**
Church of Canincunca, Cusco	6	9	8	7	7	3	4	6	8	**58**
Church of Marcapata, Cusco	10	8	8	8	6	8	2	6	8	**64**
Church of Kuchi Wasi, Cusco	10	8	7	8	6	5	2	6	7	**59**
Church of Kuño Tambo, Cusco	10	8	8	10	8	9	3	6	8	**70**
Church of Rondocan, Cusco	7	8	8	9	8	6	2	6	5	**59**
Casona Garrido Mendivil, Cusco	6	8	6	5	8	5	9	7	6	**60**
Casa Arones, Cusco	8	8	9	10	8	9	10	8	6	**76**
Casa Alonso del Toro, Cusco	6	8	6	4	4	5	8	7	6	**54**
Casa Serapio Calderón, Cusco	7	8	6	4	3	6	8	7	6	**55**
Casa Concha, Cusco	5	9	7	8	8	4	8	8	8	**65**

The buildings receiving the highest scores, and thus selected for further study, were:

- **Typology 1** – **Hotel El Comercio**: A nineteenth century three-story mud brick and quincha building in the historic center of Lima (Fig. 2.3).
- **Typology 2 – Cathedral of Ica**: An eighteenth century church with thick mud brick walls and quincha vaults and domes that was damaged by the 2007 Pisco earthquake (Fig. 2.4).
- **Typology 3 – Church of Kuño Tambo**: A seventeenth century building constructed with thick mud brick walls and a wood truss roof and located in a small Andean village near Cusco (Fig. 2.5).
- **Typology 4 – Casa Arones**: A seventeenth century two-story mud brick building with a wood truss roof, located in the historic center of Cusco (Fig. 2.6).

FIGURE 2.3
Typology 1: Hotel El Comercio, historic center of Lima.
Image: Amila Ferron.

FIGURE 2.4
Typology 2: Cathedral of Ica, Ica.
Image: Sara Lardinois.

FIGURE 2.5
Typology 3: Church of Kuño Tambo, Cusco region.
Image: Wilfredo Carazas, for the GCI.

FIGURE 2.6
Typology 4: Casa Arones, historic center of Cusco.
Image: Sara Lardinois.

In addition to the previously-described selection criteria, each site had its own unique characteristics which increased its study value; however, because of the uniqueness of these characteristics, they could not be factored into the final assessment score. Despite this, these characteristics are worth noting and are provided in the summary descriptions of each of the selected prototype buildings below.

Hotel El Comercio, which received the highest scores for typology 1, was selected for further study. Its value as a prototype building can be summarized as follows:

- It is representative of residential courtyard or patio buildings, known as *casonas*, that are typical in colonial era cities along the coast; although, the third story makes it taller than many other two-story casonas.
- It exemplifies typical Peruvian earthen construction techniques with mud brick masonry walls at the first floor, quincha walls at the upper floors, and flat wood-framed floors and roofs.
- Similar to many historic buildings in downtown Lima and other colonial cities in South America, Hotel El Comercio has become more structurally complex due to many changes in use and alterations over its history.
- Despite the fact that it is structurally more complex than a traditional casona due to its third floor and alterations, the methods and conclusions of the numerical modeling and experimental testing approach to be utilized in its seismic assessment can be applied to the study of simpler structures.
- Its location at the corner of an urban block that makes it more vulnerable than a building located at the middle of a block.

The Cathedral of Ica, which received the highest scores for typology 2, was selected for further study. Its value as a prototype building can be summarized as follows:

- It is representative of churches along the coast of Peru constructed with mud brick lateral walls, a fired brick façade, and quincha pillars and roofs. Although it is structurally more complex than some of the other churches, any proposed seismic retrofitting measures may be adapted for the less complex churches.
- The cathedral was damaged during the 2007 Pisco earthquake, and thus presents an opportunity to study existing earthquake damage and provide badly-needed solutions for its retrofit (Fig. 2.7).

FIGURE 2.7
Interior view of the Cathedral of Ica, showing damage to the vault after the 2007 earthquake.
Image: Sara Lardinois.

- The cathedral is a highly significant structure—it was declared a national monument in 1982. It has retained this status, despite the damages incurred during the 2007 earthquake.
- Its location at the corner of an urban block makes it more vulnerable than a building located at the middle of a block.

The Church of Kuño Tambo, which received the highest scores for typology 3, was selected for further study. Its value as a prototype building can be summarized as follows:

- It is representative of rural earthen churches in the mountainous interior of Peru and South America, built during the period of the Spanish Viceroyalty, with thick mud brick walls and a wood-framed gable roof. The church has undergone limited alterations and interventions; and, thus, it retains most of its original seventeenth century structural scheme.
- Like many of these rural churches, the site is remote and only accessible by a narrow and winding road through the mountains. This will have a bearing on the types of retrofit measures that can be developed and implemented, as it may be difficult to bring in outside materials, equipment, or expertise.
- Any proposed retrofitting techniques will need to be designed and implemented in such a way that the decorative interior finishes, such as extant wall paintings, are not impacted in the process. This will be the case for many earthen sites located in the area and other seismic regions in the world.

Casa Arones, which received the highest scores for typology 4, was selected for further study. Its value as a prototype building can be summarized as follows:

- It is representative of a typical house in Cusco, dating to the period of the Spanish Viceroyalty, with an interior patio surrounded by stone and fired brick masonry arcades.
- Similar to Hotel El Comercio, its location at the corner of an urban block makes it more vulnerable than a building located at the middle of a block.
- Unlike Hotel El Comercio, it is constructed with two-story mud brick walls and a wood-framed gable roof.

2.3 Assessment Methodology

The project has been structured in different phases, beginning with research and investigation of the selected prototypes and ending with dissemination and implementation of the tested retrofitting techniques. As part of the research and investigative phase, data was acquired through historic research and architectural and structural surveys and investigations. The collected data is summarized in chapters 3–6 of this report, and it will inform the development of the experimental tests and numerical modeling and seismic analyses of the building prototypes in the next project phases.

2.3.1 Survey and investigations

As part of the architectural and structural investigations, the prototype buildings' structural configurations and conditions were documented and assessed through two field survey campaigns carried out in 2010. In order to properly assess the selected sites, various documentation methods were utilized: (1) survey forms targeted to address structural configurations and conditions, largely completed using visual observations; (2) non-destructive investigations, such as thermal imaging; and (3) the opening up of specific areas of the buildings to better understand their internal structural configurations and connections.

2.3.1.1 Survey sectors and forms

As the four prototype sites have different structural configurations, the project team divided each building into sectors for the purposes of the survey. The selection of sectors was based upon how the buildings may perform during a seismic event.

For the residential structures, the selection of sectors was largely based upon the direction of the floor and roof beams and joists. Each residential structure was divided into four sectors per floor. Hotel El Comercio was divided into (a) sector A: the area of the building adjacent to the north corner; (b) sector B: the series of rooms adjacent to the longer northwest lateral façade; (c) sector C: the series of rooms bordering with the adjacent structure to the southeast; and, (d) sector D: the rooms at the northeast side of the patio (Fig. 2.8). Casa Arones was divided into (1) sector 1: rooms along the street to east, Calle Arones; (2) sector 2: rooms along Calle Nueva Alta, including the gallery at the north side of the patio; (3) sector 3: rooms between sector 1 and the main patio; and (4) sector 4: rooms at the south side of the patio, bordering the neighboring structure (Fig. 2.9).

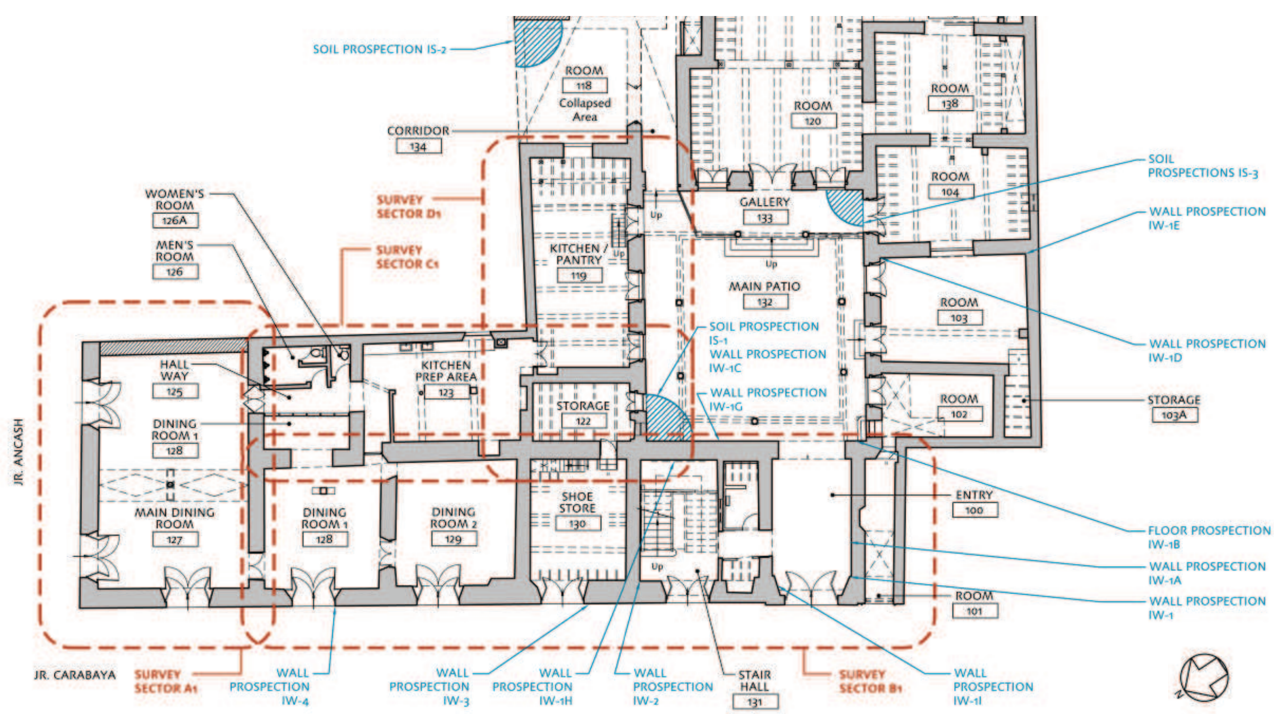


FIGURE 2.8
Hotel El Comercio, survey sectors shown in red. As the fi rst and second patios have a similar confi guration, only the fi rst patio and north-east section of the building were surveyed.
Drawing: Base drawing provided by the Instituto Nacional de Cultura and edited by the GCI.

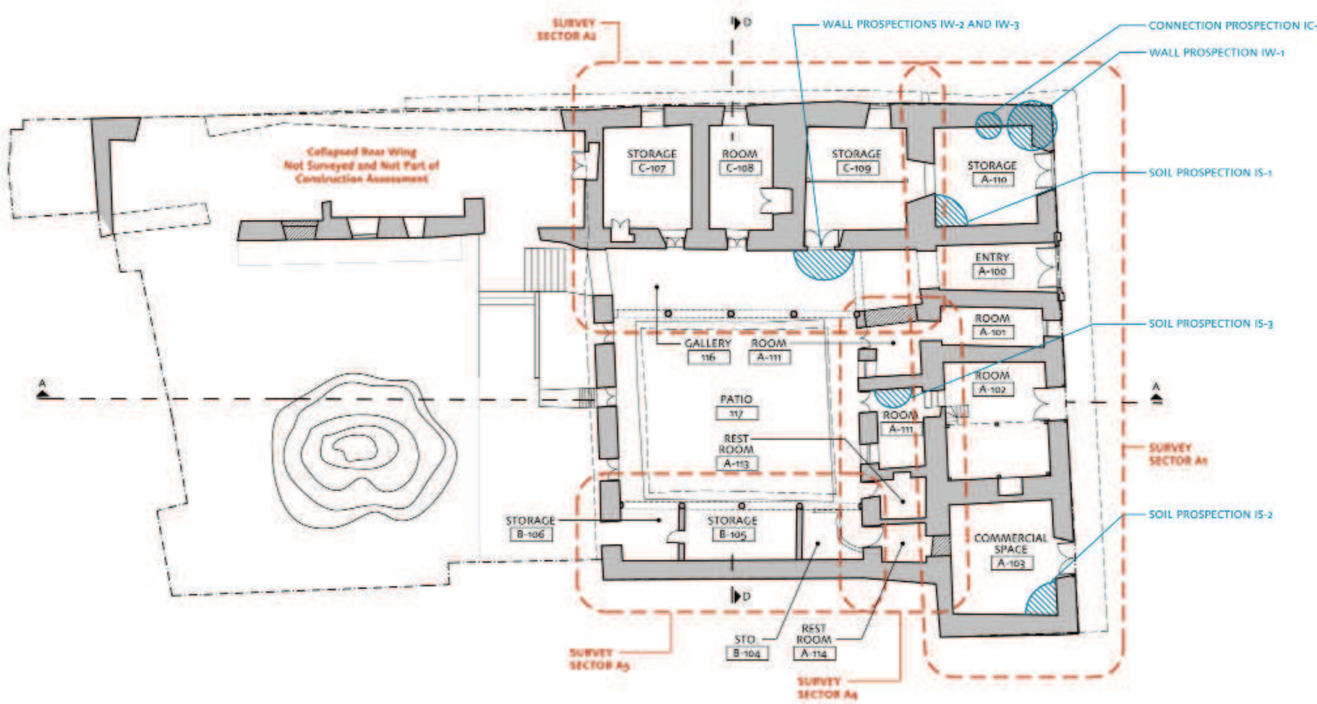


FIGURE 2.9

Casa Arones, survey sectors shown in red.

Drawing: Base drawing prepared by Enrique Estrada and edited by the GCI.

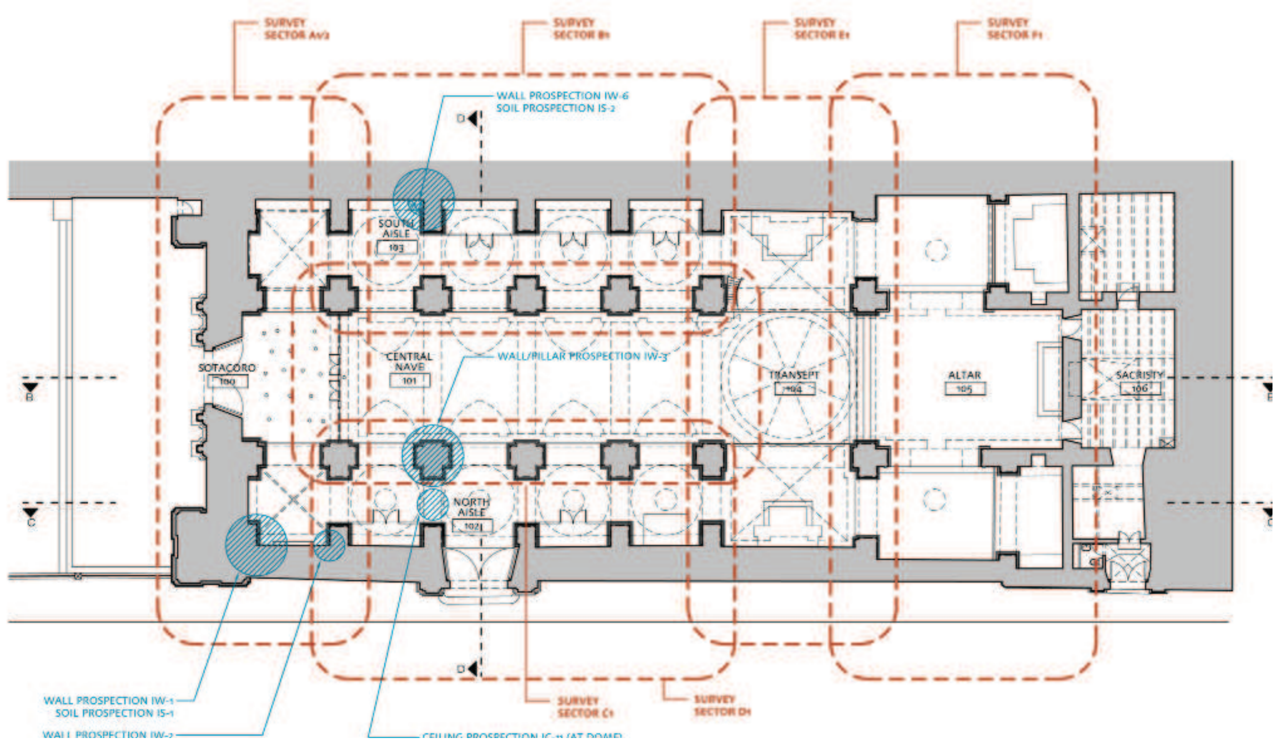


FIGURE 2.10

Cathedral of Ica, survey sectors shown in red.

Drawing: Base drawing prepared by Mirna Soto and edited by the GCI.

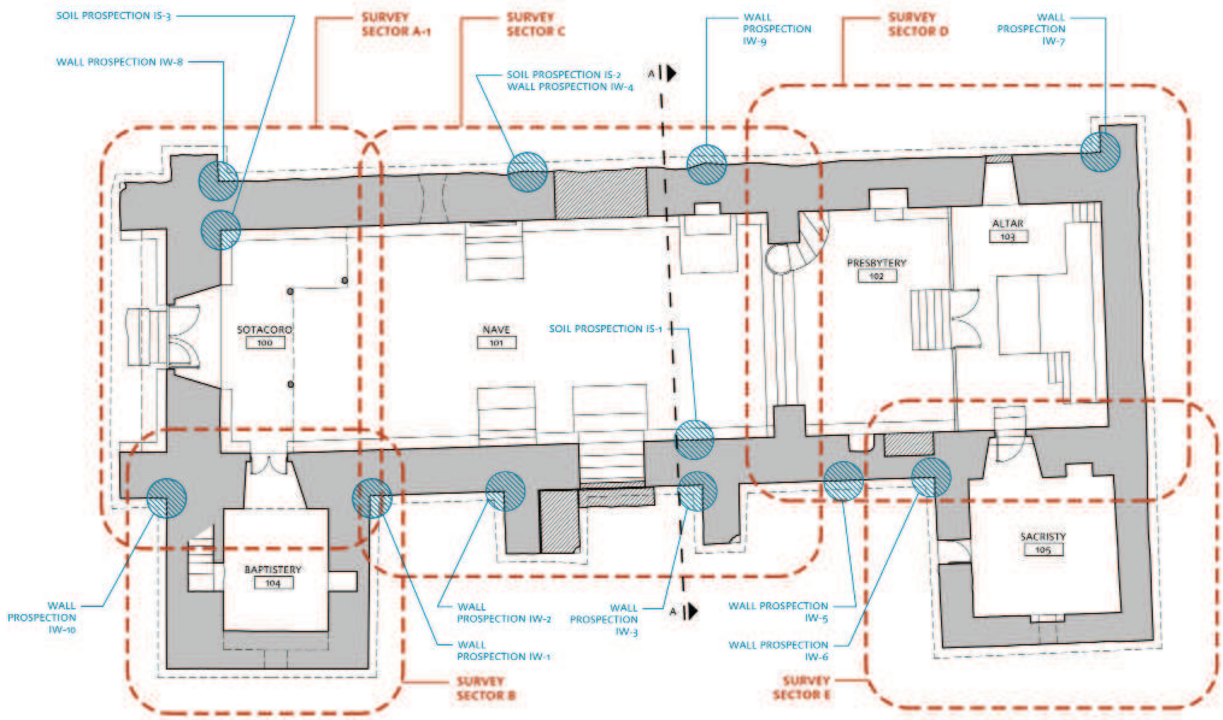


FIGURE 2.11
Church of Kuño Tambo, survey sectors shown in red.
Drawing: Base drawing prepared by Ruben Estrada Tapra and edited by the GCI.

The selection of sectors in the religious structures was based on their architectural configuration. The Cathedral of Ica was divided into six sectors: (a) sector A: the two-story choir loft, *sotacoro* (area under the choir loft), façade, and bell towers; (b) sector B: central nave; (c) sector C: side aisle along the street, Jirón Cajamarca; (d) sector D: side aisle bordering the adjacent structure; (e) sector E: the crossing and transept; and (f) sector F: the altar (Fig. 2.10). The Church of Kuño Tambo was divided into five sectors: (a) sector A: the two-story choir loft and sotacoro; (b) sector B: the baptistery; (c) sector C: the central nave; (d) sector D: the presbytery and altar; and (e) sector E: the sacristy (Fig. 2.11).

A general survey form was developed to gather information on the structure as a whole, and sector-by-sector survey forms were developed to obtain critical information regarding construction techniques, as well as the severity of the structural element conditions (Figs. 2.12, 2.13). The forms were accompanied by detailed drawings graphically indicating the location of construction materials and conditions described in the forms (Figs. 2.14, 2.15).

The general survey form collected the following data for each site:

i. Building information: name and address, original construction date or period, images, and floor plan
1. Building type: casona (one or two stories of adobe / adobe and quincha, two or more stories) or church (adobe walls with quincha vaults or domes / adobe walls with wood truss roof system)
2. Context: within historic district/center, urban, or rural environment; adjacent to other buildings, including the location within the block; close to other buildings, including distances from them; or isolated

3. Setting: flat or sloped
4. Occupancy: unoccupied or occupied (indicating average number of occupants per day and night)
5. Shape in plan: rectangular, square, C, L, or other/mixed
6. Wall density
7. Use: residential, commercial, museum, religious, office, or other
8. Socioeconomic characteristics: economic level of inhabitants and type of ownership (rent / own)
9. General architectural description
10. History of alterations
11. Description of soil configuration/type
12. Level of maintenance: existence of maintenance plan (if yes, by whom and how often) and reports of previous earthquake damage
13. Quality of original workmanship at the roof, ceiling, masonry, and foundations

The following data was collected for each survey sector of a particular building:

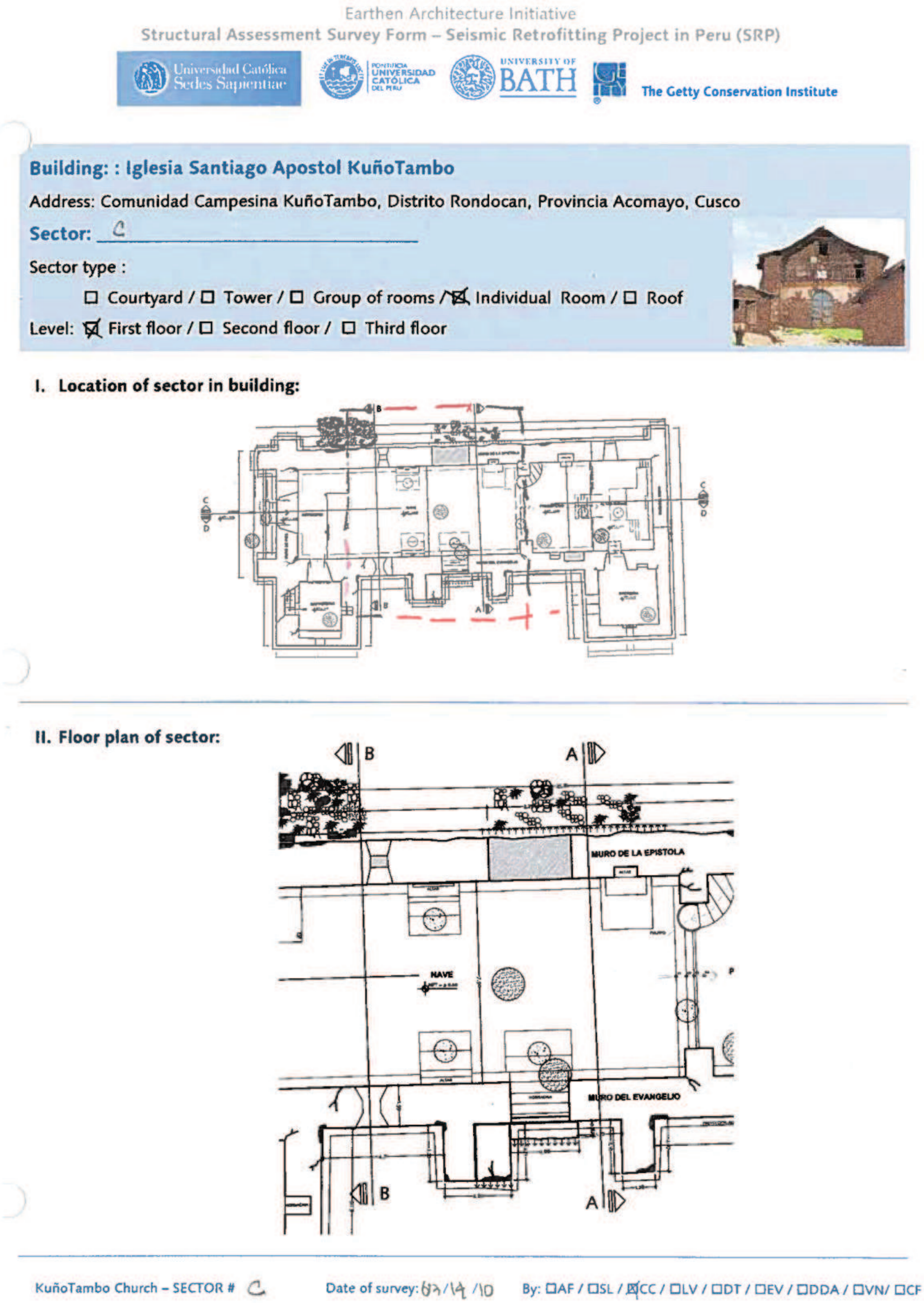
1. Sector number, type (courtyard / tower / group of rooms / individual room / roof), and floor level
2. Overall floor plan, indicating the location of the sector in the building
3. Enlarged floor plan of sector
4. Cross sections, elevations, or photos
5. General seismic performance and vulnerability:
    - Shape of the building sector: rectangular, square, C, L, or mixed
    - Average span between walls in x and y directions
    - Wall density
    - Indication if vertical load-bearing walls appear to be attached to the foundation (first floor only) or floor/roof structures (others and last floor)
    - Maintenance: general condition of building sector materials, noting any building elements damaged by previous earthquake(s) that have not been repaired
6. Key plan indicating location of photographs taken to record surveyed conditions
7. Description of sector structural system:
    - Foundations and *sobrecimiento* (base course):
        - Foundations: natural (solid rock / stiff soil / structure rock), man-made (rubble stone masonry / coursed stone masonry), or no foundation (walls sitting on natural unmodified ground), with indication of condition (cohesive / not cohesive)
        - Base course: man-made (rubble stone masonry / coursed stone masonry), with indication of condition (cohesive or not cohesive)
    - Load bearing masonry/quincha walls:
        - Adobe masonry (noting dimensions of block and mortar, if any), rammed earth, fired brick masonry, or stone masonry
        - Quincha walls with wood frames (cane and reed / adobe block infill / fired brick infill)
    - Previous structural reinforcements:
        - Reinforced adobe or fired brick masonry walls with embedded concrete columns

   - Concrete frame with unreinforced adobe or fired brick masonry walls
   - Other reinforcements: iron/steel bars (across walls / inside walls), anchors (top to roof / wall to wall), wooden keys, or isolated concrete or wood beams (located at top of longer walls / shorter walls / across room / around the room)
- Plaster on walls and ceiling (mud / lime / cement / painted surface only), with indication of painted or unpainted finish
- Floors: wood or concrete beams or joists, indicating number of framing elements, dimensions, and spacing
- Roofs: truss, concrete structure, quincha vault/dome, flat, or other, indicating number of framing elements, dimensions, and spacing

8. Conditions impacting seismic performance of sector:

- General conditions: stable or instable
- Condition of the adobe/quincha walls:
   - Total collapse (all walls / half of the walls / one quarter of the walls)
   - Partial wall collapse, not considering the condition of the plaster (at the center / corners / upper section)
   - Settlement of walls (at center / on edges)
   - Corner damage (full height / upper part of the walls)
   - Out-of-plane displacement (inward / outward / bowing; in upper / lower, / middle section of the walls)
   - Structural cracking: horizontal (lower / upper / center); vertical (lower / upper / center / coming out of openings / at corners); flexural (wall to wall / mid-wall); diagonal (top to bottom / top to mid-height / bottom to mid-height); or X-shaped (top to bottom / top to mid-height / bottom to mid-height)
   - Detachment of plaster
   - Plaster loss
   - Beetle damage
   - Erosion
   - Moisture damage
   - Presence of vegetation
- Condition of the wood beams, rafters, and quincha frames:
   - Deformation: floors (joists and beams), roofs (rafters, purlins, ridge purlin, collar tie, and arches and ribs), and quincha frames (vertical and diagonal posts)
   - Rotting: floors (joists and beams), roofs (rafters, purlins, ridge purlin, collar tie, and arches and ribs), and quincha frames (vertical and diagonal posts)
   - Termite damage: floors (joists and beams), roofs (rafters, purlins, ridge purlin, collar tie, and arches and ribs), quincha frames (vertical and diagonal posts), and adobe masonry, typically at the base of the façade
- Condition of connections:
   - Corrosion on metal anchors/nails
   - Failure/disconnections: wall-to-wall connections, lintels, floor-to-wall connections, and roof/top-of-wall connections

A complete example of the survey forms is provided in Appendix A.


Earthen Architecture Initiative
Structural Assessment Survey Form – Seismic Retrofitting Project in Peru (SRP)

Universidad Católica Sedes Sapientiae | Pontificia Universidad Católica del Perú | University of Bath | The Getty Conservation Institute

Building: : Iglesia Santiago Apostol KuñoTambo

Address: Comunidad Campesina KuñoTambo, Distrito Rondocan, Provincia Acomayo, Cusco

Sector: C

Sector type :

☐ Courtyard / ☐ Tower / ☐ Group of rooms / ☒ Individual Room / ☐ Roof

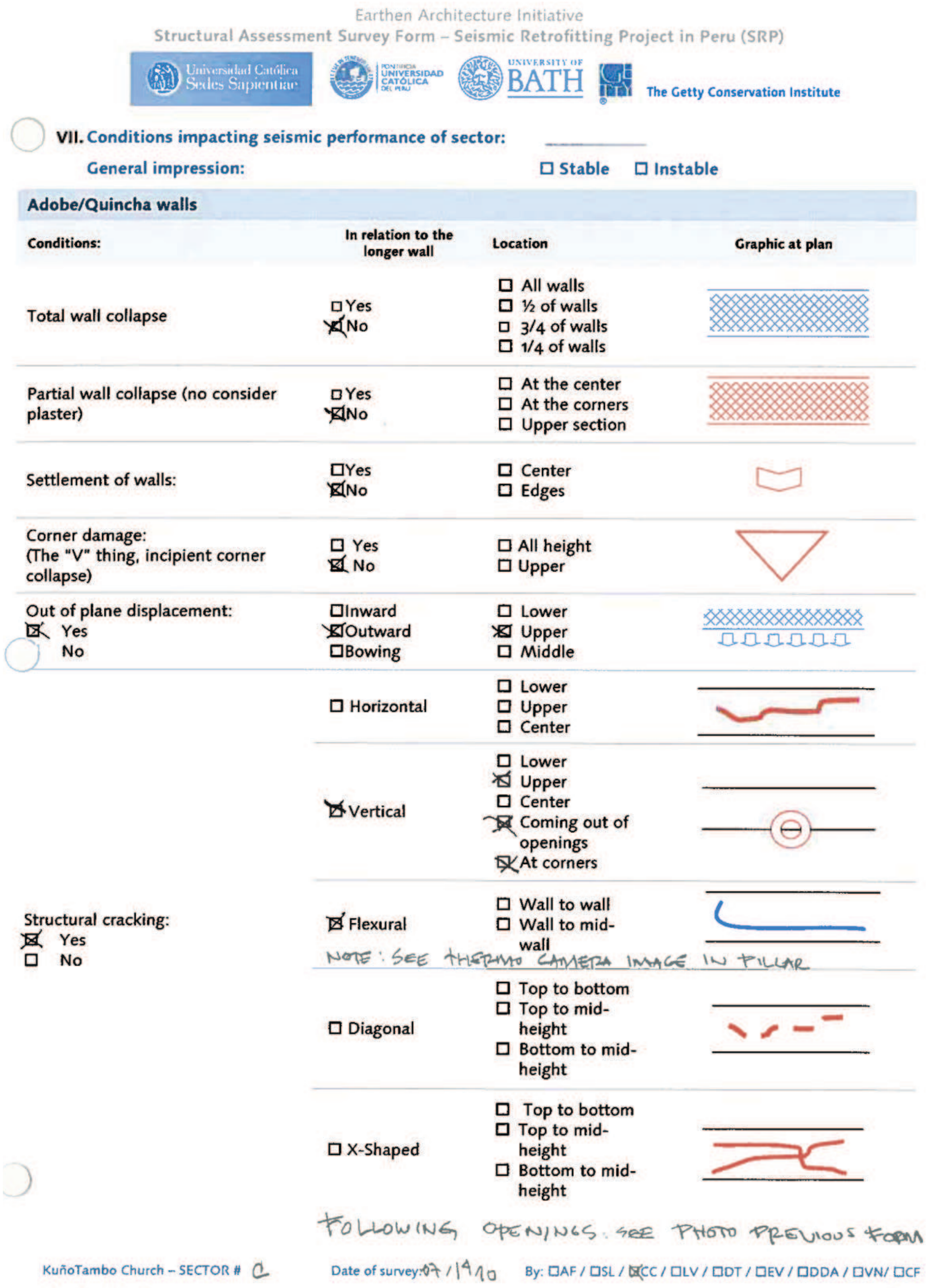
Level: ☒ First floor / ☐ Second floor / ☐ Third floor

I. Location of sector in building:

II. Floor plan of sector:

KuñoTambo Church – SECTOR # C   Date of survey: 07/14/10   By: ☐AF / ☐SL / ☒CC / ☐LV / ☐DT / ☐EV / ☐DDA / ☐VN/ ☐CF

FIGURE 2.12
Example of completed sector-by-sector survey form, page 1.



Earthen Architecture Initiative
Structural Assessment Survey Form – Seismic Retrofitting Project in Peru (SRP)

Universidad Católica Sedes Sapientiae | Pontificia Universidad Católica del Perú | University of Bath | The Getty Conservation Institute

VII. Conditions impacting seismic performance of sector:

General impression: ☐ Stable ☐ Instable

Adobe/Quincha walls

Conditions:	In relation to the longer wall	Location	Graphic at plan
Total wall collapse	☐ Yes ☒ No	☐ All walls ☐ ½ of walls ☐ 3/4 of walls ☐ 1/4 of walls	
Partial wall collapse (no consider plaster)	☐ Yes ☒ No	☐ At the center ☐ At the corners ☐ Upper section	
Settlement of walls:	☐ Yes ☒ No	☐ Center ☐ Edges	
Corner damage: (The "V" thing, incipient corner collapse)	☐ Yes ☒ No	☐ All height ☐ Upper	
Out of plane displacement: ☒ Yes ☐ No	☐ Inward ☒ Outward ☐ Bowing	☐ Lower ☒ Upper ☐ Middle	
Structural cracking: ☒ Yes ☐ No	☐ Horizontal	☐ Lower ☐ Upper ☐ Center	
	☒ Vertical	☐ Lower ☒ Upper ☐ Center ☒ Coming out of openings ☒ At corners	
	☒ Flexural	☐ Wall to wall ☐ Wall to mid-wall	
	☐ Diagonal	☐ Top to bottom ☐ Top to mid-height ☐ Bottom to mid-height	
	☐ X-Shaped	☐ Top to bottom ☐ Top to mid-height ☐ Bottom to mid-height	

NOTE: SEE THERMO CAMERA IMAGE IN PILLAR FOLLOWING OPENINGS. SEE PHOTO PREVIOUS FORM

KuñoTambo Church – SECTOR # C Date of survey: 07 / 19 / 10 By: ☐AF / ☐SL / ☒CC / ☐LV / ☐DT / ☐EV / ☐DDA / ☐VN / ☐CF

FIGURE 2.13
Example of completed sector-by-sector survey sector form, indicating conditions.

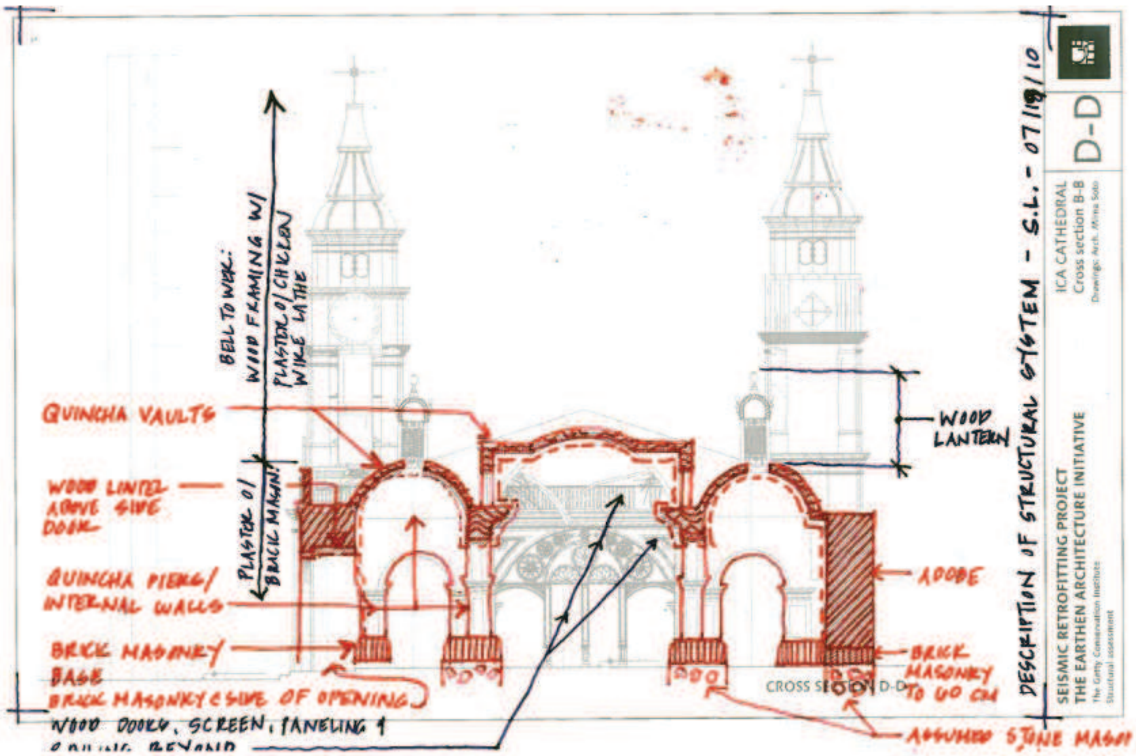


FIGURE 2.14
Example of detailed drawing accompanying survey form, graphically indicating the location of construction materials.
Drawing: Sara Lardinois.

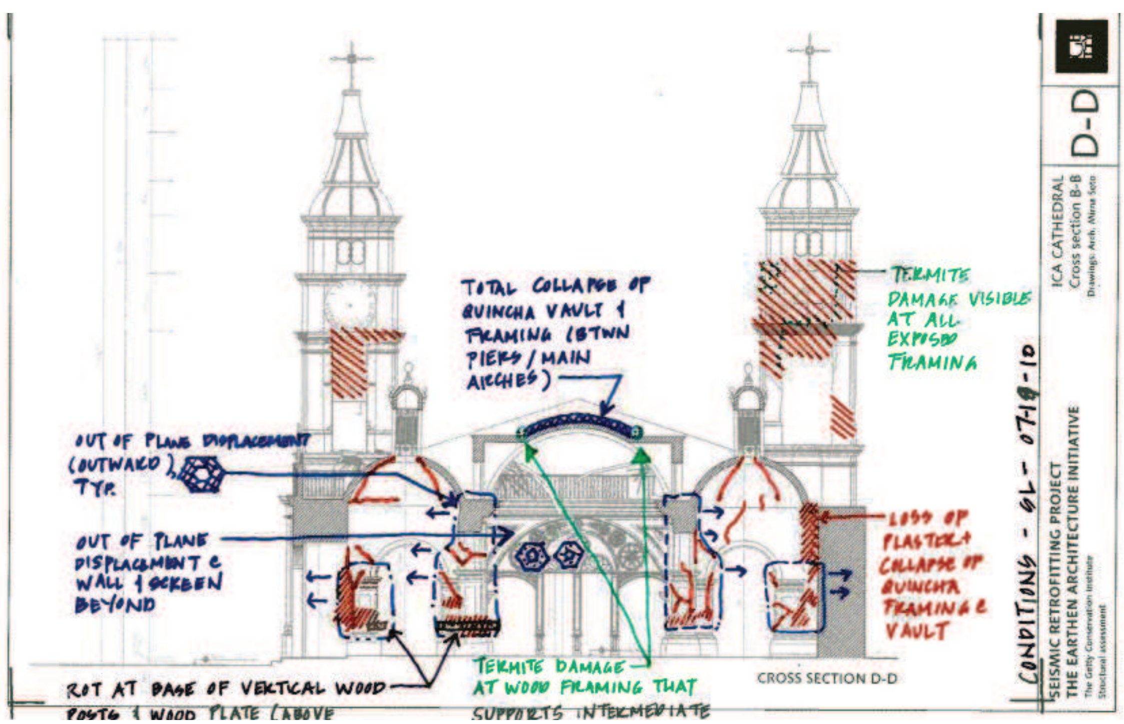


FIGURE 2.15
Example of detailed drawing accompanying survey form, graphically indicating location of observed conditions.
Drawing: Sara Lardinois.

2.3.1.2 Nondestructive investigations

The structural assessment of an existing building requires an understanding of materials and connections that are usually not readily apparent through visual analysis. Unless there has been extensive damage to a building, most structural materials will be covered by protective or decorative plasters and finishes. Even when some areas of the building are exposed, it cannot always be assumed that these sections of the building were constructed in the same manner as those that are not exposed, necessitating further investigation. In many cases, this is performed by dismantling portions of the wall, ceiling, or floor, or digging into the foundation of the building which may cause further damage to the building and not be appropriate depending on the nature of the investigation or the importance of the architectural finishes. To avoid this type of damage, nondestructive investigation techniques have been adapted from other fields for use with historic architecture. The use of these techniques on earthen buildings remains a largely unexplored topic, but one which could provide great benefits to the field of earthen architectural conservation. In light of this, several nondestructive assessment methods were evaluated and considered for use with this project; and, of these, infrared photography and thermal imaging were identified for on-site trials.

Infrared photography

Infrared photography is a method of capturing non-visible light waves that reflect off of surfaces. Because it produces images that draw from light waves outside the usual visible range it can be utilized for the detection of materials—particularly on surfaces—that would not normally be seen. In some cases it can illuminate a faint rendering or underpainting that would otherwise go unnoticed. Additionally, some painting materials will effloresce at certain infrared wavelengths and can be detected with the camera. While infrared analysis is not structural in nature, assessment of painted surfaces will inform the planning of interventions, especially if new paintings are found in areas previously thought to be undecorated.

For the on-site trials, a Nikon D70s single-lens reflex camera was used. The internal infrared filters were removed from the camera, and one of three external filters was used:

- "X-Nite CC1", to block infrared waves and allow for common visible light photography
- "X-Nite 850", to pass infrared with wave-lengths above 850 nm
- "X-Nite 1000B", to pass infrared with wave-lengths mostly above 1000 nm

In some cases no filter was attached to the camera, to allow both visible and infrared light to be collected.

The process for infrared photography can be relatively simple, although there are many ways to improve the methodology for more advanced use. Essentially, the camera is mounted on a tripod and remains stationary, without adjusting direction or zoom, while the lenses are exchanged to collect the target light spectra.

During the trials, the infrared images were collected as *.nef files (Nikon's raw format) and adjusted with Adobe Photoshop's Camera Raw 5.2 plug-in. The adjustment process can produce very different images from the same file so working standards should be tailored for each specific use. In the SRP trials, each image was adjusted differently to optimize visibility of the paintings.

On the walls of the Church of Kuño Tambo, no new information was revealed by the infrared photography; but, in one area on the west wall by the choir loft, a painted area that had been covered by a thin film of dirt showed more clearly in the infrared images.

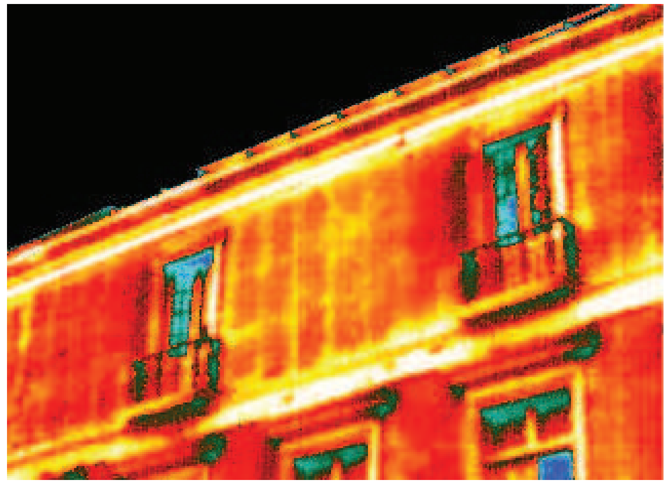
In light of this experience it seems that infrared photography holds potential for investigations of painted walls either in areas where paintings are believed to exist under soiled surfaces or where materials that effloresce may have been used in the painting.

Thermal imaging

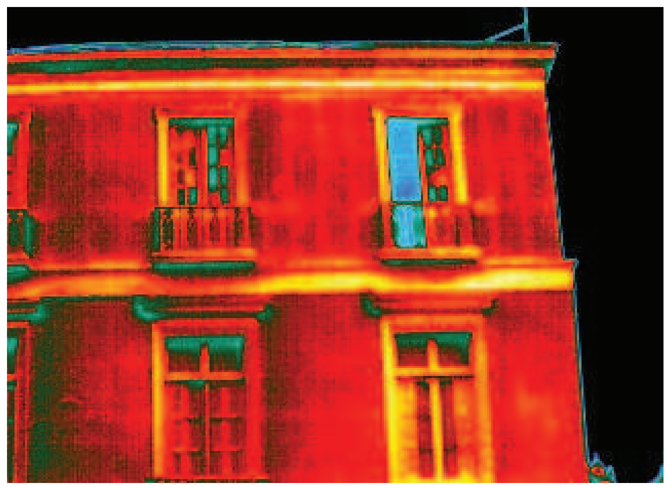
Thermal imaging is a way of visually capturing information on surface temperature. Since the materials within a wall can affect surface temperature, thermal imaging has the potential to reveal where different materials such as wood members, steel plates, brick, or stone have been placed within a building.

For the on-site testing at the four prototype buildings, a FLIR B400 (30 Hz) thermal camera was used. It was set in manual mode so the temperature range could be controlled to improve the legibility of construction materials. The use of the camera was timed to coincide with sunrise in order to take advantage of temperature changes in the building and thus produce the clearest images, especially for exterior elevations. On building interiors, the use of heating devices (such as lights, heat lamps, and wall heaters) to create temperature shifts to illuminate differences in materials was tested; but in the case of the SRP, these artificial heat sources did not significantly improve the legibility of the different materials in the thermal images. Camera settings and environmental conditions which can affect the thermal image—such as emissivity, reflectance, atmospheric temperature, and relative humidity—should be recorded with every image captured to allow transfer of the thermal imaging methods to similar buildings and obtain comparable results.

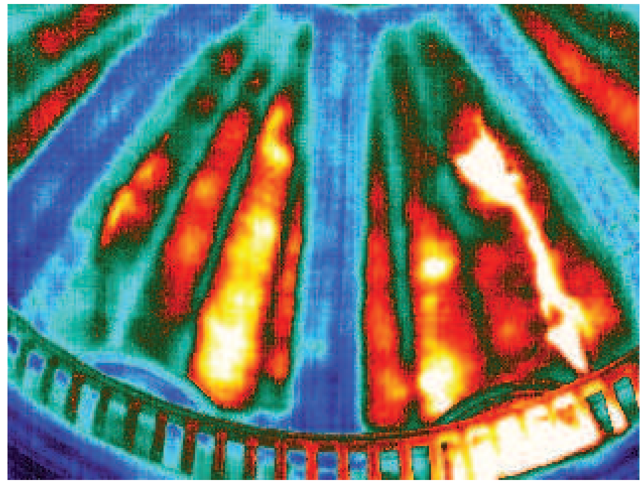
In the SRP on-site testing, thermal imaging proved to be most useful from a structural standpoint for locating the position the quincha posts in the upper stories of the walls at Hotel El Comercio (Figs. 2.16–2.19). Thermal imaging also proved useful in determining the number and placement of wood structural elements in the vaults and domes of the Cathedral of Ica (Figs. 2.20–2.23).

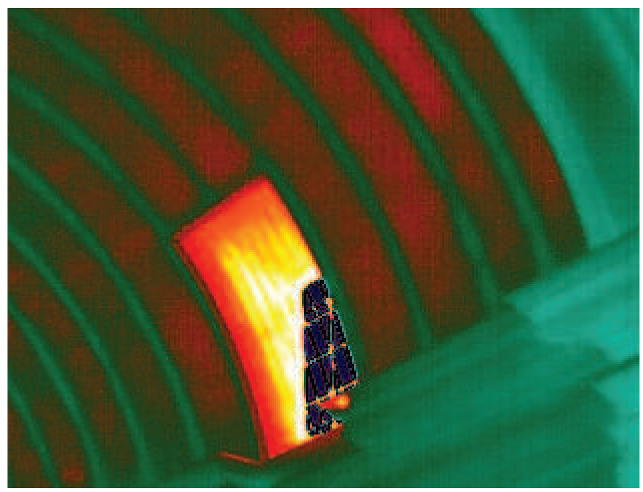
FIGURES 2.16 (LEFT) AND 2.17 (RIGHT)
Northwest façade of Hotel El Comercio: photograph (left) and thermal image (right) of the same sector, indicating the location of the internal wood posts in the third floor quincha walls.
Images: Amila Ferron.

FIGURES 2.18 (LEFT) AND 2.19 (RIGHT)
Northeast façade of Hotel El Comercio: photograph (left) and thermal image (right) of the same sector, indicating the location of the internal wood posts in the third floor quincha walls.
Images: Amila Ferron.



FIGURES 2.20 (LEFT) AND 2.21 (RIGHT)
Dome of the Cathedral of Ica: photograph (left) and thermal image (right) of the same sector, indicating the location of the internal wood ribs or arches.
Images: Claudia Cancino.



FIGURES 2.22 (LEFT) AND 2.23 (RIGHT)
Barrel vault over altar at the Cathedral of Ica: photograph (left) and thermal image (right) of the same sector, indicating the location of the internal wood ribs or arches.
Images: Claudia Cancino.

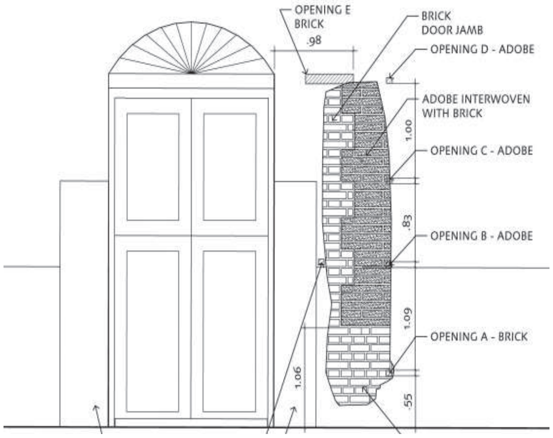
FIGURE 2.24
Prospection in the patio of Hotel El Comercio to determine the foundation configuration.
Image: Mirna Soto, for the GCI.

2.3.1.3 Prospections

To complement the detailed structural survey, annotated detail drawings illustrating structural elements, systems, and connections were provided for the four prototype buildings. These drawings were prepared by opening up select areas the building foundations, wall, and roof structure for further investigation— a process referred to as "prospection."[2] The areas to be opened up were selected by the project partners. In determining which areas of a building to open up, it was necessary to strike a balance between what type of data was desirable to attain and what was feasible to obtain and would not jeopardize the integrity of the site. The work was carried out by GCI consultant Mirna Soto, a Peruvian architect and architectural conservator, and her team of masons (Fig. 2.24). The buildings were opened up during a team field campaign in July 2010; and while the building was open, each prospection area was recorded through field sketches, photographs, and narrated videos. The number and location of prospections did not require the permanent removal of original building materials; and, any necessary repair work was carried out to return the prospection areas to their configuration and appearance prior to the start of work. As the Cathedral of Ica sustained heavy damage during the 2007 earthquake, structural shoring was erected to prevent further damage to the building and to provide a safe working environment for the investigations to be carried out.

The collected data was used to prepare a series of measured drawings, called "prospection drawings." The prospection drawings included:

- Detailed and annotated drawings of the foundation construction techniques, indicating soil stratification for all selected sites. Where feasible, details included cross sections of slopes, internal and external grade levels, and floor levels.
- Isometric annotated drawings illustrating mud brick layouts in the following walls: front façade and lateral wall at the Cathedral of Ica; front façade, lateral walls, and buttresses at the Church of Kuño Tambo; first and second floor walls at Casa Arones; and, first floor walls at Hotel El Comercio. In the case of El Comercio, annotated elevations indicating the layout of the brick surround at first floor openings were also provided (Fig. 2.25).
- Annotated elevations and cross sections of quincha walls at the second and third floors at the corner of sector A and at the façade and internal wall connection in sector B of Hotel El Comercio.
- Isometric drawing and annotated detailed cross section of one pillar at the Cathedral of Ica to show the internal structure, including the connections between wood posts and any extant wall plates at the vault above; and isometric annotated drawing of the central dome and vault structure (Fig. 2.26).
- Isometric drawings and annotated roof plans of typical wood-framed floors and roofs, indicating size, number, and spacing of joists or rafters and collar ties and the position of any extant tie beams.
- Isometric drawings and annotated detailed cross sections illustrating the connections between the main façade and the lateral mud brick walls at the Cathedral of Ica; connections between the façade and lateral walls, façade, and wood balcony and each wall-to-buttress connection at the Church of Kuño Tambo; connections between sectors 1 and 2 at Casa Arones, including roof–wall and wall–ceiling connections; and connections between the



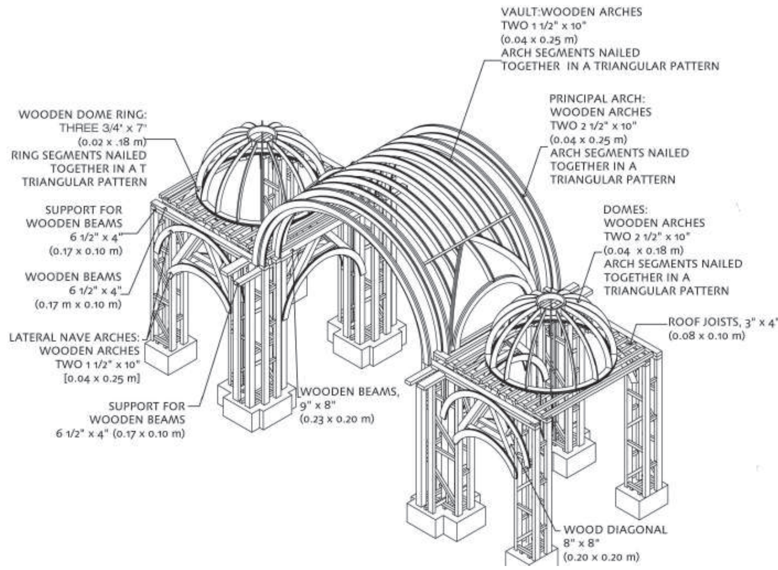


FIGURE 2.25
Example of annotated elevation showing brick layouts at door surrounds, Hotel El Comercio.
Drawing: Mirna Soto, for the GCI.

FIGURE 2.26
Example of isometric detail of wood structure at quincha pillars, vaults, and domes of the Cathedral of Ica.
Drawing: Mirna Soto, for the GCI.

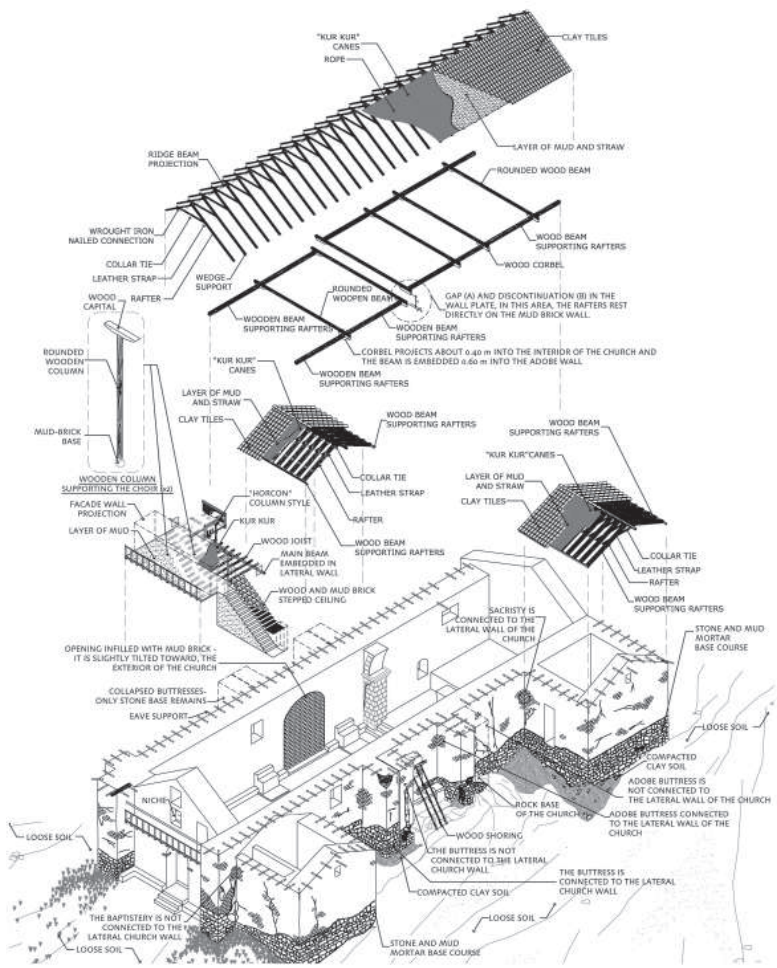


FIGURE 2.27
Example of isometric drawing illustrating the overall structural scheme of the Church of Kuño Tambo.
Drawing: Mirna Soto, for the GCI.

quincha walls and floors, indicating the location of floor joists and quincha posts at Hotel El Comercio.
- Isometric drawings illustrating the overall structural scheme of each building, to provide an overall understanding of the typical construction components (Fig. 2.27).

The full set of prospection drawings prepared for each building is provided in Appendix C. Measurements are typically provided in metric; however, some of the original measurements for wood framing were provided in United States customary or imperial units, as is common practice in Peru. Any original imperial measures have been retained in the both the drawings and report text; and, in such cases metric equivalents have been provided in parentheses following the original measurements.

2.3.2 Basis of preliminary findings

The assessment report also provides preliminary findings on the structural behavior of the prototype buildings. These preliminary findings are based upon the previously-described qualitative investigations. The project team utilized their past experience with historic earthen construction to interpret that data collected through research and observation and develop preliminary ideas on the possible structural behavior of the sites. These preliminary findings will be explored further in the next phases of the project through quantitative methods, including the experimental testing and numerical modeling and seismic analyses. Following the quantitative testing and analyses, the preliminary findings will be revised as necessary and expanded upon to provide a complete diagnosis and evaluation.

2.3.3 Terminology

A number of standard terms have been used to describe the conditions of the prototype buildings. The standard terms, and their associated meanings as defined for the Seismic Retrofitting Project, are as follows:

Poor: A feature is badly deteriorated and immediate corrective measures are necessary to ensure its preservation.

Fair: A feature is beginning to appear to be disturbed or is deteriorating and immediate action is recommended.

Good: A feature exhibits little evidence of deterioration or disturbance and no immediate action is necessary.

Alteration: Any modification performed by man on the original non-structural or structural systems.

Damage: A change of state of a structural or non-structural system, usually caused by natural agents such as earthquakes or floods.

Decay: Long-term processes leading to the deterioration of materials.

Irregularity: A state that is not in accordance with proper construction practices and/or conditions. Irregularities can be caused by construction deficiencies or phenomena occurring during the lifetime of the building.

Notes

1 The colonial period begins with the Spanish foundation of the city of Lima in 1535, includes the period of the Spanish Viceroyalty of Peru (1542–1821), and ends with the declaration of Peruvian independence in 1821 and the establishment of the Republic of Peru.

2 The term “prospection” is derived from the Spanish *prospección*.

CHAPTER 3

Hotel El Comercio

3.1 Summary

Hotel El Comercio is located in the historic center of Lima, at the corner of an urban block near the Government Palace and Plaza Mayor of Lima (Fig. 3.1). Founded in 1535 and capital of both the Spanish Viceroyalty and present day Peru, the Historic Centre of Lima was inscribed on the UNESCO World Heritage list in 1991 and is home to a collection of highly significant buildings constructed in mud brick masonry and quincha. The site of Hotel El Comercio had been occupied by a number of earlier Spanish colonial and pre-Hispanic structures; however, the current structure dates to the middle of the nineteenth century. Hotel El Comercio is representative of a typical courtyard or patio building, known as a casona (Fig. 3.2). The three-story, 4,600 m^2 building consists of 131 rooms arranged around two interior patios. Several commercial spaces are located at the first floor along Jirón Carabaya, including El Cordano—a historically and socially significant bar. Hotel El Comercio is constructed with rubble stone masonry foundations; a fired brick masonry base course; mud brick and fired brick masonry walls at the first floor; and quincha walls at the second and third floors. The floors are constructed with a raised finish floor over wood sleepers over wood tongue-and-groove boards, joists, and beams. The roof is flat and of similar construction to the floors, but it is finished with layers of mud plaster. The building has been subject to a number of

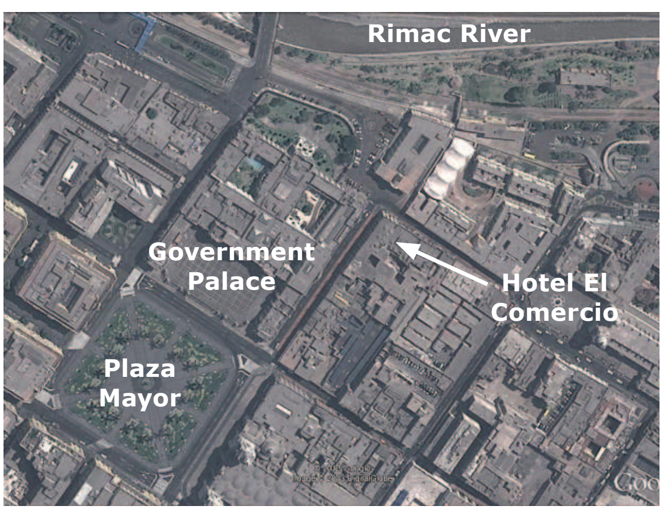


FIGURE 3.1
Satellite image showing the location of Hotel El Comercio in the Historic Centre of Lima.
Image: © 2013 Google. Image © 2013 Digital Globe.

FIGURE 3.2
Hotel El Comercio, as viewed from the northeast.
Image: Amila Ferron.

alterations, particularly in the northeast corner where internal mud brick walls were removed and replaced with columns and openings were enlarged to accommodate the programmatic needs of El Cordano bar. The building is owned by the Ministerio de Cultura del Perú and is largely unoccupied at the present time. The structure is in fair condition overall; and the preliminary findings indicate that the structural performance of the building is compromised by the previously mentioned alterations; the presence of humidity in the base of the mud brick walls; ongoing exposure of the structural elements in the quincha wall frames to termites; insufficient connections between the quincha frames and floor structure; and the insufficient embedment of the quincha frame sill plates into the top of the mud brick walls.

3.2 Historical Background, Context, and Significance

3.2.1 Historical background and context[1]

Hotel El Comercio was constructed in the middle of the nineteenth century; however, its site and the area surrounding the Plaza Mayor in Lima had long been occupied by a number of earlier Spanish colonial and pre-Hispanic structures.

When the city of Lima was founded by the Spanish on January 18, 1535, there were already a number of pre-Hispanic buildings in the area of the future Plaza de Armas, which would later become known as Plaza Mayor (Fig. 3.3). The Spaniards built over many of these structures. For example, Governor Don Francisco Pizarro built his own house over the house of Taulichusco, the last indigenous ruler of the area. This house was altered and expanded over the centuries and later became known as the Government Palace of Peru. Today, it is still possible to see some remains of Taulichusco´s house below the Government Palace.

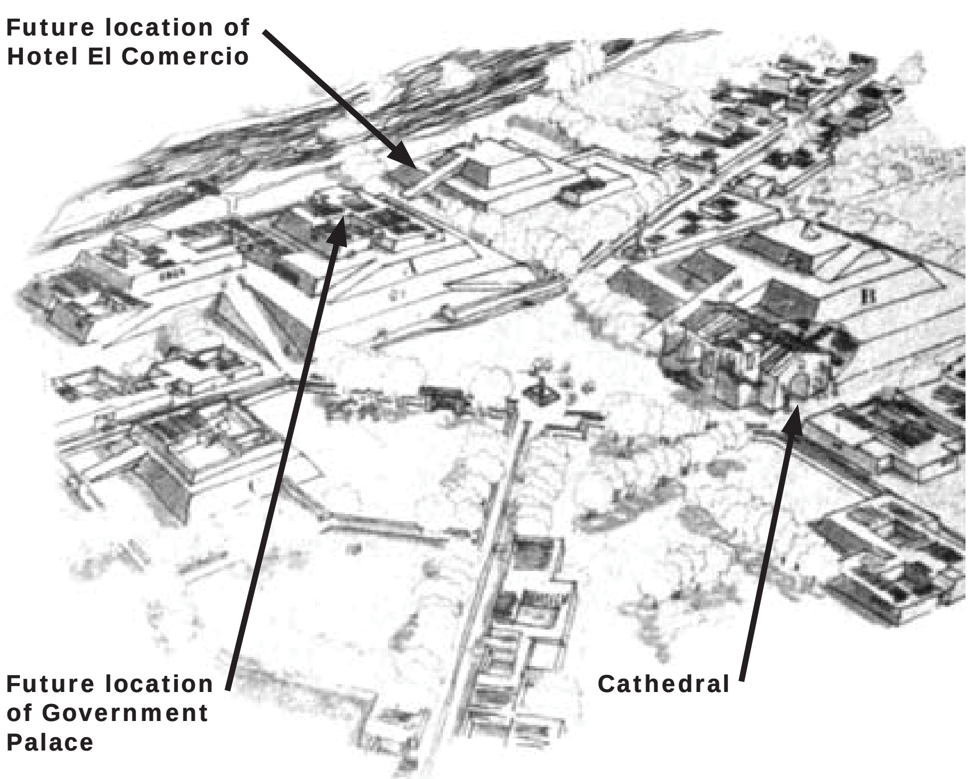


FIGURE 3.3
Hypothetical reconstruction of pre-Hispanic buildings in the area of the future Plaza Mayor, circa 1535.
Image: Juan Günther Doering, Patronato de Lima, with additional annotations by GCI.

The site of Hotel El Comercio was also home to an existing pre-Hispanic structure—a pyramid-shaped structure that functioned as a small sanctuary. The Spanish called this sanctuary *Huaca Riquelme*, as it was located in an area of the city that had been given to Don Alonso de Riquelme, who at the time was secretary to Governor Pizarro and later became the royal treasurer. During the Spanish period, structures such as *Huaca Riquelme* disappeared quickly, as they were disassembled so that their materials could be reused for the construction of new earthen buildings in the new city. Some remains of *Huaca Riquelme* have been found in the area surrounding Hotel El Comercio.

In the sixteenth century, a two-story house was built on the site of Hotel El Comercio. This house appears on Pedro Nolasco Mere's 1685 map of Lima. The house survived for the next two centuries, until 10:30 p.m. on October 28, 1746 when a three-minute earthquake destroyed the city of Lima. Nearly 3,000 houses in Lima collapsed as a result of the earthquake. Only 25 houses survived, but they were severely damaged and were eventually demolished. Following the earthquake, most houses were rebuilt; and, many of the churches, convents, and monasteries were partially or fully rebuilt as well. Most reconstructed and new buildings were generally limited to a height of two stories. In the nineteenth century these restrictions were relaxed to allow for the construction of three-story houses, such as Hotel El Comercio.

Author José Gálvez writes about the current Hotel El Comercio structure in his 1943 publication *Calles de Lima y meses del año*, noting that in 1848, owner José Simeón Ayllón Aramburú "construye 'un gran edifi cio' en esa calle" (constructed a great building in that street).[2] He is describing the current three-story structure, which would have been viewed as an enormous building in what was at the time a low-rise city. In 1897, Don Manuel Quimper purchased the three-story building at the corner of Jirón Carabaya and Jirón Ancash. In the legal records, the house was described as having six doors along Jirón Carabaya and two doors facing Jirón Ancash. This transaction confi rms that Hotel El Comercio was certainly in existence by the end of the nineteenth century. A *plano panorámico* (bird's eye view) of Lima published in 1924 shows Hotel El Comercio with a mass and volume that is similar to its current appearance (Fig. 3.4).

FIGURE 3.4
The current mass and volume of Hotel El Comercio is shown in this portion of the *Plano panorámico de Lima en homenaje al primer centenario de la Batalla de Ayacucho*, drawn by Julio E. Berrocal in 1924 and edited by the Librería F. y E. Rosay.
Image: Juan Günther Doering.

Soon after the construction of Hotel El Comercio, the surrounding neighborhood began to change. On March 2, 1878 a new rail line serving Callao, Lima, and Matucana was inaugurated, with the Lima station located near Hotel El Comercio. The station transformed this part of the city, making it a transit center. In 1912 a new train station opened in front of Hotel El Comercio, further increasing activities in the area. The urban landscape was further modified in the 1930s when the old Jesuit Church of Nuestra Señora de los Desamparados, located on the same street as Hotel El Comercio, was destroyed.

During the 1980s, Hotel El Comercio was converted to an army printing center and heavy machinery installed within the building.

The building is currently owned by the Ministerio de Cultura del Perú and is unoccupied, except for a few commercial spaces at the first floor and the site guards' residences.

3.2.2 Significance

Hotel El Comercio is located within the boundaries of the Historic Centre of Lima, which was inscribed on the UNESCO World Heritage list in 1991. The structure was registered as a Peruvian national monument on July 23, 1980. Due to its design and construction details, it is architecturally significant as an example of a casona that is typical of Lima and other historic Viceroyalty cities in South America. As the home of El Cordano bar, where Peruvian presidents dined during the Republican period, the site also possesses historic and social significance (Fig. 3.5).

FIGURE 3.5
El Cordano bar.
Image: Claudia Cancino.

3.3 Architectural Description

Hotel El Comercio is located across the street from the government palace and one block away from Lima's main plaza (Plaza Mayor), cathedral, and city hall. The building is adjacent to a four-story modern concrete structure at Jirón Carabaya and a two-story mud brick and quincha casona at Jirón Ancash (Fig. 3.10). The building has a 1,480 m^2 footprint and contains three stories, two patios, three stairs, and a total of 131 rooms—27 at the first floor, 51 at the second floor, and 53 at the third floor (Figs. 3.6–3.9). The section adjacent to the construction at Jirón Ancash and the bay between the two patios has collapsed (Fig. 3.11). As the first and second patios have a similar architectural configuration and demonstrate the same construction techniques, this assessment and future structural analyses will only consider the first patio and the northeast section of the building.

Hotel El Comercio is constructed with a fired brick masonry base course and a rubble stone masonry foundation. Above the base course, the first floor walls are constructed of mud brick, with fired brick surrounds at the door openings. The second and third floor walls are made of quincha (Fig. 3.12). All exterior and patio façades are covered with painted plaster that appears to be recently applied. Both the second and third floors are constructed with tongue-and-groove wood floor boards over wood sleepers over wood floor boards over wood joists. The flat roof is of similar construction to the floors, but it is finished with layers of mud plaster.

The three-story northwest façade along Jirón Carabaya has a 1:3 proportion and is comprised of seven openings with brick masonry surrounds set in the adobe walls at the first floor, thirteen openings in the second floor quincha walls, and eight openings in the third floor quincha walls, mostly vertically and horizontally aligned (Fig. 3.13). The northeast façade along Jirón Ancash is of similar construction to the northwest façade, but it has an almost 1:1 proportion with two openings at the first floor, three openings at the second floor, and three openings at the third floor (Fig. 3.15).

The entrance to the building is through a double wooden door at the west end of the Jirón Carabaya façade. The entrance opens directly into the entry hall (*zaguán*), which connects the building entrance with the northwest end of the first patio (Fig. 3.14). The patio is comprised of an elevated gallery at the southeast side of the first floor and wood-framed balconies with steel columns at all four sides of the second and third stories (Fig. 3.16). At the first floor there are seven wooden columns which support the second floor balconies. The steel columns above are vertically and horizontally aligned between the second and third floor balconies but not with the wood columns at the first floor below. The patio façades also have a 1:1 proportion but the openings are not vertically aligned.

A grand wood staircase, to the northeast of the entry hall, provides access to the second floor. A separate staircase, to the east of the grand staircase, provides access between the second and third floors.

The interior rooms are typically finished with tile floors at the first level and wood floors at the second and third levels; painted plaster at the walls; and painted wood board ceilings that are attached to the underside of the floor joists above. Wood doors with glazed lites provide access to the rooms, and the street-facing rooms at the second and third stories also have similar doors providing access to balconies (Fig. 3.17).

FIGURE 3.6
First floor plan of Hotel El Comercio.
Drawing: Base drawing prepared by the Instituto Nacional de Cultura and edited by the GCI.

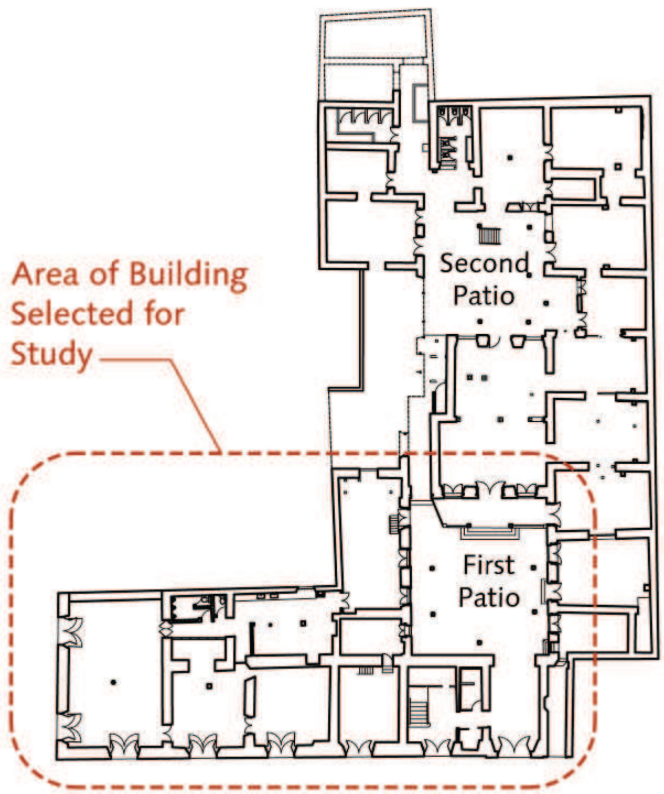


FIGURE 3.7
Detailed first floor plan of Hotel El Comercio, illustrating the area selected for study.
Drawing: Base drawing prepared by the Instituto Nacional de Cultura and edited by the GCI.

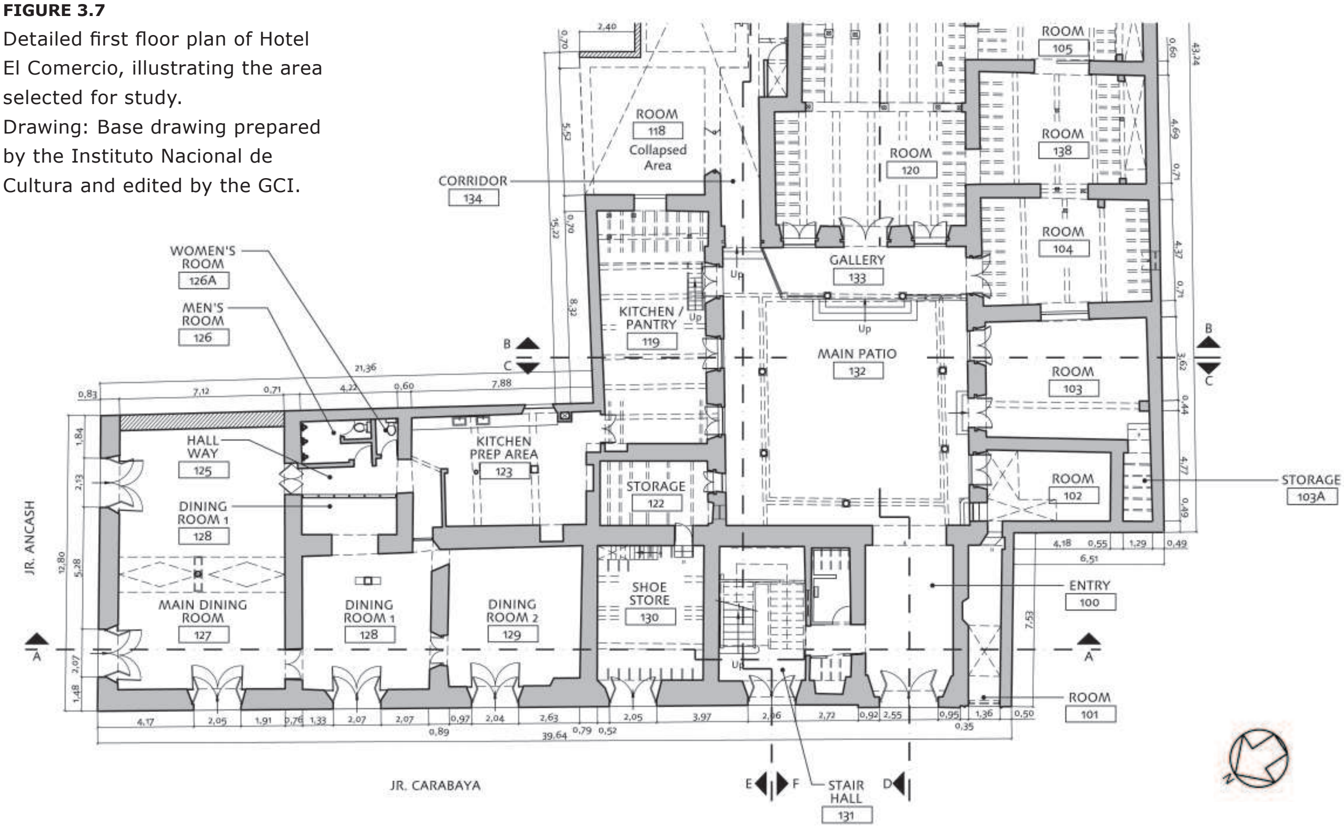


FIGURE 3.8
Detailed second floor plan of Hotel El Comercio, illustrating the area selected for study.
Drawing: Base drawing prepared by the Instituto Nacional de Cultura and edited by the GCI.

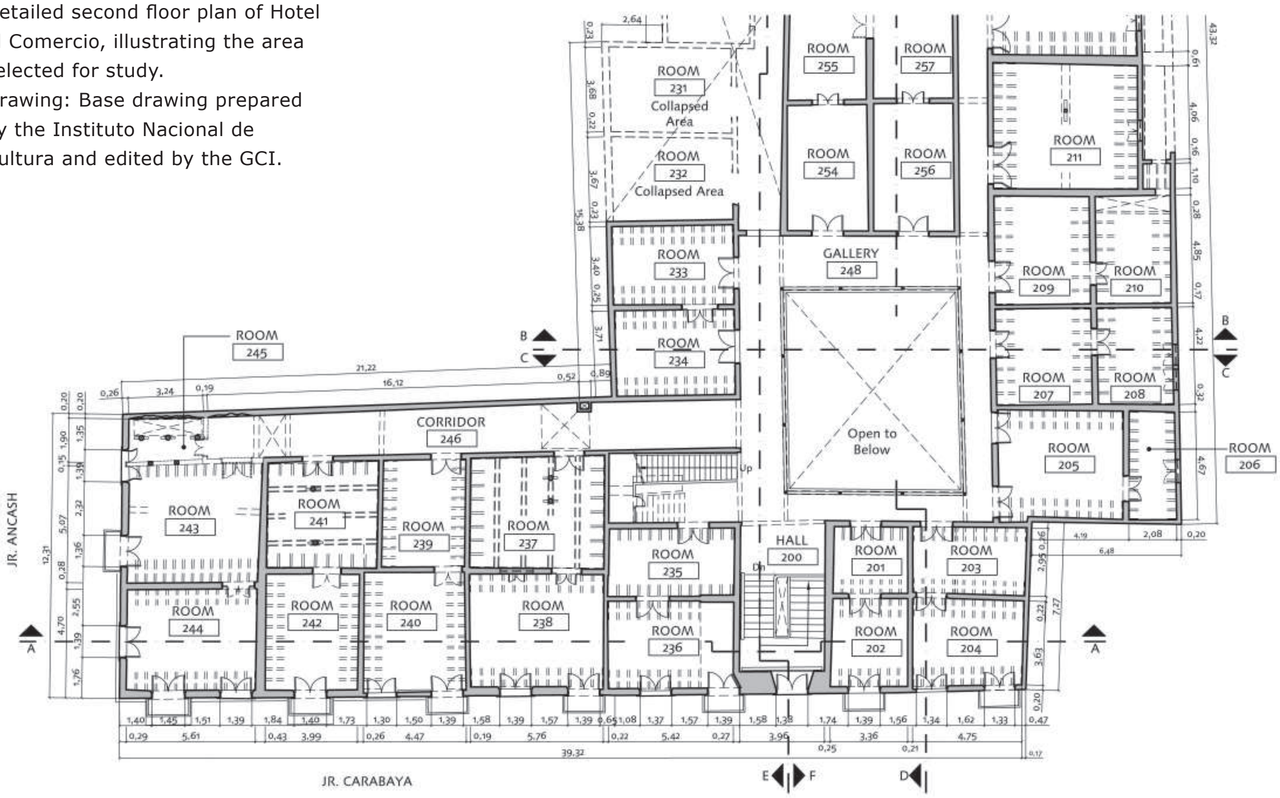


FIGURE 3.9
Detailed third floor plan of Hotel El Comercio, illustrating the area selected for study.
Drawing: Base drawing prepared by the Instituto Nacional de Cultura and edited by the GCI.

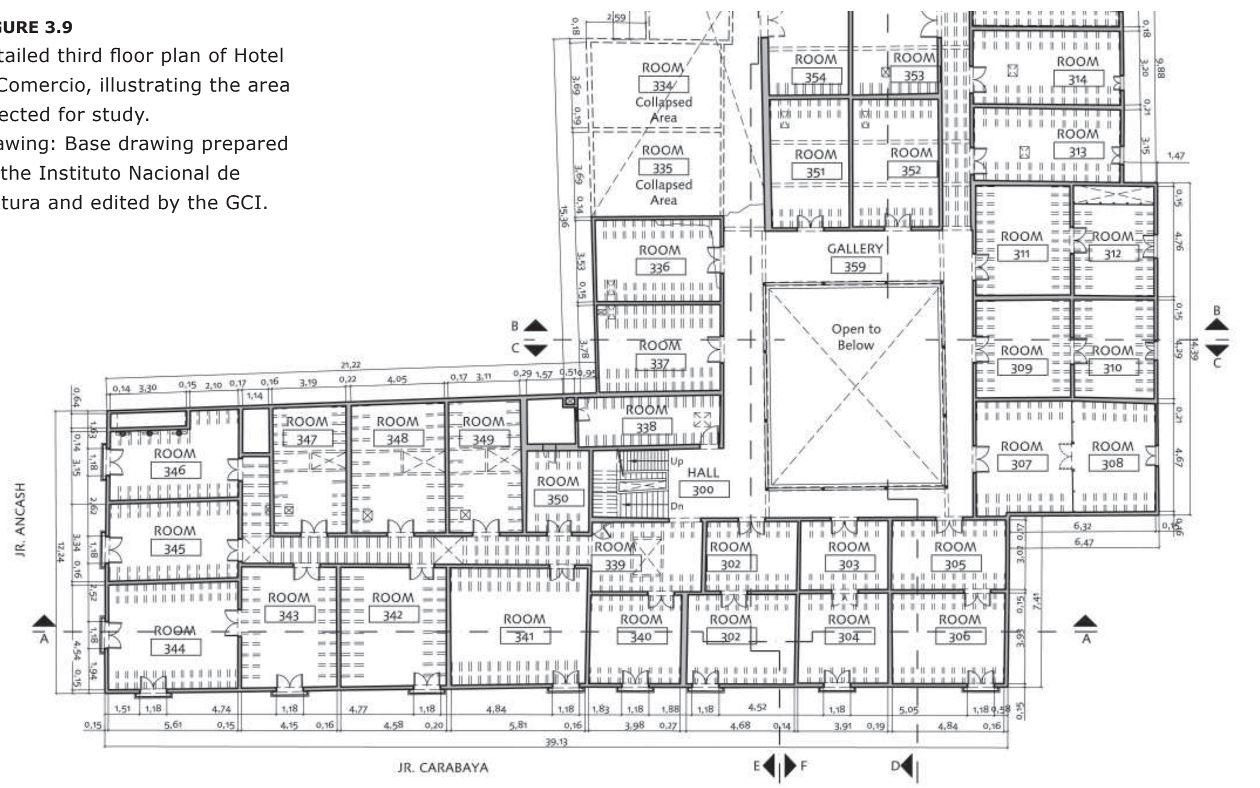


FIGURE 3.10 (LEFT)
Northwest façade of Hotel El Comercio along Jirón Carabaya, and adjacent concrete structure, 2010.
Image: Amila Ferron.

FIGURE 3.11 (RIGHT)
Collapsed bay between the two patios.
Image: Sara Lardinois.

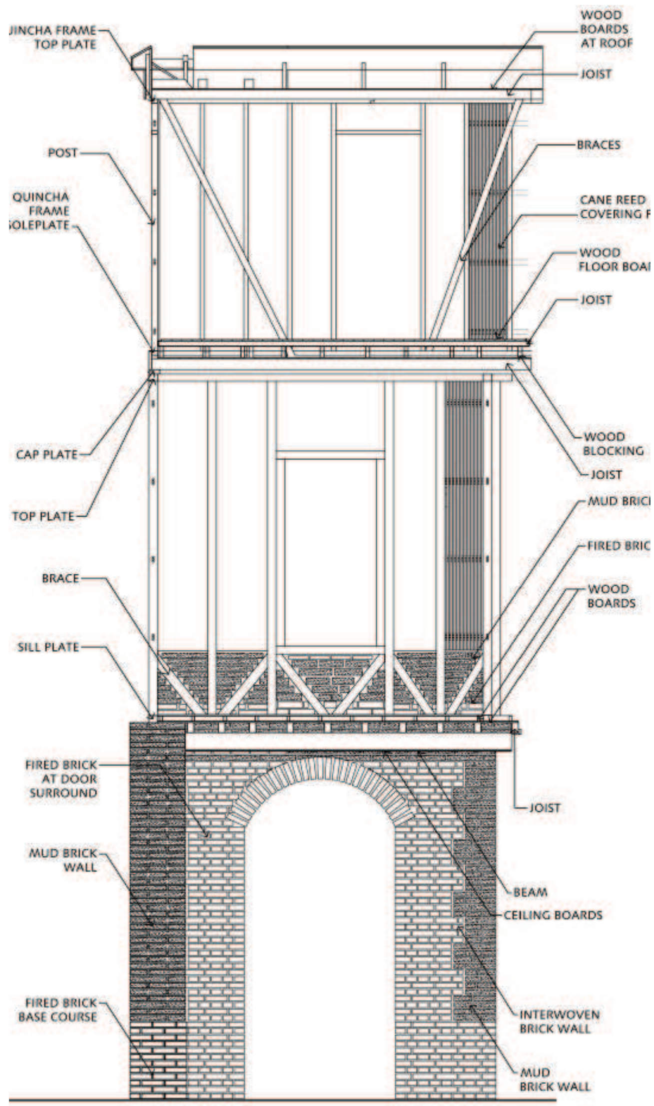


FIGURE 3.12
Elevation showing a typical construction bay at the northeast façade.
Drawing: Mirna Soto, for the GCI.

FIGURE 3.13 (ABOVE LEFT)
Northwest façade of Hotel El Comercio along Jirón Carabaya, 2010.
Image: Sara Lardinois.

FIGURE 3.14 (ABOVE RIGHT)
Entry hall, 2010.
Image: Sara Lardinois.

FIGURE 3.15 (LEFT)
Northeast façade of Hotel El Comercio along Jirón Ancash, 2010.
Image: Amila Ferron.

FIGURE 3.16 (RIGHT)
First patio, 2010.
Image: Sara Lardinois.

FIGURE 3.17
Typical third floor room (room 306), with doors providing access to the balcony.
Image: Mirna Soto, for the GCI.

3.4 Geological and Environmental Description

3.4.1 Geological description and seismic history

Hotel El Comercio (lat 12°02'41" S; long 71°01'42" W) is located in the center of Lima, where the rocky soil originates from the ejection cone of the Rimac River and extends to a depth of 50–100 m. In the vicinity of Hotel El Comercio, the rocks have a diameter between 0.20 and 0.30 m. The great depth is one of the main reasons why adobe structures in the historic center of Lima have performed well during past earthquakes.

The building is located in a level 3 seismic risk zone, as classified by the Peruvian Building Code, which is the highest level on a scale of 1 to 3.[3] As Hotel El Comercio was constructed in the middle of the nineteenth century, it has been subject to a number of seismic events throughout its history, including the 1974 earthquake near the coast of Peru, approximately 80 km to the southwest of Lima (M_W 8.1); the 1966 earthquake centered just off the coast of Callao, the port city to the west of Lima (M_W 8.1); and the 1940 Callao earthquake (M_W 8.2).[4]

3.4.2 Regional climate

The annual average temperature in Lima is 18°C, ranging from a minimum of 12°C to a maximum of 32°C. There is almost no rainfall in the area, and it is it prone to flooding when rain does occur. Termites are active in the area, which has an impact on wood elements within the structure.

3.5 Structural Description

The following sections describe the different structural materials, elements, and systems making up Hotel El Comercio (Fig. 3.18). Their current condition and any irregularities, alterations, damages, and decay observed during the construction assessment survey are described in greater detail in section 3.6 that follows the structural description.

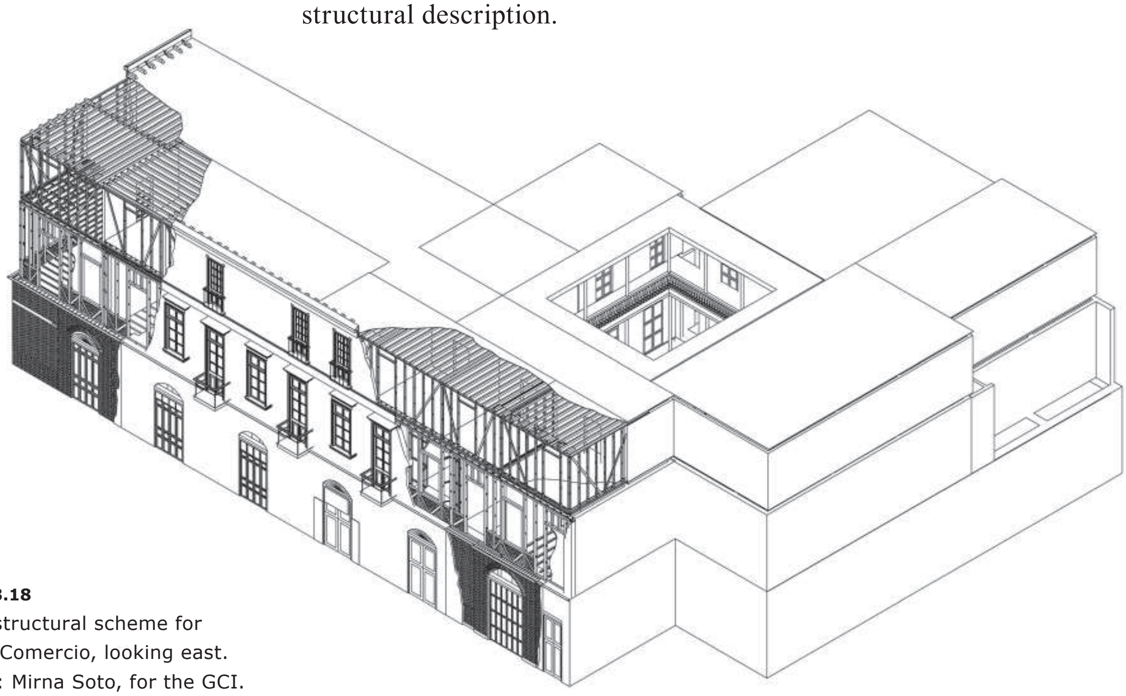


FIGURE 3.18
Overall structural scheme for Hotel El Comercio, looking east. Drawing: Mirna Soto, for the GCI.

3.5.1 Survey sectors

For the purposes of conducting the construction assessment survey, the first patio and northeast wing of Hotel El Comercio were divided into four sectors (Fig. 3.19). All four sectors appear to have been constructed at approximately the same time and exhibit similar construction materials and techniques. The sectors were selected based upon differences in their structural configuration, primarily related to the direction of the floor and roof joists. The sectors are as follows:

- **Sectors A-1, 2 and 3**: The building corner, including El Cordano bar, rooms 243 and 244 at the second floor; and rooms 344, 345 and 346 at the third floor.
- **Sectors B-1, 2 and 3**: From sector A-1, 2 and 3 to the far southwest end of the façade at Jirón Carabaya, including rooms 128 and 129 (El Cordano bar), room 130 (shoe store), stair hall 131, the entry hall 100, and room 101 at the first floor; rooms 242, 240, 238,236, 202 and 204 at the second floor; and, rooms 343, 342, 341, 340, 302, 304 and 306 at the third floor.
- **Sectors C-1, 2 and 3**: Also bordering sectors A-1, 2 and 3, including the bar bathrooms, kitchen preparation area, and the shoe store storage area at the first floor; rooms 241, 239, 237, corridor 246; rooms 307, 348, 349, 350, 338; and the stair from second to roof.
- **Sectors D-1, 2 and 3**: Bordering sectors B and C, sector D includes the kitchen pantry of El Cordano bar at the first floor; rooms 234 and 233 at the second floor; and, rooms 337 and 336 at the third floor.

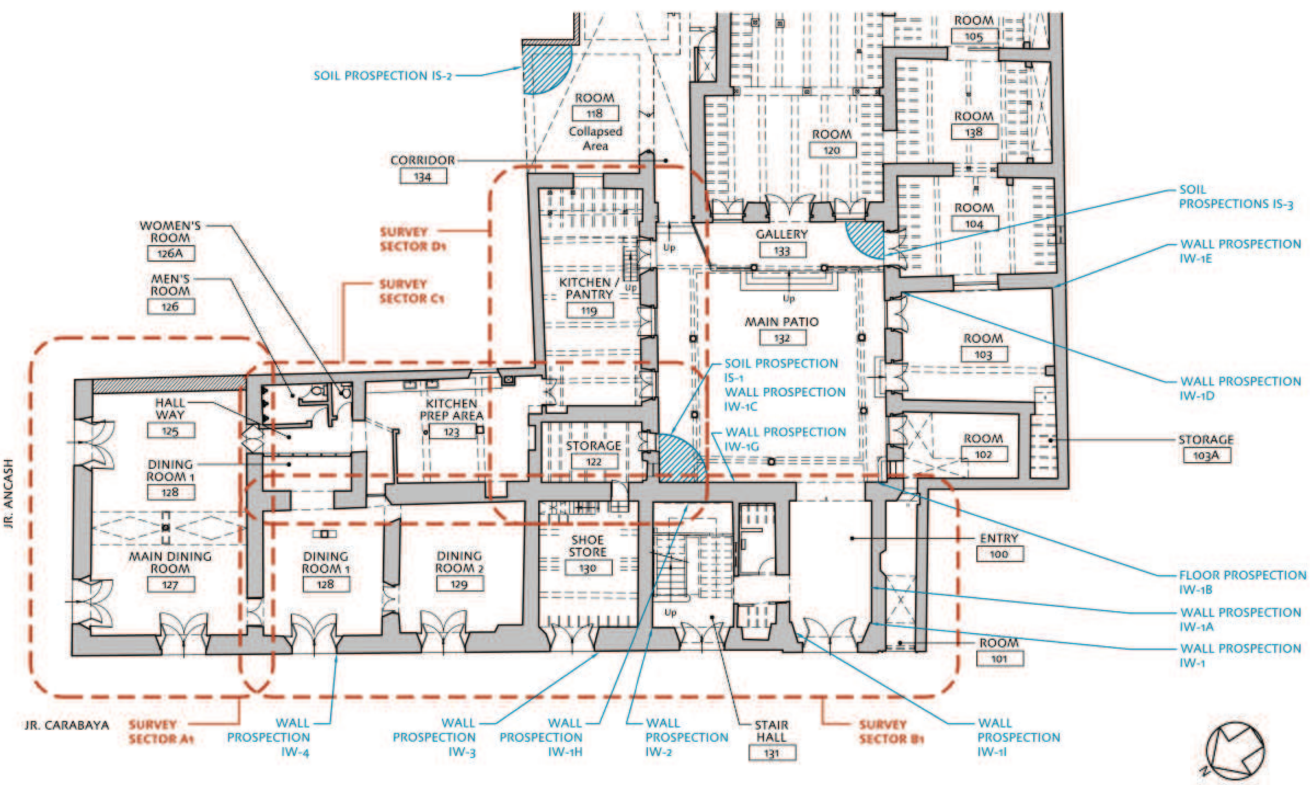
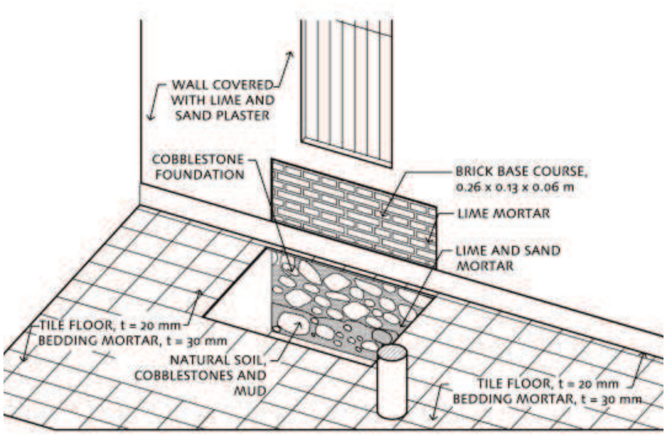


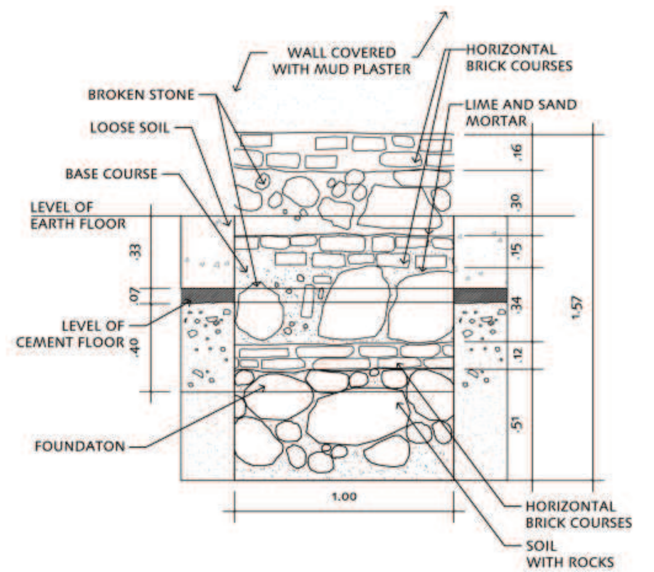
FIGURE 3.19
First floor plan, showing sector and prospection locations.
Drawing: Base drawing prepared by the Instituto Nacional de Cultura and edited by the GCI.

3.5.2 Foundations and base course

It is important to note that Hotel El Comercio has been constructed over the remains of earlier structures on the site, as it may have an impact on the way the structure performs during an earthquake. Below the tile floor of main patio 132, fired brick walls were found through prospection IS-1. These walls have a different layout than the current patio walls, indicating that they are the remains of a previous structure.

The current structure has a manmade foundation and base course. The foundation is typically constructed with rubble stone masonry set in a lime and sand mortar. The foundation hits rocky soil at an average depth of 0.50–0.80 m below the finish floor level. The base course is constructed with fired brick masonry set in a lime mortar, and it rises to an average height of 0.70–1.00 m above the finish floor level. The brick base course is incorporated into the fired brick surrounds at the door openings (see section 3.5.3.1 for further discussion). The horizontal and vertical mortar joints in the fired brick masonry have an average thickness of 25–30 mm (Figs. 3.20, 3.21). Prospection IS-2, carried out in collapsed room 118, showed a different configuration at the base course, with alternating courses of rubble stone and fired brick masonry (Figs. 3.22, 3.23).





FIGURES 3.20 (TOP) AND 3.21 (BOTTOM)
Prospection IS-1, at the northeast side of patio.
Drawing: Mirna Soto, for the GCI.

FIGURES 3.22 (TOP) AND 3.23 (BOTTOM)
Prospection IS-2, showing the foundation and base course at the northeast side of room 118 (the collapsed area).
Drawing: Mirna Soto, for the GCI.

3.5.3 Walls

3.5.3.1 Load-bearing mud brick masonry and quincha façade walls

Hotel El Comercio is constructed with mud and fired brick walls at the first story and quincha walls at the second and third stories.

Mud brick is typically used for the first floor walls. These walls have an overall height, including the base course, of 5.20 m from the finish floor level to the top of the mud brick wall. The exterior façades range in thickness from 0.85 m at the 12.80 m long northeast façade along Jirón Ancash to 0.82–1.25 m at the 39.65 m northwest façade along Jirón Carabaya. Thus, with a slenderness ratio between 4 and 6, they can be considered thick.[5] The patio façades have an average length of 10 m and a more consistent width, ranging from 0.80 to 0.90 m. Thus, they have a slenderness ratio of 6.5. At the door openings, there are fired brick surrounds that range in width from 0.42 m at prospection IW-2 to 0.98 m at prospection IW-3, extend the full depth of the wall, and interlock with the adjacent mud brick wall construction in nearly all of the surrounds (Fig. 3.24). The exterior and patio façades are covered with 30–40 mm of mud plaster and a 2 mm thick gypsum finish coat. A layer of cement plaster has been applied to the patio façades.

At the second floor, the typical quincha wall is 4.63 m high and is constructed with a wood frame made of 0.12 × 0.12 m posts (*pies derechos*); a 0.12 × 0.10 m top plate (*carrera*); and a 0.12 × 0.10 m sill plate (*viga solera*), which rests on the adobe wall below. The posts are connected to the top and sill plates by means of 0.06 m diameter by 0.10 m long dowels that go all the way through the plates. A 0.15 × 0.05 m wood cap plate (*viga de amarre*) spans across the top of the frame. The bottom 0.90 m of the frame is filled with mud bricks over two courses of fired bricks, as well as 0.11 × 0.11 m diagonal wood braces (*tornapuntas*). Over this filled base, four horizontal canes span across the posts, providing reinforcing, and vertical cane reeds are interwoven with the horizontal canes. In some panels *caña chancada*, or flattened cane reeds, are nailed over the wood posts. The panels are then covered with a 35 mm thick mud and straw layer, followed by a 25 mm thick mud layer, a 4 mm thick gypsum finish coat, and a final paint layer. The quincha posts do not align with the floor joists below (Figs. 3.25–3.29).

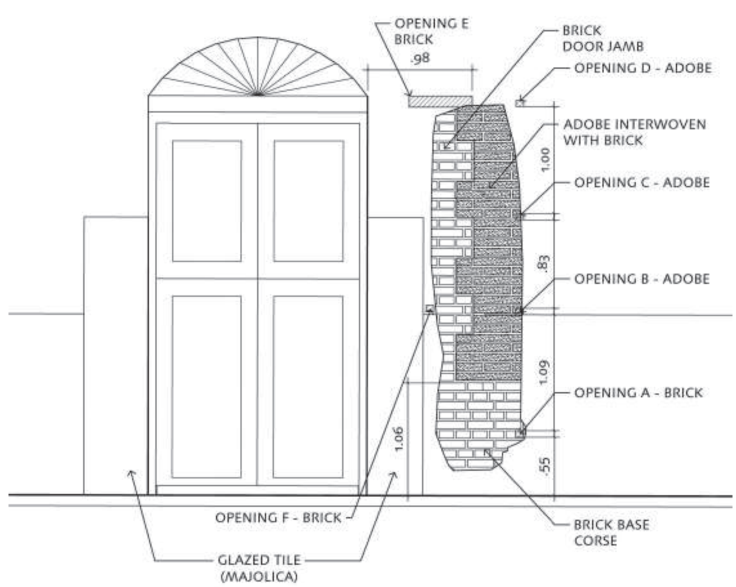


FIGURE 3.24
Prospection IW-E, showing fired brick masonry surrounds at openings in first floor mud brick walls at the northwest façade.
Drawing: Mirna Soto, for the GCI.

At the third floor, the quincha walls are of a similar construction to the second floor walls; however, they are somewhat shorter, the wood frame elements are smaller, there is not any mud brick infill at the base of the frames, and the diagonal bracing extends the full height of the frame. The third floor quincha wall frames are made of 0.08 × 0.05/0.06 m posts (*pies derechos*); a 0.08 × 0.06 m top plate (*carrera*); and a double 0.08 × 0.06 m sill plate (*viga solera*), which rests on the third floor joists below. The posts are joined to the top and sill plates with 0.04 m diameter by 0.06 m long pins or dowels. The 0.09 × 0.03 m diagonal wood bracing typically spans across two to three posts. The diagonals are connected to the top and sill plates by means of nails (Figs. 3.30, 3.31).

The wall construction is different at the main stair (stair hall 131 and hall 200) to accommodate the intermediate landing between the first and second floors. The exterior quincha walls at the second floor are constructed with two separate frames with a void in the middle. The external frame is vertically aligned with the external face of the mud brick façade below, while the interior frame is aligned with internal face of the mud brick façade. The mud brick infill in the lower portions of the frame is only used at the exterior frames and not the interior frames (Fig. 3.33).

The ratio of openings to the total vertical surface area of the façade walls is provided in Table 3.1.

Table 3.1: Ratio of openings to total vertical surface area of façades

Façade	Area of Openings/Total Vertical Surface Area of Façade
Northwest façade, along Jirón Carabaya	23.4%
Northeast façade, along Jirón Ancash	16.8%
Average of exterior façade ratios	**20.1%**
Northwest patio façade	31.06%
Northeast patio façade	16.90%
Southeast patio façade	23.10%
Southwest patio façade	28.70%
Average of all patio façade ratios	**25%**

3.5.3.2 Load-bearing mud brick masonry and quincha interior walls

Similar to the exterior walls, the interior walls are constructed with mud and fired brick at the first story and quincha at the second and third stories. The 0.60 –0.80 m thick interior mud brick walls at the first floor are somewhat thinner than the exterior walls. Thus, the slenderness ratio for these walls ranges from 6.5 to 8.6, which falls somewhere between the relatively thick and thin classifications. The only truly slender walls are at the El Cordano kitchen preparation area and pantry (rooms 123 and 119), which appear to be shared walls with the adjacent casona. These walls are 0.43–0.48 m thick. All of the interior mud brick walls appear to have interlocking corners. The interior quincha walls at the second and third floors are similar in design to the exterior walls; however, there is not a wood cap plate at the top of the third floor frames and there does not appear to be any diagonal bracing at the second floor frames. At the second floor, the sill plate at the base of the frame rests directly on the floor joists—not the adobe walls. Where the interior walls intersect with the exterior walls, the frames are connected with half-lap joints at the top and sill plates (Fig. 3.32). The longest quincha wall occurs at the second floor corridor 246—it is 27 m long and separates El Comercio from the adjacent casona.

FIGURE 3.25 (ABOVE)
Typical quincha wall at the second floor, showing the mud and fired brick infill at the bottom of the frame (prospection IIS-2). The horizontal canes at the right have been used to infill an earlier door opening.
Image: Mirna Soto, for the GCI.

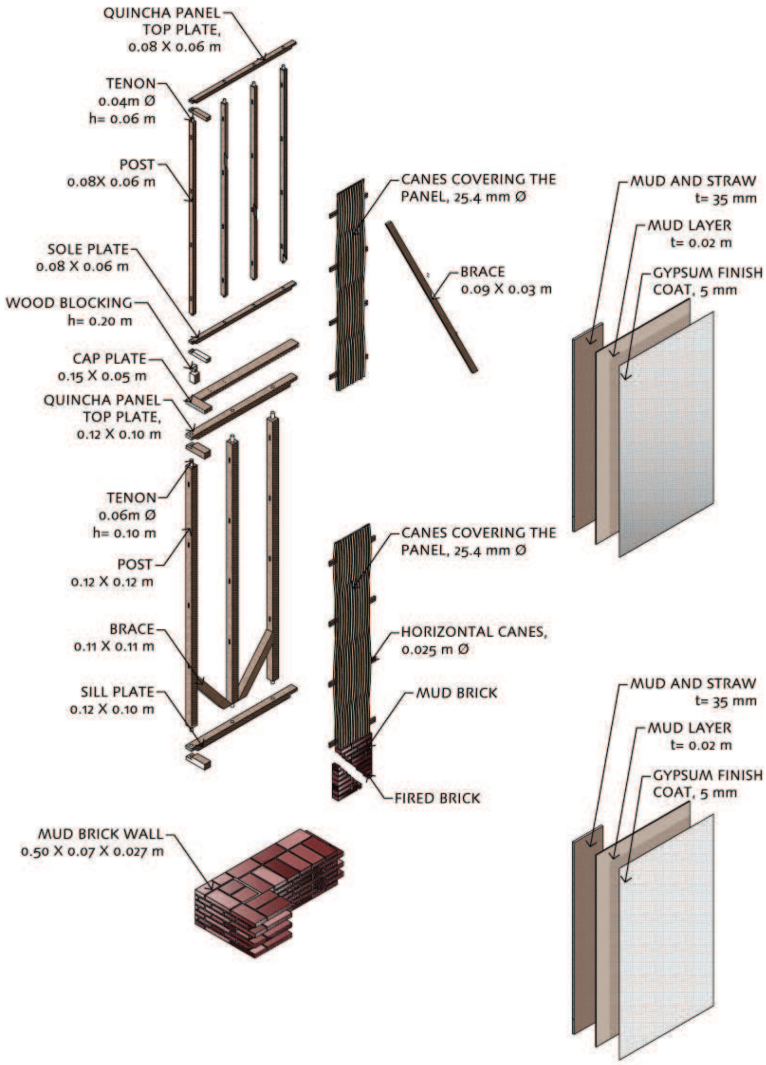
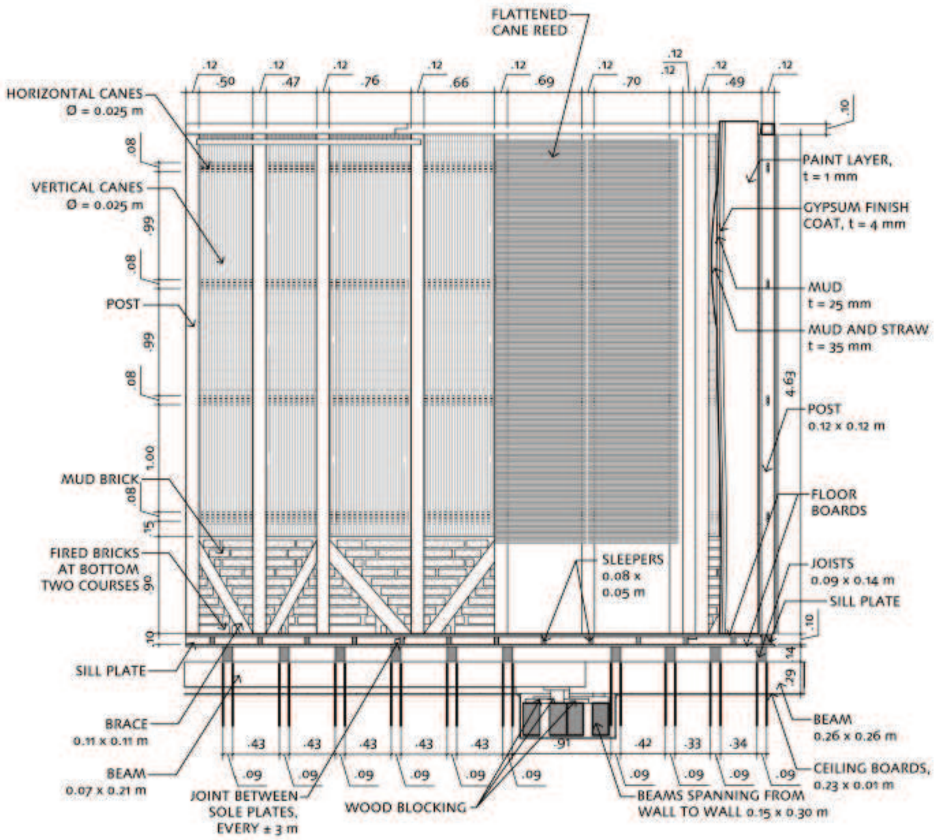


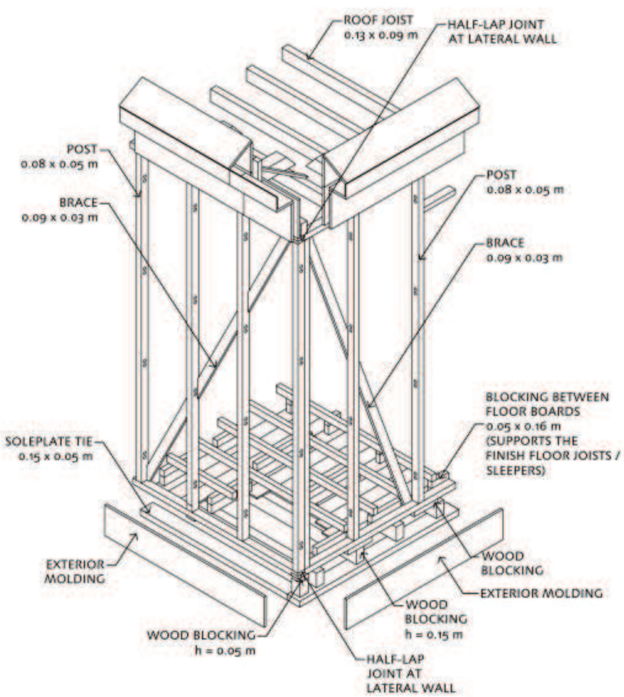
FIGURE 3.26 (RIGHT)
Exploded isometric view, showing the quincha wall construction at the second and third floors of the northeast façade.
Rendering: Jabdiel Zapata, for the GCI.

FIGURE 3.27 (NEAR RIGHT)
Detail view showing the connection of vertical quincha post and horizontal canes.
Image: Claudia Cancino

FIGURE 3.28 (FAR RIGHT)
Prospection IIIS-1, showing the quincha posts and floor joists do not align.
Drawing: Mirna Soto for the GCI.

FIGURE 3.29
Prospection IIS-2, elevation of typical second floor quincha wall. Drawing: Mirna Soto for the GCI.





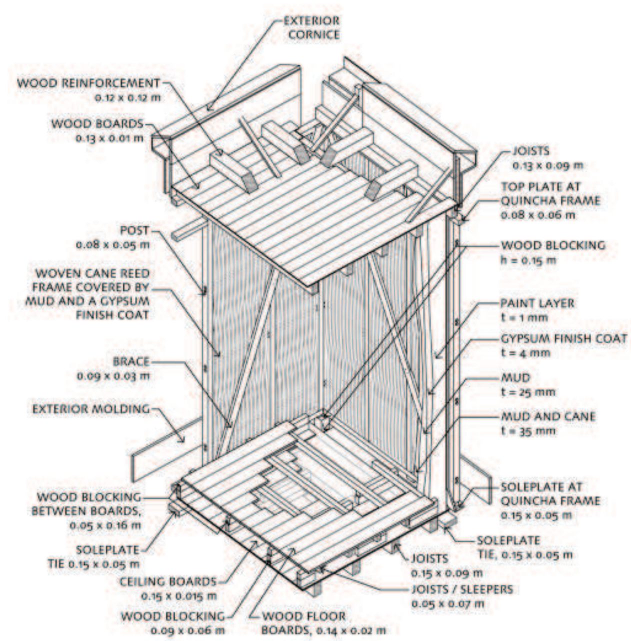
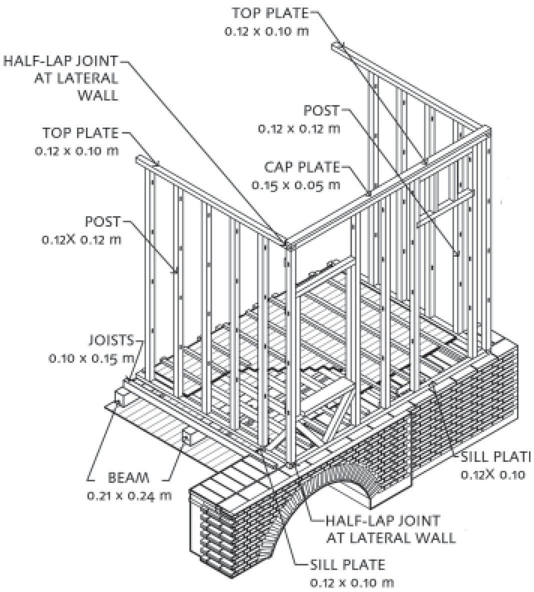


FIGURE 3.30
Prospection IIIS-1, third floor quincha wall frame. Drawing: Mirna Soto for the GCI.

FIGURE 3.31
Prospection IIIS-1, third floor quincha wall frame and cover. Drawing: Mirna Soto for the GCI.



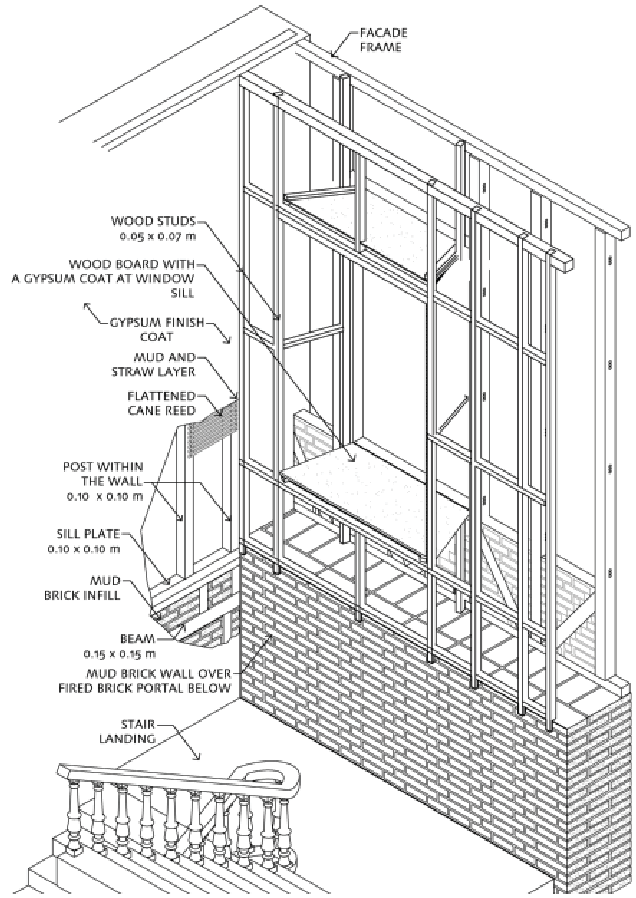


FIGURE 3.32 (ABOVE)
Prospection IIW-2, showing the framing connection between the front façade and lateral walls.
Drawing: Mirna Soto for the GCI.

FIGURE 3.33 (RIGHT)
Prospection IW-1F, illustrating the double quincha frame construction at stair hall 131.
Drawing: Mirna Soto for the GCI.

3.5.4 Floors

The floors at Hotel El Comercio are constructed with tongue-and-groove wood floor boards over wood sleepers over wood floor boards over wood joists. Wood boards are typically attached to the underside of the floor structure to provide a finish ceiling for the room below (Figs. 3.34–3.36). The second and third floors are of a similar construction; however, at the second floor the sill plate at the bottom of the quincha frame and the floor joists are embedded in the top of the first floor mud bricks walls.

During the survey and investigations, particular attention was given to the floor configurations at the corner of the building above El Cordano bar, including second floor rooms 243 and 244 and third floor room 344, through prospections IIW-1, IIW-2, IIS-1, and IIIS-1. This area appears to have undergone a number of alterations, including the removal of a first floor wall and replacement with a column and four closely-spaced beams or girders (see section 3.6.4 for further description). The second floor construction (as described from bottom to top) consists of a false wood ceiling nailed to wood beams running parallel to the northeast façade along Jirón Ancash. These beams do not span the full length of the bar below, rather shorter lengths overlap one another by a significant amount above the column and girders. This beam configuration may be an alteration related to the removal of the adobe wall below. Over the beams, joists run in the opposite direction. The joist ends are pocketed into the mud brick walls along Jirón Ancash (Figs. 3.37–3.40). Over the floor joists are wood boards, followed by wood sleepers running in the same direction as the joists and nailed to the joists, and finally tongue-and-groove wood boards which serve as the finish floor. The space between the sleepers is filled with a mud and lime-based mixture. The third story floor construction is similar, but without overlapping beam ends. It is important to mention that the quincha partition wall between rooms 243 and 244 does not align with the floor beams which would have originally been embedded at the top of the now removed mud brick wall below. This suggests inadequate construction or later alteration of the second floor walls.

A slightly different configuration was observed at the floor structure in rooms 204 and 306 through prospections IIW-3 and IIIS-2 (Figs. 3.41, 3.43). In this area, the wood beams run parallel to the long façade at Jirón Carabaya with perpendicular joists above. The second floor joist ends are pocketed into the mud brick walls, and the third floor joist ends rest on a sill plate tie over the second floor quincha frames. Over the joists there is another layer of wood framing, wood boards, and sleepers with a mud and lime-based soil infill between them. As with the earlier prospection, the sleepers run in the same direction as the joists. Finally, there is a tongue-and-groove wood plank finish floor.

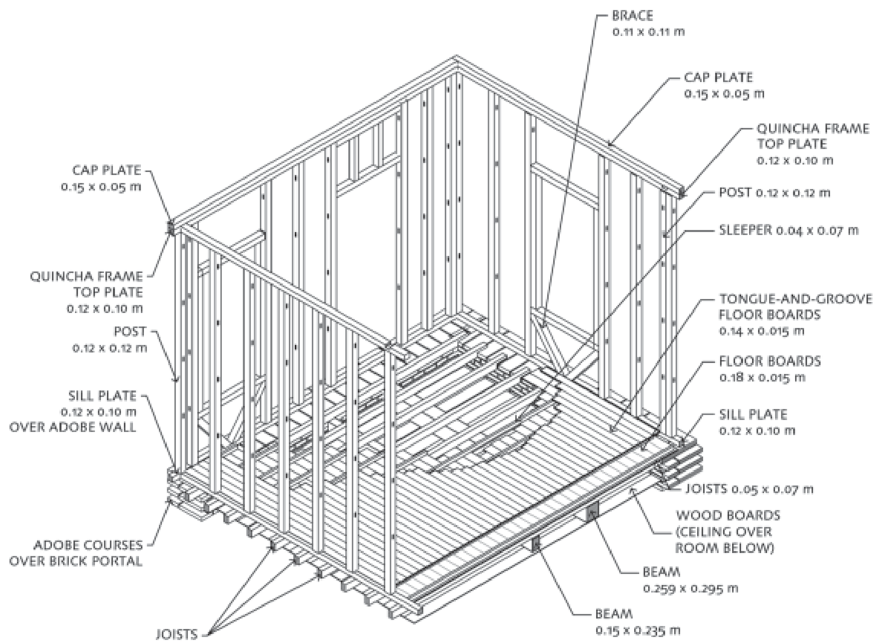


FIGURE 3.34
Prospection IIW-1, showing the second floor construction in the north corner of the building.
Drawing: Mirna Soto, for the GCI.

FIGURE 3.35 (NEAR RIGHT)
Prospection IIS-3, showing the third floor construction at the patio galleries.
Image: Sara Lardinois.

FIGURE 3.36 (FAR RIGHT)
Typical finish ceiling at the underside of the floor construction.
Image: Amila Ferron.

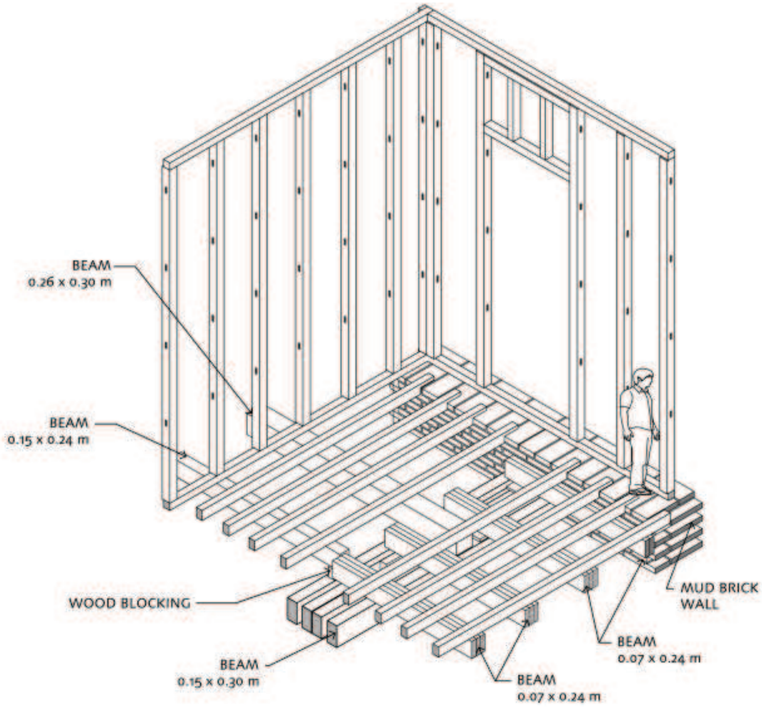


FIGURE 3.37 (TOP)
Prospections IIS-1 (room 243), showing the second floor construction above El Cordano bar with overlapping beams.
Drawing: Mirna Soto, for the GCI.

FIGURE 3.38 (BOTTOM)
Prospection IIS-1, showing the joist ends pocketed into the top of the first floor mud brick wall at the northeast façade.
Image: Sara Lardinois.

FIGURES 3.39 AND 3.40 (TOP AND BOTTOM)
Prospection IIS-1, showing the overlapping beam ends, which presumably relate to the removal of a wall in the bar below.
Image: Mirna Soto, for the GCI.

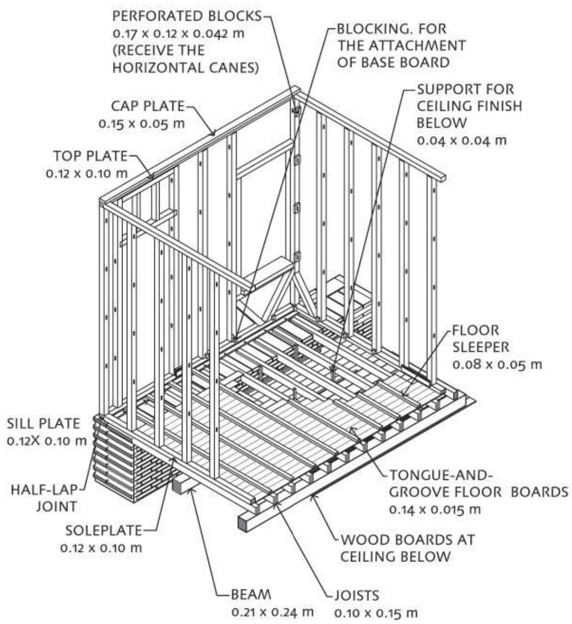


FIGURE 3.41
Prospection IIW-3, showing the second floor construction at the northwest façade (room 204).
Drawing: Mirna Soto, for the GCI.

FIGURE 3.42
Prospection IVR-1, showing the roof construction at the northwest façade.
Image: Mirna Soto, for the GCI.

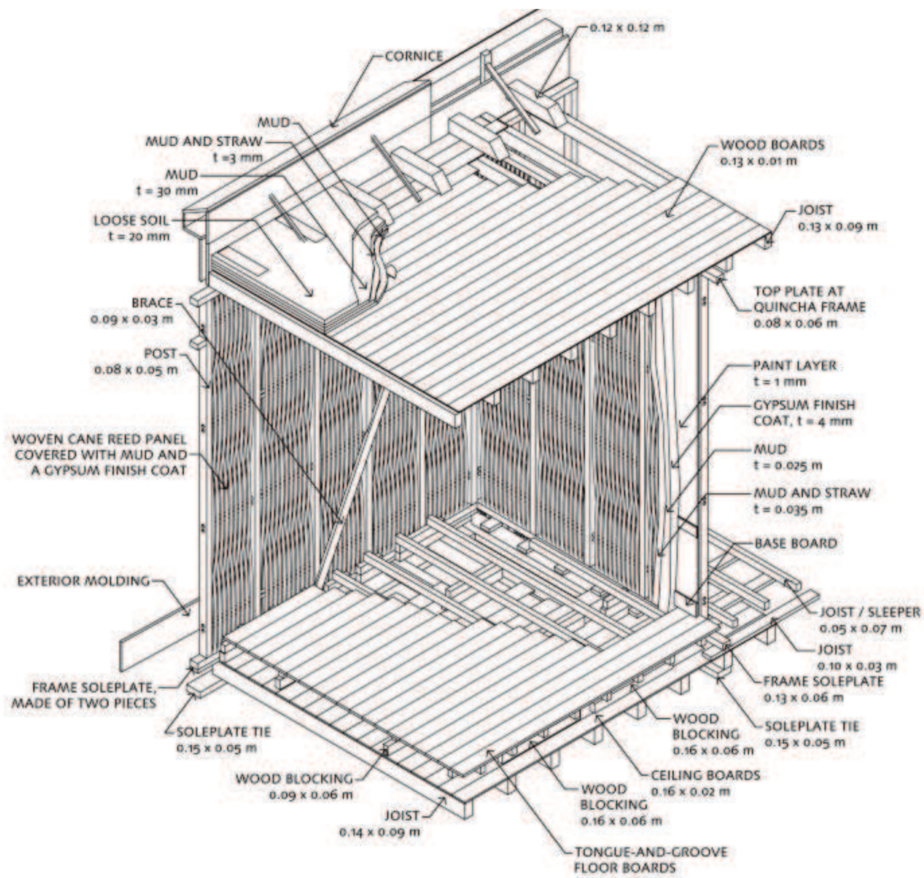


FIGURE 3.43
Prospections IIIS-2 and IVR-1, showing the third floor and roof construction at the northwest façade (room 306).
Drawing: Mirna Soto, for the GCI.

3.5.5 Roof

The roof framing system is similar to the floor framing. One notable difference is the lack of a finished ceiling at the third floor which leaves the roof joists exposed. The top of the joists are covered with a layer of wood boards, followed by a 30 mm layer of mud, a 30 mm layer of mud with straw, a second 30 mm layer of mud, and a 20 mm layer of loose soil (Fig. 3.42).

3.6 Irregularities, Alterations, Damages, and Decay

The following sections describe the current condition of the different structural materials, elements, and systems making up Hotel El Comercio and any irregularities, alterations, damages, and decay that were visually observed during the construction assessment survey.

3.6.1 Foundations and base course

The foundation and base course appear to be in fair condition overall, and the masonry is generally cohesive. In those areas that were opened up for the structural prospections, humidity was observed in the soil. This humidity is likely the result of improper site drainage in the patios of Hotel El Comercio and the adjacent casona. As a result of this humidity, disaggregation was noticeable at the soil layer above the rocky soil, particularly in the collapsed area of room 118.

3.6.2 Walls

The following irregularities in the wall construction were observed during the construction assessment survey:

- The mud brick and quincha walls do no align vertically between the floors, thus creating some stress and deformation at the floor and ceiling structure, particularly between the first and second floors of sector A and the second and third floors of sectors B and C.
- The quincha frames are only connected to the floor and roof joists by a cap or top plate and sill plates and, thus, are not properly interlocked.

The structural configuration of the walls been modified through recent alterations, including:

- **Sector A**: The southeast wall of the main dining room at El Cordano bar (rooms 127 and 128) has been reconstructed. The bar owners indicated that it was rebuilt with mud bricks; however, this was not verified through any investigative work by the project team.
- **Sectors A and B**: New openings have been cut in the adobe walls to connect the main dining area with auxiliary dining rooms 128 and 129, in order to improve the functionality of El Cordano bar.
- **Sector C**: New partitions have been added to create bathrooms adjacent to the El Cordano dining rooms.

Both of the street façades show some signs of cracking, particularly at the second floor spandrels. There is diagonal and vertical structural cracking at the corner of the first floor at the northeast end of the long northwest façade (Jirón Carabaya). The northeast façade along Jirón Ancash also shows significant cracking in the second floor at the southeast end near the adjacent casona and at the third floor spandrels (Figs. 3.44, 3.45). The patio façades are in fair condition but also show signs of cracking at the third level spandrels and also at the corners of the openings (Figs. 3.46, 3.47).

Humidity was observed in the base of the mud brick walls, which could jeopardize their structural performance, particularly during a seismic event. The cement plaster finish at the patio façades prevents any dampness from migrating out of the wall, which has likely led to the interior deterioration of the mud bricks. This humidity may in part be related to changes in use and the insertion of plumbing lines in the kitchen and bathrooms. If not properly installed, plumbing may introduce water in the base of the walls. For example, humidity was observed in the base of the walls in sector D, where the bar kitchen pantry is located.

The second floor quincha walls are in poor condition, particularly in sector A and at the long wall in sector B that borders the adjacent casona. Cracks and plaster detachment were observed in many walls, typically in areas corresponding to posts within the walls and at openings. The detachment of the painted mud plaster at the quincha frame bases and posts is exposing the internal wood structure to deterioration (Figs. 3.48–3.51). The presence of termites in nearly all wood elements suggests that the panel structure connections may not perform well during future seismic events. The deterioration and previously-mentioned lack of proper connections / interlocking makes it difficult for the quincha frames to restrain lateral or vertical movements.

The second floor walls in sector B and D are in better condition, but still exhibit cracking and plaster detachment at their bases and around openings.

The quincha walls at the third floor are also in better condition with the exception of sector A, where the walls are structurally exposed to detrimental environmental conditions such as pigeon and buzzard nests and excrement. The damage to the quincha walls seems to be superficial, although it is difficult to determine the level of deterioration at the quincha structural elements and connections.

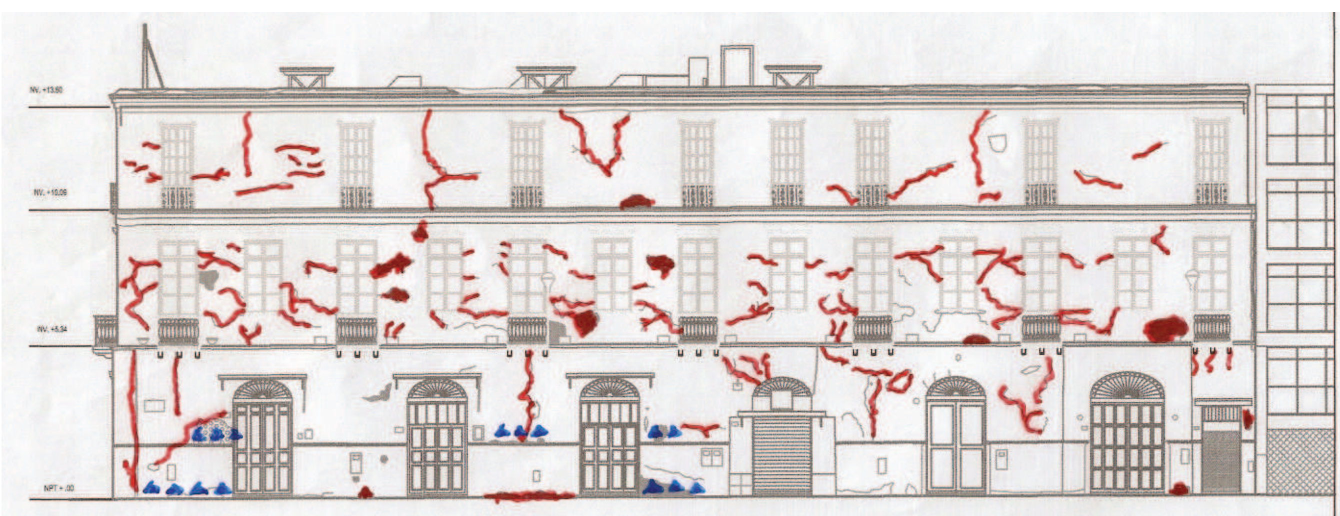


FIGURE 3.44
Northwest façade, graphic condition survey indicating observed cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

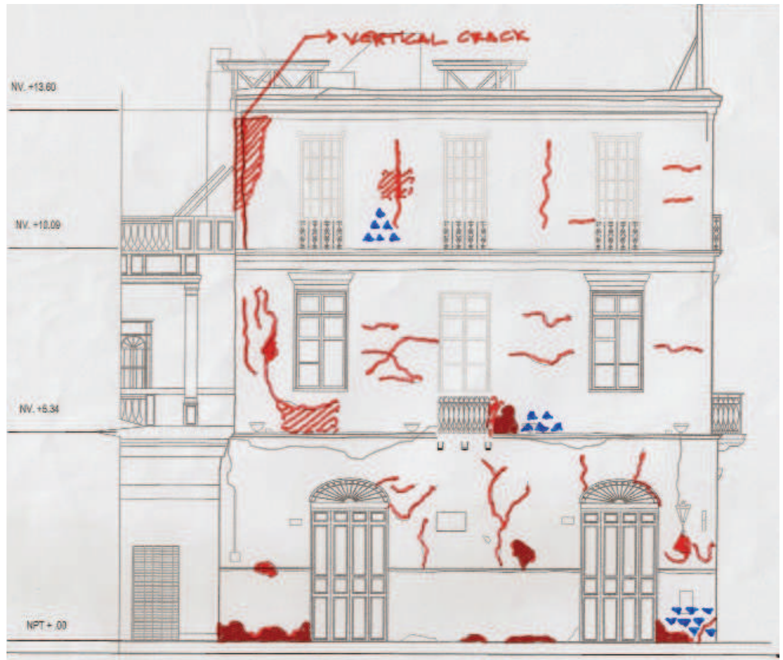


FIGURE 3.45
Northeast façade, graphic condition survey indicating observed-cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

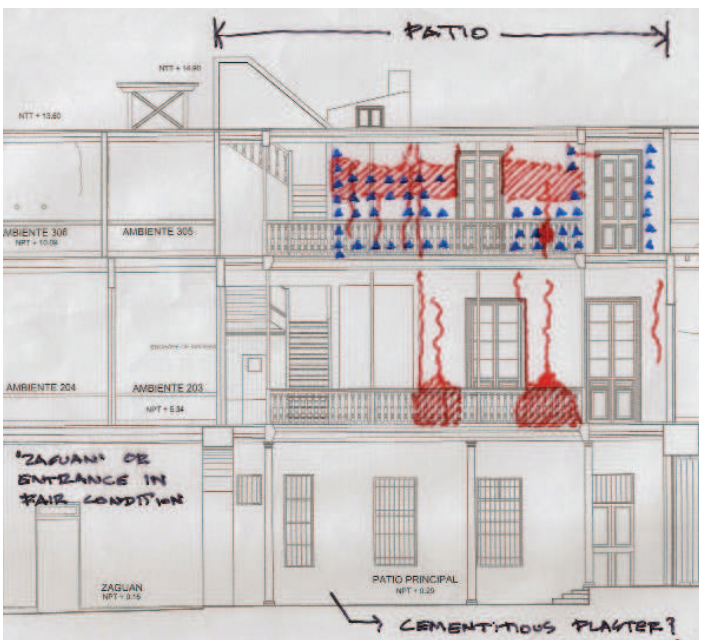


FIGURE 3.46
Northeast patio façade, graphic condition survey indicating observed cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

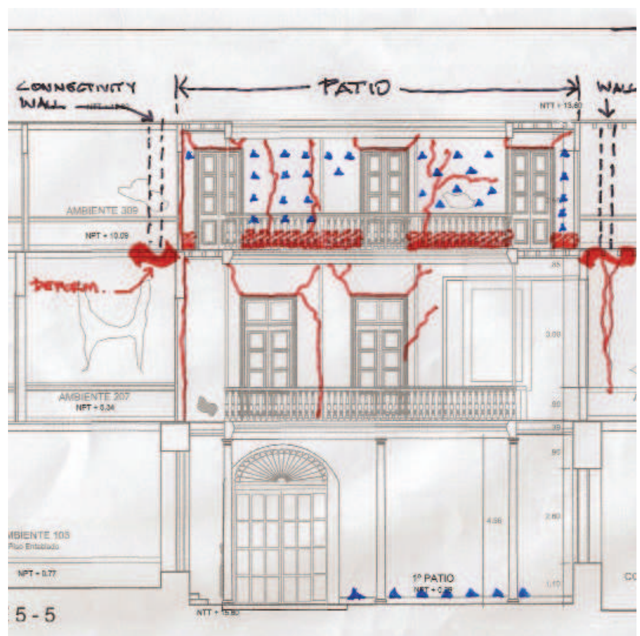


FIGURE 3.47
Northwest patio façade, graphic condition survey indicating observed cracks and areas of plaster loss in red and humidity in blue.
Drawing: Claudia Cancino.

FIGURE 3.48
Typical plaster detachment at quincha wall bases and posts.
Image: Claudia Cancino.

FIGURE 3.49
Typical crack pattern at openings in quincha walls.
Image: Claudia Cancino.

FIGURE 3.50
Typical crack pattern, corresponding to the quincha post locations.
Image: Claudia Cancino.

FIGURE 3.51
Vertical cracks corresponding to quincha post locations, southeast wall of corridor 246, sector C.
Image: Amila Ferron.

3.6.3 Floors

The floor structures are in fair condition in most sectors; however, the area above rooms 125 and 127 in sector A (El Cordano bar) has suffered significant damages. The floor beam ends are weakly embedded in the tops of the mud brick load-bearing walls and do not properly distribute the vertical forces. The presence of soil between sleepers in some areas adds load to the floor structure and makes the diaphragm stiffer.

The installation of heavy machinery in the building in the 1980s damaged the floor structure. The damage is most severe at the southwest area of second and third floors, adjacent to the neighboring concrete building, and includes severe deformation of the floors. Shoring has been installed to avoid collapse of this area, however, it remains in a precarious state.

FIGURE 3.52
Northwest wall of room 243.
Image: Claudia Cancino.

3.6.4 System-wide irregularities, alterations, damages, and decay

The structural configuration of the building has been modified through recent alterations, including:

- **Sector A**: It is likely that the wall separating sectors B and C at the first floor probably originally to the northeast façade. It has since been removed to create a larger dining room for El Cordano bar and a metal column has been installed to support the floor structure above. The overlapping wood beams at the second floor, above the El Cordano main dining room, appear to be alterations made to accommodate this transformation. Of particular concern is the northwest wall of room 243 over the bar dining room. With the removal of the mud brick wall, the second floor quincha wall frame was left hanging from the third floor quincha frame and is not bearing on the floor, thus creating a total disconnection between two floors (Fig. 3.52).
- **Sector B**: The original configuration of the entry hall and staircase is unclear.
- **Sector B**: At the first floor shoe store (room 130), a storage mezzanine was constructed with metal beams running parallel to the northwest façade.
- **Sector B**: The kitchen preparation area contains two wooden columns supporting two wood beams. It is unclear if this is part of the original design or a later alteration.
- **Sector D**: The mezzanine in the kitchen pantry area was likely added by the bar owners.
- **Sector D**: The area adjacent at the far southeast end of the sectors D-1, 2 and 3 has collapsed.

3.7 Preliminary Findings

The following preliminary findings on the structural behavior of Hotel El Comercio are based upon qualitative methods, including historical research and direct observations made by the investigative team during surveys carried out in 2010. The investigative team utilized their past experience with historic earthen construction to interpret the data collected through research and observation and develop preliminary ideas on the possible structural behavior of the building. These preliminary findings will be explored further in the next phases of the project through quantitative methods, including static and dynamic testing and numerical modeling analyses. Following the quantitative testing and analyses, the preliminary findings will be revised as necessary and expanded upon to provide a complete diagnosis and safety evaluation.

The preliminary findings are:

- Hotel El Comercio is a highly complex structure due to the multiple modifications of its floor structures and other modifications related to changes in use. However, this situation is typical for many historic buildings in Lima and other Spanish colonial cities in South America. Despite the modifications, the site is in fair condition overall but with areas in serious danger of collapse.
- The structure of sector A is in most danger, as it appears that an original internal mud brick wall that originally supported the quincha walls above has been replaced with a column. Furthermore, the placement and overlapping of the wood floor beams above does not work and only adds load to the structure above. At that same sector, the conditions of the quincha partition walls at the second floor are poor and may lead to the collapse of the third floor area above the bar. Finally, the fact that this sector is located at the corner makes the building even more vulnerable to collapse during an earthquake.
- The presence of humidity at the base of the mud brick walls is a condition that jeopardizes the stability of the walls and may also have a negative effect in the event of an earthquake.
- The ongoing exposure of the quincha structural elements to the environment and termite damage creates a severe threat to the frames.
- The insufficient interlocking between quincha wall frames may reduce the structural performance of the building in future earthquakes. Without proper connections, the wall frames are unable to restrain lateral or vertical movements without collapsing. The collapse of the quincha walls may lead to collapse of the floor and roof structure above.
- The embedment of the wood sill plates at the bottom of the second floor quincha wall frames into the top of the mud brick walls below does not appear to be sufficient enough to allow the floor structure to work as a proper diaphragm.

Notes

1 The information in the following section is summarized from a 2010 report, "Hotel Comercio," on the history and significance of Hotel El Comercio prepared by María del Carmen Corrales Pérez of the former Instituto Nacional de Cultura in Peru.

2 As quoted in Corrales Pérez 2010, 9.

3 Seismic zones are defined in Capítulo II, Parámetros de Sitio of the *Norma Técnica de Edificación E.030: Diseño Sismorresistente*, which is available online at http://www.igp.gob.pe/web_page/images/documents/ltorres/norma_tecnica_edificaciones.pdf.

4 Information on earthquake dates, epicenter locations, and moment magnitudes (Mw) is summarized from United States Geological Survey (USGS), Historic World Earthquakes, Peru, http://earthquake.usgs.gov/earthquakes/world/historical_country.php#peru.

5 Criteria for determining slenderness ratios are based upon those provided in Tolles, Kimbro, Webster, and Ginell 2000.