PENN PRAXIS/THE ARCHITECTURAL CONSERVATION LABORATORY

GEORGE NAKASHIMA ARTS BUILDING AND CLOISTER CONSERVATION & MANAGEMENT PLAN



GEORGE NAKASHIMA
ARTS BUILDING AND CLOISTER
CONSERVATION & MANAGEMENT PLAN

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Left:
The Arts Building. View from the north.
William Whitaker. January 2017

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PART I

Acknowledgements

Through its Keeping It Modern initiative, The Getty Foundation has provided the financial support that has made possible the continuation of a new partnership between the George Nakashima Foundation for Peace, George Nakashima Woodworkers and the University of Pennsylvania's School of Design to study in depth a less well known and a more craft-oriented tradition of modern architecture in the United States. The Getty's past and ongoing commitment to the preservation of modern heritage helped us to catalyze the efforts undertaken during the various phases of the planning project.

We are indebted to Mira Nakashima, Kevin Nakashima, and Jonathan Yarnall. Their contributions have been essential to understanding the values of the place, unravel the complexities of George Nakashima's designs and philosophical approach, and untangle the many connections embedded in the Arts Building and Cloister. Thanks are extended to Soomi Amagasu, John Lutz, and Alexis Rosa Caldero, as well as other members of George Nakashima Woodworker who have welcomed and hosted us during the various visits to the site and contributed their insights in the preparation of this Conservation and Management Plan (CMP).

This CMP project has made possible the engagement of external consultants and graduate students in a complex research collaboration We would like to convey our thanks to the consultants for the excellent work done: Ron Anthony, David Biggs, Michael C. Henry, and Nicholas Pevzner. We acknowledge the collaboration of Professor Joelle Wickens from the Winterthur/University of Delaware Arts Conservation Program (WUDPAC), Professor Petr Kabele, from the Czech Technical University/Advanced Masters in Structural Analysis of Monuments and Historical Constructions (CTU/SAHC), as well as the contributions of graduate students Andi Troci (CTU/SAHC), Leah Bright (WUDPAC), Shin-Yi Kwan and Jancki A. Vyas, from the Master of Environmental Building Design (MEDB), and Araba Prah and Nicole Mariel Declet from the Graduate Program in Historic Preservation, both at the University of Pennsylvania.

Finally, we are grateful to the staff from the Singh Center for Nanotechnology at the University of Pennsylvania for their assistance in the analysis of materials, as well as to the archivists from the James A. Michener Art Museum Archives for their support on the historical research.

Site: George Nakashima Woodworker Complex. 40°20’25.0”N, 74°57’20.2”W



Introduction

Unusual in its use of time honored Pennsylvania and Japanese craft techniques and outstanding in the ingenuity of a thoroughly modern hyperbolic paraboloid plywood roof, the Arts Building and Cloister (1963-67), designed by architect and woodworker George Nakashima (1905-90), is one of over a dozen designs built on his property in New Hope, Pennsylvania. Christened as Minguren Museum, the building was intended as a space to display artwork by Ben Shahn (1898-69) and other artists, Nakashima's own furniture, as well as a place for artistic exchange and contemplation.

Of paramount significance is the fact that the Arts Building and Cloister embodies Nakashima's constant search for understanding beauty, art, and spiritual transcendence, as no other building at the property does. His ‘private museum’ became a place to nurture spiritual and intercultural dialogue, but also served family and business needs. Although minor changes have occured within a tradition of spontaneous response to deterioration, the compound exhibits a high degree of originality and integrity. This integrity is also perceptible through its continued original uses.

The complex relationship between living tradition and historic site, as the property transitions and continues to serve the making of furniture, has compelled the Foundation to lead the preservation of the building and the collection for the public benefit while continuing to serve George Nakashima’s vision for peace. In exploring the cultural significance of the builiding and setting out policy as well as guidance, the Conservation and Management Plan (CMP) aims to help the Foundation in its new role as steward.

Some policies and recommendations might be seen as a long-term objective, others respond to immediate need, and a few are meant to be applied on a routine basis and are critical to preventive conservation. Regardless of their varied nature, it is fundamental that policies and recommendations are reviewed periodically and are subject to confirmation, modification, or deletion through thoughtful consideration.

The CMP is divided into three parts. Part I provides documentary, graphic, and physical information about the Arts Building and Cloister’s contextual history and condition, including the immediate surrounding landscape and the collections. Part II contains the policies and guidance based on the research findings as well as vulnerabilities to the cultural significance. Lastly, Part III comprises the attachments to the work done by the consultants and members of the Architectural Conservation Laboratory, including the contributions of graduate students and related institutions.

The three parts are designed to be used independently, although references to each other throughout the documents are inevitable. Each volume is divided into sections, which are a reflection of the sequence in the preparation of this CMP.

Part I.

Chapter 1 contains a site development chronology based on the information

provided by the 2013 National Historic Landmark nomination, the depreciation accounting books, and the Nakashima Property List of Buildings (September 12, 1990). In addition, the section provides a construction chronology as well as an account of the alterations to the building after its completion.

Chapter 2, presents a summary of the historical research based on published and unpublished sources of a different nature: articles in journals, scholarly publications, account books, hand drawings, letters, and photographs. With the aim to understand the attributes which make this place of value, this section provides an analysis of the education and earlier influences on George Nakashima through 1941, the design and construction of the building, the rise of the hyperbolic paraboloids in the US, as well as Nakashima's design ethos. The section closes examining the many artistic and spiritual connections recognizable through both the building and the collections.

Chapter 3 focuses on understanding the setting, which is based on Nakashima's consideration of creating integrated environments. In addition to the importance of the landscape features carefully selected by Nakashima, this section highlights the importance of the views from the interior and exterior of the building towards the south and the west. Although the integrity of the landscape is high, the clearing on the south property, the modification of the pathway, and the minor loss of features divert the role of the landscape from its original intent.

Chapter 4 explores the understanding of the architectural and technological characteristics of the building and provides an account of the existent conditions, a section of which is dedicated to the characterization and assessment of the wooden elements. The Arts Building and Cloister was Nakashima's last interpretation of modernist structural theory through the combination of Japanese and local vernacular craft techniques. Consequently, the hyperbolic paraboloid roof gets special attention. Observations on the building envelope, the environment and the collections are included as well.

Part II.

Chapter 1 explains the concept of National Historic Landmark and clarifies professional terms used throughout the document.

Chapter 2 expounds the main values that make the Arts Building and Cloister culturally significant as an integrated environment by George Nakashima and a place largely legible through the setting, the collections and the Foundation mission.

Chapter 3 and 4 contains the statement of significance and identifies the character defining elements while offering a few notes for the management of future use.

Chapter 5 includes the body of policies and recommendations in response to the cultural significance, vulnerabilities and the conservation issues identified through the preliminary studies. The various sections include general policies, landscape and management plan, the building itself, environmental management and hygrothermal performance, as well as use, collections and interpretation. Each consultant has informed site policy and guidance in their respective area of expertise.

1. Developmental History

1.1 Site Chronology*

Year	Event	
1943	**George Nakashima arrives to New Hope**	Sponsored by architect and former employer Antonin Raymond, George Nakashima and his family were released from their interment during WWII at Camp Minidoka in Idaho and lived on Raymond's farm in New Hope, Pennsylvania. Since many of Raymond's comissions were government related, Nakashima could not work as an architect and helped on the farm and set up a small furniture workshop.
1945	**George Nakashima leaves the farm**	George Nakashima and his family move into a house near Meetinghouse Road, in New Hope, and continued his activity as woodworker.
1946	**George Nakashima moves to Aquetong Road in New Hope**	George Nakashima purchases three acres of land from a Quaker farmer in exchange for carpentry work. The family lives in a tent on the property, while George builds the first structure on the site, the Workshop.
1946	**The Workshop**	This building is enlarged over the years. Originally, it included a workshop area and an exhibition space but over time, the building becomes specialized for furniture making.
1946	**Nakashima House**	The residence for the Nakashima familiy is built shorlty after the Workshop. In 1954, it is expanded south to provide an additional bedroom for the new born Kevin Nakashima.
1953-1954	**The Showroom**	Using a rich variety of wood species along with 20th century materials, Nakashima builds the Showroom to display furniture and to house a small-office space. The building sits on concrete posts and is covered with a gable roof. On its west end, it opens towards an outdoor terrace and a pool.
1954	**Nakashima House Expansion**	The family residence is enlarged by adding a new bedroom on the south elevation.
1954-1955	**The Finishing Department**	Originally built as a lumber storage, the building is soon repurposed to house the furniture finishing processes.

1958-1959	**The Main Lumber Storage Building**	Together with consulting engineer Paul Weidlinger, George Nakashima experiments with the use of plywood to build his first hyperbolic paraboloid to roof a new storage shed.
1956-1957	**The Chair Department**	Formerly the clubhouse for the workmen, this building is soon converted to a space for assembling chairs. The Chair Department is built as a prototype for the larger Conoid Studio.
1956-1958	**The Conoid Studio**	The Studio displays a distinctive corrugated reinforced concrete roof that represents a particular application of a conoidal shell roof. This roof shape confers aesthetical qualities and produces the required strength through form while maintaining the same thickness across the section, approximately 2 1/2 inches. The building provides spaces for furniture design, meeting, and display of furniture and decorative arts.
1958	**The Lanai**	Sponsored by the Sipmpson Redwood Company, George Nakashima designs this small structure using California redwood. A cantilevered roof mounted upon two concrete piers houses a sitting area which includes a stone Dutch oven.
1958	**The Pool Storage House**	Built as a prototype for the Pool House, this small structure of concrete block is covered with a canted barrel vault roof. Nowadays, it is used for storing chemicals and the necesary equipment for the neighboring Swimming Pool. Mira Nakashima participated in the construction.
1960-1961	**The Pool House**	With its distinctive canted barrel vault roof supported on its sides by stone and concrete block walls, this structure is open on both ends establishing a direct relationship with the landscape. The roof is constructed of plywood and is covered with a waterproofing membrane and copper flashing. It houses dressing rooms and an open space for leisure activities.
1960	**The Swimming Pool**	The amoeba shaped pool was built of reinforced concrete and has a cantilevered overhand on its southern side.
1961	**The Main Lumber Storage Building Expansion**	This lumber storage was expanded adding a new storage space towards the south. Its tilted hyperbolic paraboloid roof is likely the precedent for the Arts Building.

1964-1967	**The Arts Building and Cloister**	With a soaring hyperbolic paraboloid roof, the Arts Building contrasts a restrained and smaller adjacent Cloister. The Arts Building structure consists of the interplay of wood, a reinforced concrete grid slab and walls, and uncoursed random rubble masonry walls and abutments, which ultimately support the tilted hyperbolic paraboloid roof. The Cloister structure is comprised of exposed concrete block masonry walls. Both the Arts Building and Cloister are connected by a covered walkway or engawa, creating an asymmetrical composition. It was intended as an exhibition space and place for interchange in relation to craftsmanship and the arts.
1967	**Nakashima Garage**	The garage is a small rectangular concrete block building with a gable roof covered with corrugated Transite®. The walls are covered with stucco and have a foundation of stone. It is a one-car garage with an overhead door and a round window. It also includes a laundry room and storage.
1968	**The Main Lumber Storage Building Expansion**	For the second time, the lumber storage is expanded.
1970	**Mira Nakashima House**	Designed and constructed by George Nakashima for his daughter Mira, this rectangular two-story building is covered with a distinctive scissor truss roof covered with cedar shake shingles. Wall materials include concrete block, wood, and textured stucco.
1970	**Mira Nakashima Guest House**	Adjoining Mira Nakashima´s House, this building mirrored the construction features of the main building. It is connected to the house by a covered walkway.
1971	**The Main Lumber Storage Building Expansion**	The building is enlarged again by adding a tractor shed.
1974-1977	**The Reception House**	Using also a scissor truss roof system and open floor plan, George Nakashima built this house with a Japanese style tea room and sunken bath to serve as a guesthouse and space for meetings. Wall materials include stone, concrete block, stucco, Kyoto plaster, and Japanese tiles. A series of sliding shoji doors hides the kitchen.

1977	**The Heating House**	This small structure consists of concrete block walls covered with a gable roof to house a heating plant. The fuel tank is housed in the open area.
1977	**The New Lumber Storage Building**	This storage was built of concrete block and covered with a plywood and asphalt shed roof.
1982	**Nakashima House Repair**	The earlier roof of cast concrete tiles is replaced with wood shingles.
1985	**Mira Nakashima Garage**	With a rectangular shape and vertical wood siding, this structure is covered with a cedar shake roof. It is a non-contributing building according to the National Historic Landmark nomination.
1990	**The Pole Barn**	The Pole Barn was designed in 1990, with additions in 1995 and 2008, to serve as lumber storage. It was designed by George Nakashima's grandaughter. It is a non contributing structure according to the National Historic Landmark nomination.
1990	**George Nakasima passes away**	George Nakashima passes away at 85 in New Hope, Pennsylvania.

* Based on the NHL nomination, the Depreciation Accounting Books, and Nakashima Property List of Buildings (September 12, 1990)

1.2 Construction and Alteration Chronology*

Year	Design Phase	Source
Before June 1963	Preliminary design by George Nakashima	Drawing
June 3, 1963	Earliest dated records; particularly, engineering drawings	Drawing
February 4, 1964	Earliest known drawing of the Arts Building by GKN: a schematic design scheme including ground floor plan, South, East, and West elevations.[1/8" = 1'-0" scale drawing in AAUP dated]	Drawing
March 17, 1964	Site plan, likely used for zoning submission, dated.	Drawing
March 18, 1964	Zoning Permit filed with Solebury Township	Other
	Executive/Construction Phase Begins	
May, 1964	Electrical service extended to Arts Building site, construction begins	Account book
June, 1964	First payments to Town & Country Builder as well as to Robert Lovett, who focus their work on the construction of footings, masonry walls, and poured concrete waffle slab. Work substantially completed by October 1964.	Account book
	McIlvain Co. supplies white eastern pine beams for lintels in west and south window walls (notched into masonry walls), as well as pieces over the fireplace.	Account book
	Rubble stone supplied by Delaware Quarries.	Account book
October Thru December, 1964	Temporary work stoppage on Arts Building site so the crew can focus efforts on the construction of an expansion to the Shop building. Walls and concrete work substantially completed by this time.	Account book
April Thru November, 1965	Construction of Arts Building hyperbolic paraboloid roof.	Account book
	Large order for soft wood products placed with Weyerhaeuser during April [possibly wood used for wall plates, possibly the roof ribs, and "scaffolding" to support roof edge beams and ribs during erection].	Account book
	Order placed with Daniel Buck Inc., for wood supplies, assumed to be the roof ribs.	

	Payment made to McIlvain Co., for what is assumed to be the douglas fir edge beams and main pole.	Account book
July, 1965	First payment made to Buck Inc. for what is thought to be plywood.	Account book
September, 1965	Second payment made to Buck Inc. at the end of the month, roughly double that of the first payment. Sheathing work on the hyperbolic paraboloid roof begins.	Account book
October, 1965	Substantial payment to Histand Bros., roofers. Roofing membrane installed.	Account book
	Excavation work completed on Cloister building.	Account book
November, 1965	Roofing completed. Second, very small payment made to Histand Bros.	Account book
	Payment also made to Buten & Sons, for paint supplies - assumed to be the stain for the plywood. Possibly preservatives for exterior timbers.	Account book
	Footings laid for Cloister and, possibly, cinderblock wall construction completed by the end of the month.	
November Thru May, 1966	Fabrication of windows and doors is underway. The supply and installation of glazing begins around this period. Payments made to Niece Company (local building supplier) over the coming months suggest they are the glass supplier. Near simultaneous payments made to hardware supplier, Finkel & Son, may indicate purchase of related fittings.	Account book
January Thru October, 1966	First of a series of large payments to M & M Plumbing & Heating for work on the Arts Building and Cloister. Work contiues through October of 1966.	Account book
February, 1966	Payment made to McIlvaine Co. made, possibly for black locust posts and beams used in Covered Walkway.	Account book
May, 1966	Factsheet about a well drilled close to the Arts Building.	Notes
June, 1966	Payment made for water well drilling (Zieganfuss) and large payment to M&M made the following week suggesting connection of well water supply to the Cloister Building mechanical room.	Account book

June, 1966	Payment made to Buck Inc. for plywood. Assumed to be plywood and sheathing for the Cloister building and pathway.	Account book
June Thru September, 1966	Payments to Lewis, Inc. (concrete supply) & Delaware Quarries for building stone suggest that work on the garden walls and pond occurred during this period.	Account book
July, 1966	Roof of Cloister building and pathway completed. Payment to Histand Bros., Roofer	Account book
August, 1966	Payment made to Coulton & Sons for septic system installation.	Account book
October, 1966	Vinyl tile purchased and installed during following at both the Arts Building and Cloister	Account book
	Final large payment to M&M. Assumed that the heating system was operational by this time.	Account book
November Thru January, 1967	Finishing work and electrical work continues. Work substantially completed by the end of January.	Photograph
March Thru April, 1967	Built-in Conoid bench with double-back installed, as were the exterior grills, Japanese paper lanterns, shoji screens and curtains.	Photograph
May 7, 1967	Opening reception of the Arts Building, a "small private museum" christened as the "Museum Minguren."	Other
	First Publication of Arts Building in *The Philadelphia Inquirer,* Philadelphia, PA May 7, 1967 p. 144	Printed media
	Alterations	
March, 1970 Thru January, 1971	Three payments [to Gabriel Loire] for the Ben Shahn's mosaic mural "The Poet"	Accounting book
October, 1970	Gabriel Loire Atelier ships the mosaic mural to New Hope during the fall of 1970	Letter
January, 1971 Thru July, 1971	Installation occurs. By July 1971 the mural is in place.	Photograph
August, 1990	"As we hope to set up our so-called "Museum" as a memorial exhibit of my father's life and work, we would like to be able to remove the wood which has been stored in this building to the new shed and restore the older building to its original purpose. We are currently forced to use the Museum for lumber storage, due to lack of other space." (Mira Nakahsima-Yarnall in relation to letter sent to her neighbors on Aquetong Road about the design of the pole barn.)	Letter

Before 1994	Replacement of the lintel above the fireplace damaged by carpenter ants activity. Reportedly, repairs on the plywood shell. This job included alterations to the north and east eaves as well as the installion of new copper gutters.	Oral history
March, 1994	A work list by Mira Nakashima includes repairs of exterior woodwork damage by animal and insect activity, replacement of shoji paper on the main room and Cloister closet, clean up & paint of heating units. About the Cloister: plaster repair and paint, replacement or repair of the fiberboard. First mention to the repair to the window seat projection on the west elevation, as well as the creation of signage for objects to display.	Notes
May, 1994	Detailed handdrawing by Mira Nakahsima of the roof canopy for the window seat on the west elevation of the Arts Building.	Drawing
April, 1999	A photo shows a group of craftsmen moving the Russia Altar of Peace. In the background the canopy for the west window seat is already in place. Sky domes are visible in the porch/balcony. Although not clear, gutter replacement already in place.	Photograph
Ca. 2001	Repairs on the covered walkway in front of the Cloister. Original black locust posts were replaced by ipe machine-made posts placed upon Japanese inspired truncated square pyramids.	Photograph
Before 2003	Original skydomes were replaced by new sky domes. Waterproof layer was applied on the concrete terrace.	Oral History
After 2003	At least four more black locust posts of the covered walkway were replaced. Sky domes were replaced by functional skylights.	Oral History
June Thru October, 2005	Labor and materials for roof repair at the Arts Building billed by Lucien Peebles General Construction.	Account book
July, 2016	The mezzanine floor was scrubbed and refinished.	Report
July Thru October, 2016	On the balcony, the south black locust railing is replaced in kind	Report
August, 2016	The upper section of the stone masonry chimney shaft and crown were repaired.	Report

Hand drawings by George Nakashima of the Arts Building and Cloister. All from George Nakashima Woodworker Archives. Scanned by Architectural Archives of the University of Pennsylvania.

Figure 1. Arts Building & Workshop
Nakashima New Hope PA
George Nakashima Designer
Paul Weidlinger Consulting Engineer
Mathys P. Levy Associate Engineer
Scale 1/8" = 1'-0"
Feb 12 1964

Figure 2. Undated drawing sheet. The "window wall" was first proposed as wholly screened with wood vertical grills.

Figure 3. Undated drawing sheet. South elevation (above) and West elevation (below). Elevations show a similar scheme to the as built condition. Annotations correspond to general measurements of windows and doors.

Figure 4. Undated drawing sheet. This sketch shows indications for the construction of the plywood shell.

Figure 5. Undated drawing sheet. Elevations and floorplan of the Cloister and covered walkway. It includes architectural detailing for the porch roof and the canopy.

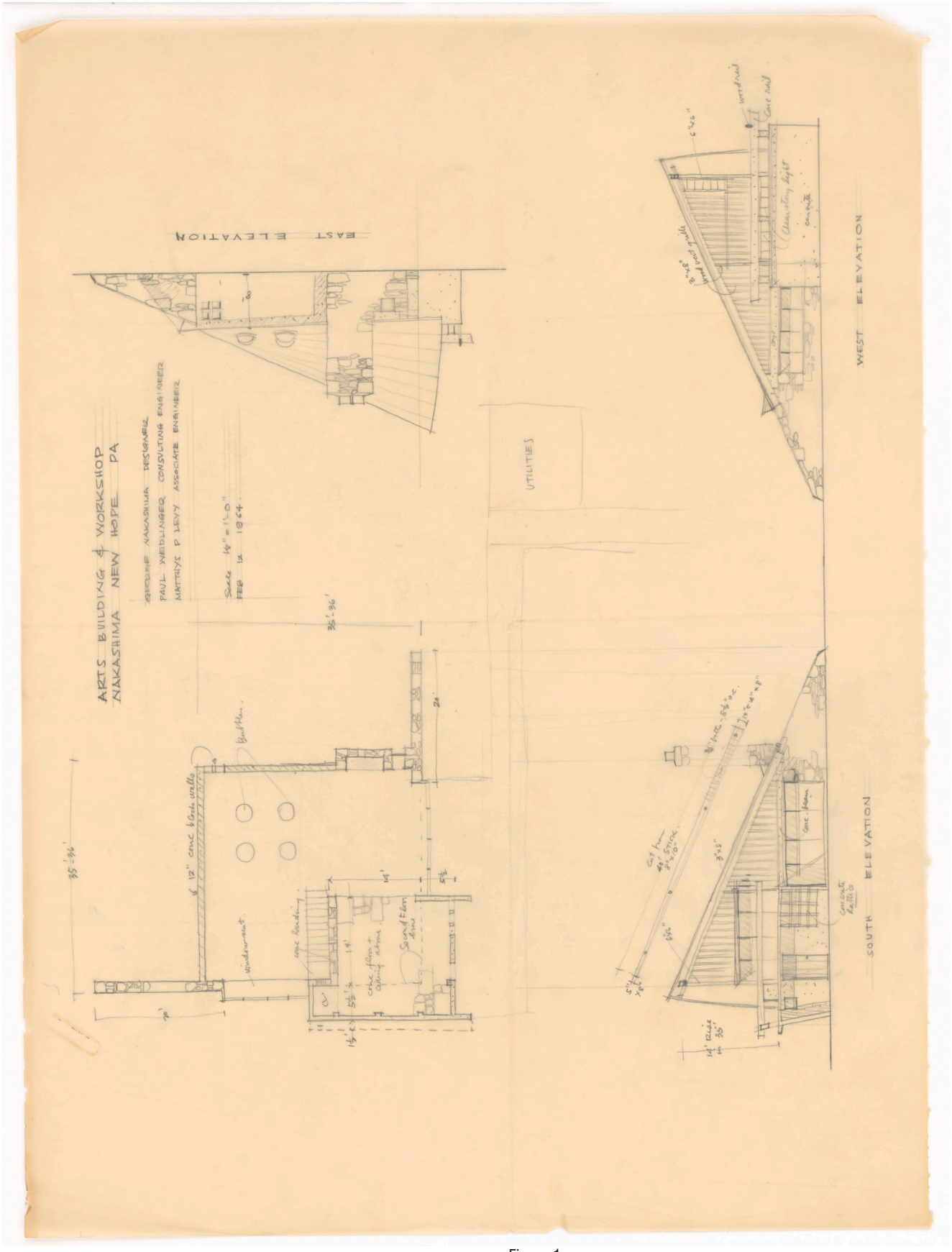

ARTS BUILDING & WORKSHOP
NAKASHIMA NEW HOPE PA
GEORGE NAKASHIMA DESIGNER
PAUL WEIDLINGER CONSULTING ENGINEER
MATTHYS P LEVY ASSOCIATE ENGINEER
Scale 1/8" = 1'-0"
FEB 12 1964
EAST ELEVATION
UTILITIES
WEST ELEVATION
SOUTH ELEVATION

Figure 1

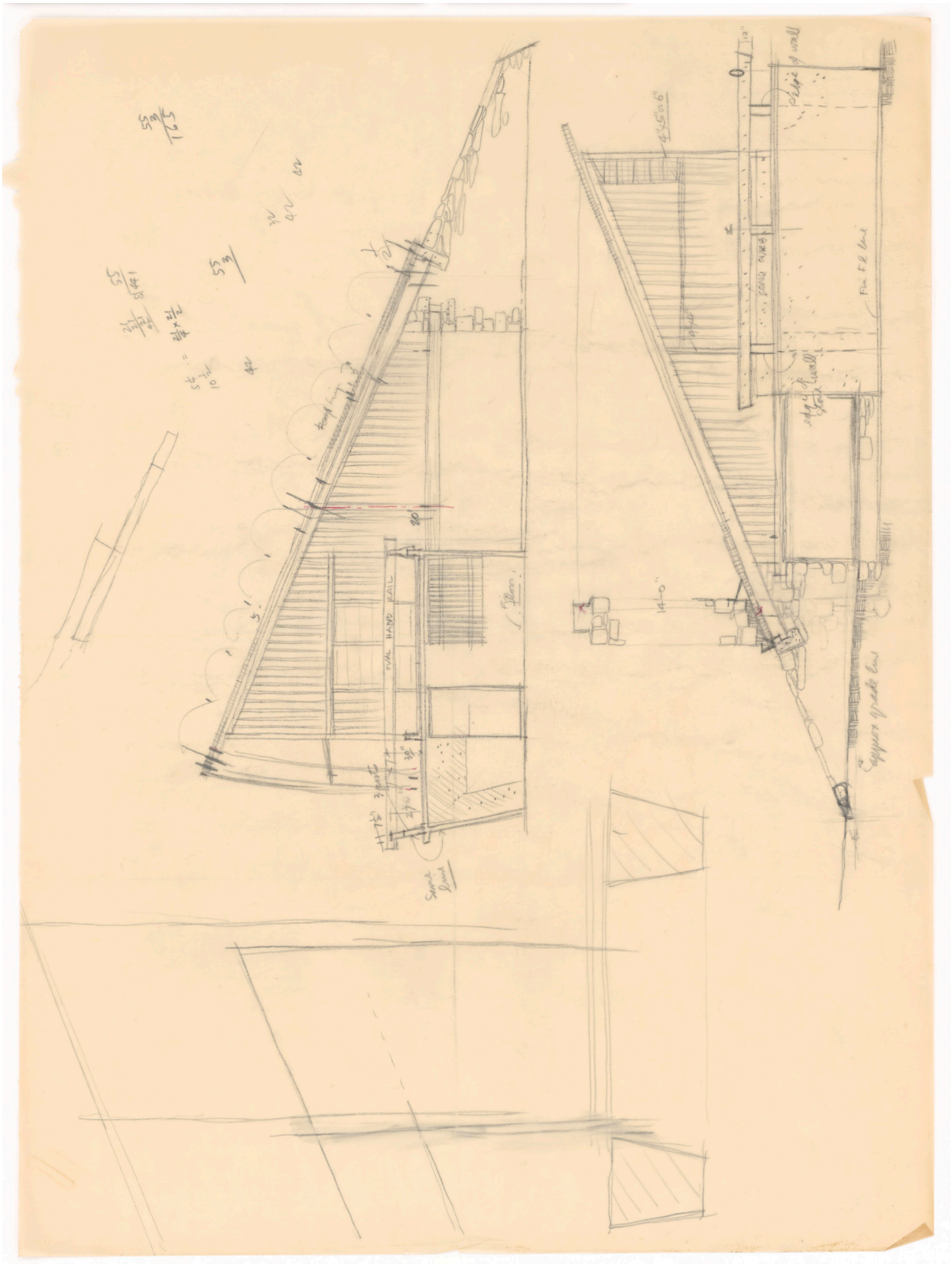


Figure 2

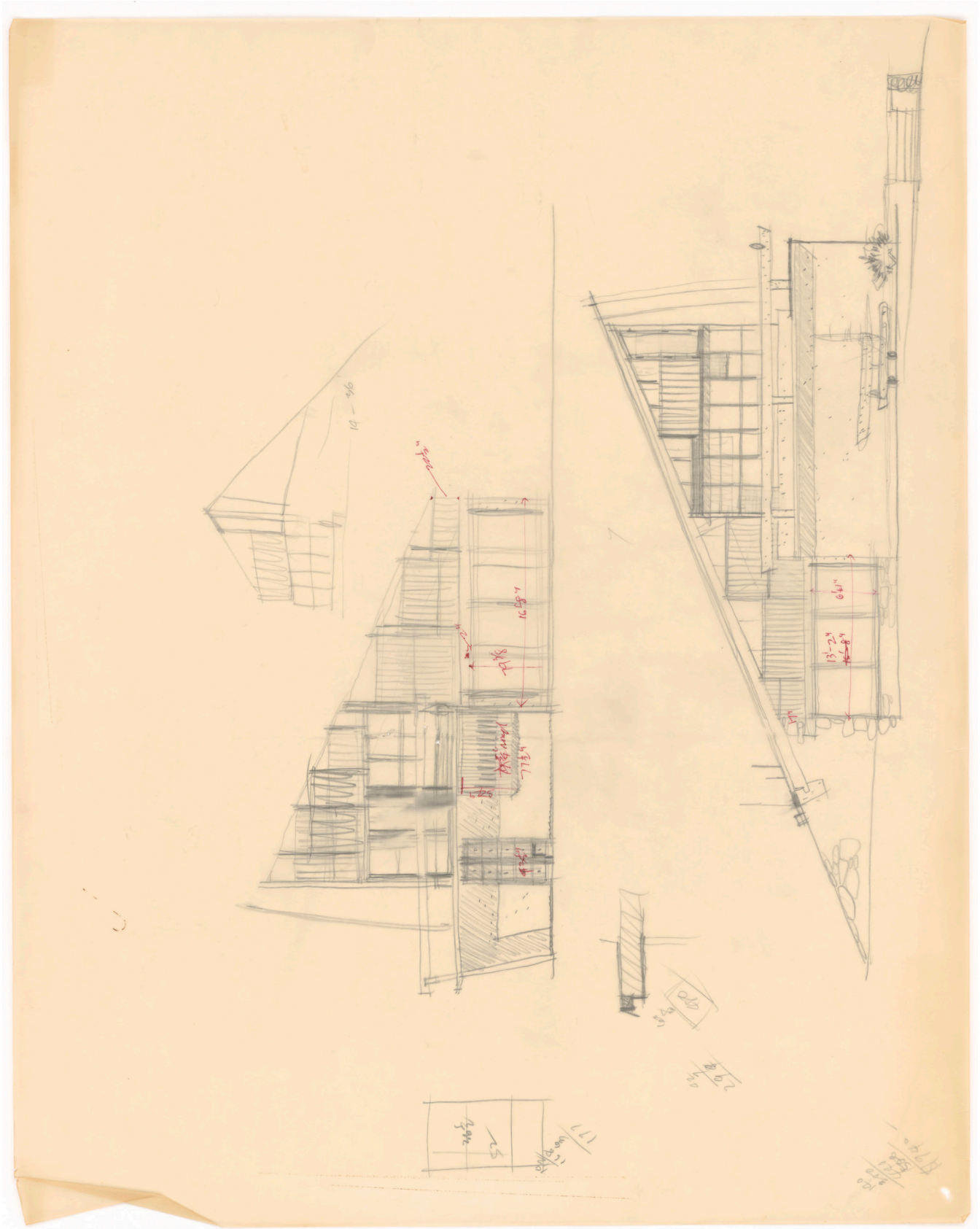


Figure 3

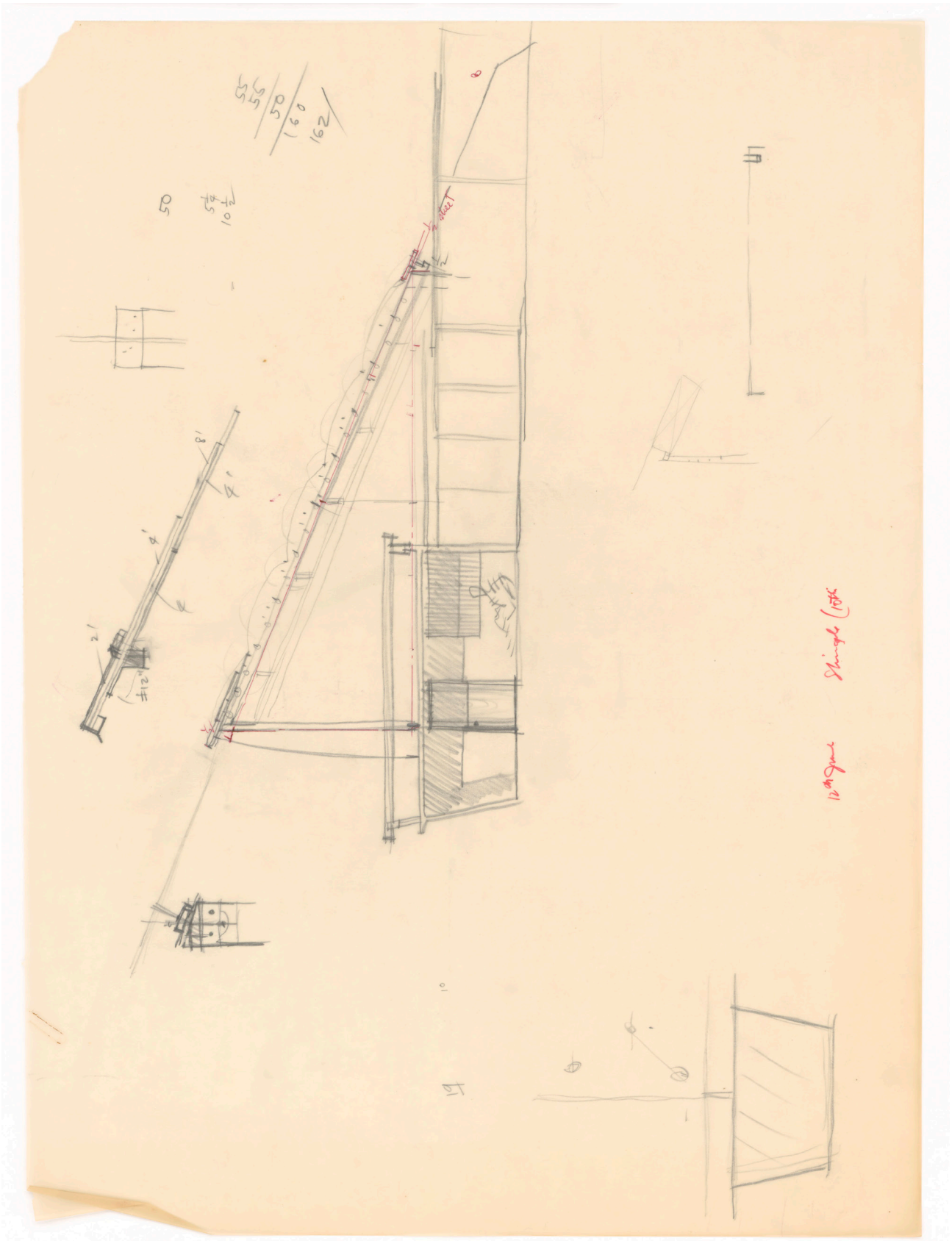


Figure 3

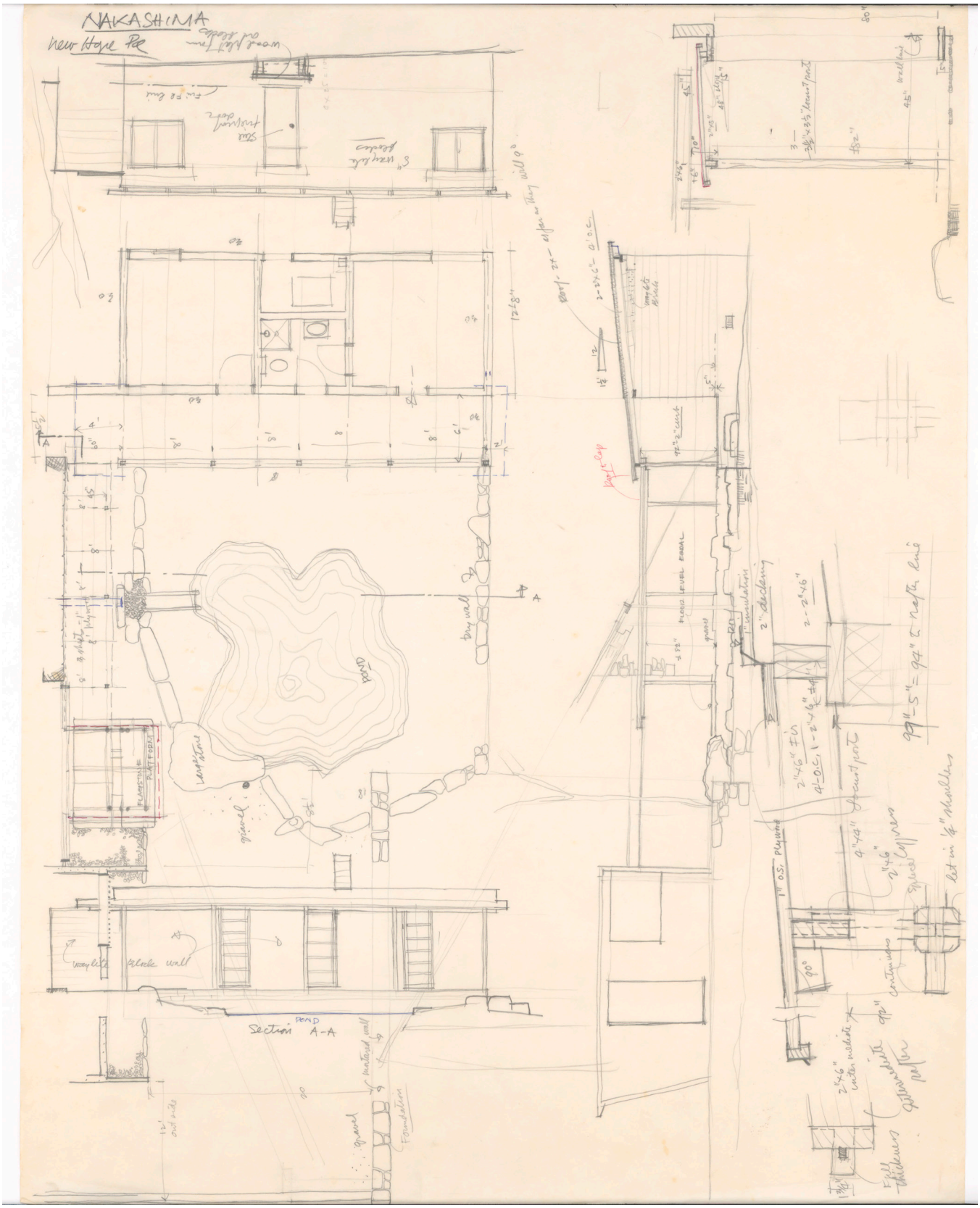


Figure 4





Left: pouring concrete during summer 1964.
Right: Note the use of plywood for concrete formwork.





Construction continues.





Left: adjusting the west edge beam to its final position.
Right: scaffold and ribs ready for placing the plywood deck.





Construction of the plywood deck





Left: the installation of glazing infill begins.
Right: Wiew of the Arts Building and Cloister from the south in the early fall of 1967





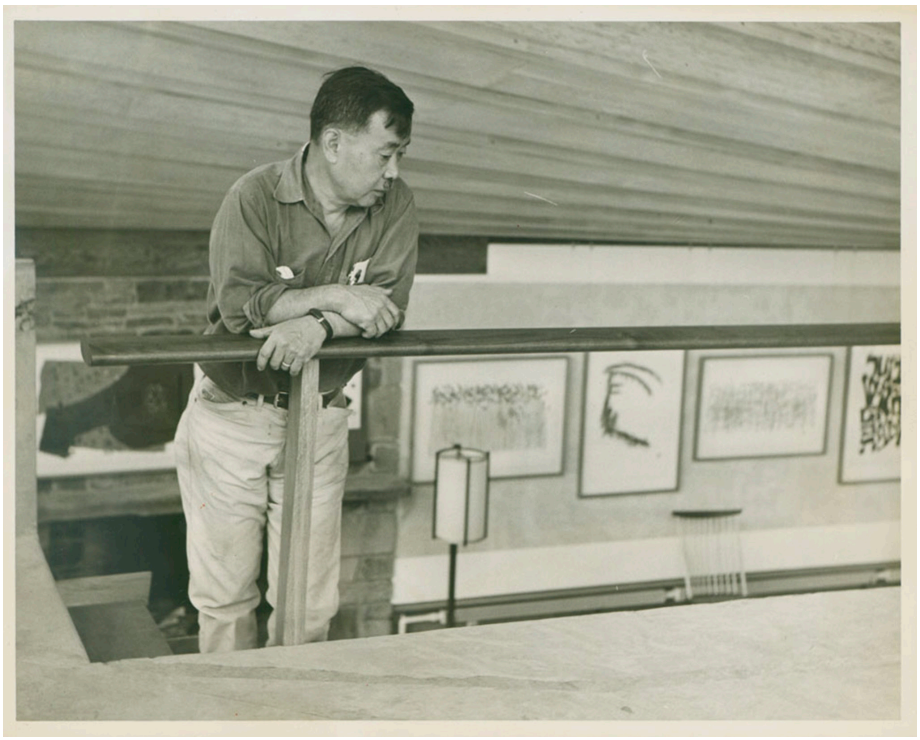








Left, from top to bottom:
Arts Building looking westwards
Cloister from the Arts Building terrace.
Looking through the south sliding door.
Gallery space looking eastwards.
Conoid bench installed on the loft.
Right:
Sculptural lamp as initially assembled.
All images courtesy of
Nakashima Foundation for Peace



Right: George Nakashima in the Arts Building. Ben Shahn's artwork hangs on the walls. This photograph was probably taken shortly after the exhibition was inaugurated in 1967. Source: George Nakashima Woodworker Archives

2. Contextual History

2.1. George Nakashima: Training and Apprenticeship

The many publications about George Katsutoshi Nakashima (1905-1990) during his lifetime contributed to the legend and mystique of the artist as a furniture maker; his work as an architect, however, is less represented. Although woodworking became for him a profession interwoven with spiritual meaning, Nakashima was formally trained as an architect. After a short stay in Paris, he followed a career in this profession that led him to embrace modernist ideas in his early years, mainly with Antonin Raymond in Japan and India. These previous experiences, especially in Japan, proved instrumental to the particular architectural synthesis Nakashima exemplified in the Northeastern United States.

Nakashima studied architecture at the University of Washington, where he graduated in 1929, and Massachusetts Institute of Technology (MIT), where he obtained his master's degree in 1930. Both institutions imparted an education primarily adapted from the methods and theories of the École des Beaux Arts in Paris, although in the case of MIT, it was amalgamated with a polytechnic system. In Europe, Nakashima might have been exposed to rising modernist ideas during his sponsored stay at the École Américane des Beaux Arts in France, where he received the Prix Fontainebleau in 1929.

This first exposure was supplemented with a second stay in Paris in 1933, where he witnessed the construction of Le Corbusier's Pavillon Suisse. This student dormitory offered Nakashima a first-hand introduction of modernist interests spreading through Europe; an experience that would be enriched greatly by his work in Japan and India.

Looking to the East, Nakashima moved first to Japan and joined Antonin Raymond (1888-1976) in April 1934. Raymond, who has been recognized as the "father of Modern architecture in Japan,"[2] had established his own practice in Tokyo in 1921 along with his wife Noémi Pernessin Raymond (1889-1980). Before that, the Raymonds had been working in different positions serving Frank Lloyd Wright (1867-1959), first in 1916 in Taliesin, Wisconsin for nine months, and then in 1919 and 1920 at Taliesin and in Tokyo, as paid staff members supervising the construction of the Imperial Hotel and the design of other projects.

This apprenticeship was influential in the Raymonds' practice, although they would ultimately break away from Frank Lloyd Wright by embracing Japanese traditional craftsmanship as "a process to be mastered on its own terms to meet contemporary needs."[3] The Raymonds considered Wright's use of Japanese inspired ornament in the Imperial Hotel as a vacuous mannerism completely separated from the local climate, traditions, people, and culture. In part, these opinions recalled Antonin Raymond's earlier training in Prague, where he was in touch with the ideas connected to the rediscovery of traditional folk architecture as a way to question contemporary eclecticism. Other influences drew on Auguste Perret's (1874-1954) use of concrete and Le Corbusier's (1887-1965) approach to collective housing, known through magazines, and Raymond's personal exposure.

In the hands of the Raymonds, Western modernist ideas were succesfully synthe-

2. As described in Antonin Raymond's obituaries published in the Japanese newspaper Mainichi Shinbun, 28 October 1973, and in the British newspaper Times, 22 November 1976. Kurt G.F. Helfrich and William Whitaker, Ed, C*rafting a Modern World: The Architecture and Design of Antonin and Noémi Raymond* (Princeton Architectural Press: New York, 2006), 29

3. Kurt G.F. Helfrich and William Whitaker, 24



Karuizawa Summer House. South and East Facades. Source: Kurt G.F. Helfrich and William Whitaker, Ed., *Crafting a Modern World: The Architecture and Design of Antonin and Noémi Raymond.*

sized with Japanese lifestyle and construction, which would be ultimately internalized by Nakashima. Antonin Raymond hired European and Japanese architects and nurtured a climate of interchange, where modernist ideas were discussed and filtered with a vernacular vision, where the spirit of the Daiku, traditional carpenters, and the Minka, vernacular farmhouses, were admired. By joining the Raymond's office, Nakashima worked with architects such as Maekawa Kunio (1905-1986), Junzo Sakakura (1901-1969), and František Sammer (1907-1973), and built a long-lasting network of professional connections and personal ties. More importantly, perhaps, was Junzo Yoshimura (1908-1997), who guided Nakashima in his study of the Japanese spirit, traditions, and architecture, including travel to the shrines and temples of Kyoto. Raymond's publications also played an influential role, like Antonin Raymond: His *Work in Japan* 1920-1935 (1935) and *Architectural Details* (1938), which included detailing evolved from Japanese traditions that Nakashima reproduced "almost literally in both his buildings and his furniture."[4]

During his stay at the Tokyo office, Nakashima was involved in two projects that would be early precedents of his architecture in New Hope: the Raymond's Summer Studio (1933) and the St. Paul's Catholic Church (1934-35), both in Karuizawa, a few hours to the northwest of Tokyo.

At the Raymond's Summer Studio, Antonin Raymond dealt with the site, local materials, and construction craft, which stemmed from Daiku, vernacular Japanese carpenter traditions, to build a complex that included a residence, a studio, and a caretaker's house. The residence and studio, laid out in an asymmetrical floor plan of interconnected spaces, were a hand-hewn chestnut and cedar framed structure upon a poured concrete plinth. The house's metal roof was covered with branches of Japanese larch, to protect the roof from the heat and to dampen the noise of the recurrent rains during summer. The main space was the living room, a double-height space organized around the fireplace and the ramp, which connected the studio in the upper floor. Overall, interior spaces flowed into the views of the surrounding landscape through a wide opening in each elevation.

Revealing an interest in the raw qualities of the materials, the house and the furniture were of the simplest means. By retaining the prints of the wooden formwork, made of the same species as the walls, the imperfections of the crafted wood were harmonized with the plasticity of the concrete. In so doing, the concrete, as a new material, dialogued with the deep-rooted tradition of wood construction in Japan. The Raymond's Summer Studio was thus a defining model for Nakashima, who witnessed first-hand the possibilities of the vernacular traditions in crafting modern architecture. In fact, Nakashima was among a select group of staff members residing in the caretaker's cottage during their visits and his work in St. Paul's Church. The caretaker's cottage and the swimming pool, which was added between the public and the private wings of the residence, might constitute the earliest references for articulation of the exterior spaces and the idea of the Cloister itself in New Hope.

The intrinsic qualities of local materials were also favored in St. Paul's Church, where Nakashima collaborated on the design and construction. In 1935, father Leo Paul Ward (1896-1942) commissioned the Raymonds to build a Catholic

4. Mira Nakashima, *Nature, Form & Spirit: The Life and Legacy of George Nakashima* (New York: Abrams, 2003), 21

church, after their Summer House and Studio, to serve the spiritual needs of the foreign community sojourning in Karuizawa. Sections and floor plans showed an asymmetrical basilica arrangement, a pitched roof and bell tower with the steeple being reminiscent of Slovakian churches. However, the building and the furnishings were expressed through the Japanese carpenter traditions, this hybrid offering a new conception for the design of sacred spaces.

Deepening in the possibilities of the Raymond's synthesis, the experience of St. Paul's Church exposed Nakashima to the use of concrete and the craft of wood. On this occasion, both wood and concrete were polished with straw and sand to emphasize again the natural qualities of the materials. Remaining sections of structural lumber was used to fabricate a variety of furniture and furnishings for the interiors.

India

In 1935, the same year that St. Paul's Church was erected, Sri Arubindo Gosh (1872-1950), the leader of an ashram, a spiritual community, commissioned Antonin Raymond to project and build a new residential dormitory for his disciples in Pondicherry, India, at that time a French protectorate. Previously, Raymond had been introduced by his close friend Philippe B. St. Hilaire (Pavitra), a French engineer and ashram disciple himself. The ashram was established in 1926 by Sri Aurobindo with his disciple Mirra Alfassa Richard (1878-1973), a French woman of Egyptian-Turkish lineage who came to be known as The Mother. Richard, St. Hilaire, and the Raymonds shared an interest in Theosophy, which made the latter sensitive to the spiritual needs of the ashram and lead to propose a modernist form to create a peace retreat opposed to prejudices embedded in the colonial fabric.[5]

In this project, Nakashima was assigned to an initial visit in 1936, and later to supervise the execution of the construction and interior furnishings along with the most recent addition to the Raymonds' office, a Czech born architect called František Sammer.[6]

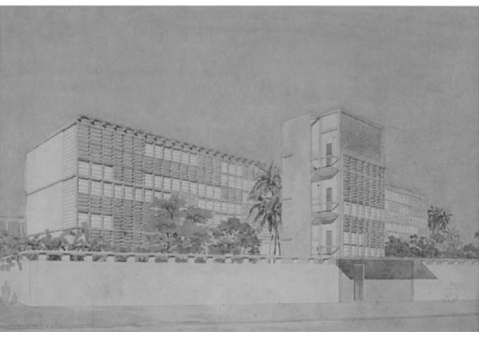
The Golconde Dormitory (1935-1942) was projected as a concrete structure facing north and south. Essentially, it was comprised of two rectangular volumes, offset to each other, joined and served by a central functional tower containing the stairs and the hygienic facilities. Modest rooms dedicated to sleep and study were placed on the upper levels, whereas the dinning and common rooms were located at the ground level. The building was engineered to adapt to tropical and humid climatic characteristics. A roof of precast concrete barrel shells, louvers and overhangs play a role of sun shield and heat control.

As a project architect, Nakashima explored and refined the construction materials and details through the construction of scaled models, which would ultimately constitute a model for his own practice in New Hope. Once again, he was in touch with the reinforced concrete technology and with the craft. On this occasion, the lack of materials, due to political unrest in Asia and Europe, and the inexperience of the ashram members compelled him to improvise and to develop alternative solutions through craft. This experience would ultimately help Nakashima to deepen even more his understanding of the possibilities of common materials.

5. Christine M. E. Guth, "Crafting Community: George Nakashima and Modern Design in India" in *Journal of Design History* 29 (2016), 366-384.
6. Sammer contributed with his previous experiences in the Centrosoyuz, the Palace of the Soviets competition (1931), and the Pavilion Suisse (1931-32), and undertook the Golconde project until its completion. Pankaj Vir Gupta, Christine Mueller, "Golconde: The Introduction of Modernism in India" in *2005 Report on University Research*, University of Austin, Texas.

Below: St. Paul's Catholic Church in Karuizawa. Entry Facade. Source: Kurt G.F. Helfrich and William Whitaker, Ed., *Crafting a Modern World: The Architecture and Design of Antonin and Noémi Raymond*





Rendering of the Golconde dormitory for Sri Arubindo's Ashram. Source: Kurt G.F. Helfrich and William Whitaker, Ed., *Crafting a Modern World: The Architecture and Design of Antonin and Noémi Raymond*

Within this context, Nakashima became himself a disciple of Sri Aurobindo, and was given the name of Sundera nanda, 'one who delights in beauty'. As a member of the ashram, Nakashima evolved a deeper understanding of life and a transcendent sense that profoundly influenced his position on craft and design. The Sadhana, a "spiritual training to attain deep concentration resulting in union with the ultimate reality,"[7] would be ultimately nurtured in New Hope. In fact, Nakashima aspired to create "a center for the evolution of life moved by higher consciousness, a life of the spirit."[8] These ideas would be summed up in his book The Soul of a Tree, published in 1981, where Nakashima revealed a spiritual interpretation of woodworking interweaved with a utilitarian dimension.

In 1939, with the threat of war and having completed most of the concrete work in Golconde's structure, George Nakashima left India to work for few months in Tokyo with Kunio Maekawa (1905-1986), a former colleague of Raymond's office, before returning to the United States. During this time, Nakashima met his future wife, the Japanese American Marion Sumire Okajima (1912-2004). After marrying in 1941, they moved to Seattle, Washington, where Nakashima worked as an architect for Ray Morin and began to make furniture as a part-time activity . However, shortly after the Pearl Harbor Japanese attack and US entry into the war, Nakashima was interned with his family in Minidoka, Idaho, as other Japanese Americans. At the camp, Nakashima met Gentaro Hikogawa, a tradiionally trained Japanese carpenter who was born in Japan and immigrated to the US. Hikogawa improved Nakashima's skill by training him in the use of traditional Japanese hand tools and wood joinery.

After receiving communication from the Dean of the MIT, Nakashima's former employers, Antoni and Noémi, sponsored the Nakashima family release, who settled on the Raymonds' farm in New Hope in 1943. Since most of the Raymonds' commissions were government-related, Nakashima could not work as an architect reflecting a climate of fear as a result of the Pacific war. He turned to farming and later to woodworking, in January 1944, as revealed by an earlier ledger book. In 1946, having bought a three-acre property along Aquetong Road in exchange for carpentry work, Nakashima began a woodworker complex. There he brought together the spiritual aspects and his first-hand experiences with local materials, available technology, and craft.

2.2. Experiments in Modernist Structural Theory: Hyperbolic Paraboloids

When Nakashima began the preliminary sketches for the Arts Building, he had already designed and built eight structures on the property, answering the demand of a business in expansion. Inspired by the growing interest in the functional and visually striking qualities of warped roofs in post war America, Nakashima experimented with the use of plywood as the essential building material to construct three early roof examples. They were the Main Lumber Storage, using a hyperbolic paraboloid, a conoidal roof clubhouse for workers, which quickly became the chair assembly shop or the Chair Department, and the Pool Storage House. While the latter became the model for the Pool House, and the clubhouse roof inspired the corrugated concrete shell for the Studio, the Lumber Storage became the prototype for the Arts Building.

7. George Nakashima, *The Soul of a Tree*, (Tokyo, New York: Kodansha International, 1981), p.138
8. Mira Nakashima, 18

Of European origin, hyperbolic paraboloids were introduced to America during the 1950s within a general climate of innovation. Two main groups favored this context: engineers, architects, and builders, who emigrated from Europe fleeing from war ravages, searching for new opportunities; and manufacturers' associations, like the Douglas Fir Plywood Association (1933-1964), which promoted the use of materials used during the war through experimentation in domestic construction and design. Simultaneously, a myriad of publications in journals, university researchers, and conferences accompanied the rising interest in hyperbolic paraboloids. In publishing an article devoted to this type of roof in 1955, *Architectural Forum* illustrated the trend and offered a concise definition:

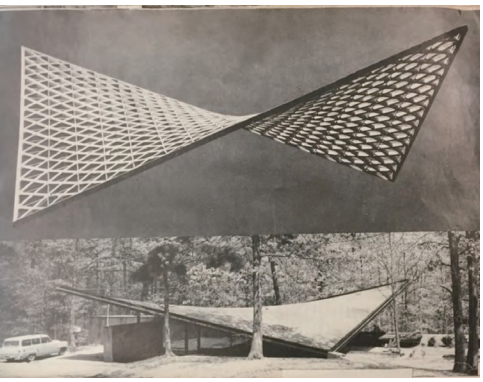
> A hyperbolic paraboloid is a warped double-curved surface, saddle-shaped, generated by straight lines that slide along two straight line directrices not in the same plane and remains parallel to plane director. Any intersection of surfaces with vertical plane parallel to its diagonals produces parabolic curves. Although it is double-curved surface, its intersection with vertical plane parallel to edges of surface produces straight lines. Only central lines are horizontal.[9]

The article showed various structural combinations, including the two eventually used by Nakashima: the hyperbolic paraboloid and the tilted hyperbolic paraboloid. *Architectural Forum* was familiar to Nakashima, as his Showroom (1954) had been published by the journal a few months earlier accompanied with some photos in color. Although there is no documented evidence of it, in the case of the Main Lumber Storage, the most direct typological reference might be the sweeping roof built in Raleigh, North Carolina, in 1954, which was designed by Argentinian architect Eduardo Catalano (1917-2010) for his own house. Catalano used bent timber planking for constructing a shell. This was the result of a research program that he implemented at North Carolina State College, continuing the efforts of his predecessor Polish architect Matthew Nowicki (1910-1950). In Ra-

9. “A New Way to Span Space” in Architectural Forum vol. 103 (November, 1955), 174



Left: George Nakashima Woodworker’s Complex before the Arts Building and Cloister. 1962. Author: Ezra Stoller, Esto Photographics. Source: George Nakashima Woodworker Archives



Eduardo Catalano's hyperbolic paraboloid. Source: Architectural Forum, November 1955.

leigh, Nowicki, local architect William H. Deitrick (1895-1974), and engineer Fred Severud (1899-1990) had designed the J.S. Dorton Arena (1952), a structure covered with a parabolic cable roof, which earned ample recognition in the United States. In 1955, *Architectural Forum* published Catalano's hyperbolic paraboloid roof, and other influential works such as those of Pier Luigi Nervi (1891-1979). *Progressive Architecture* did the same with Félix Candela (1910-1997), who had attracted attention with his hyperbolic paraboloids in the early 1950s. Nervi and Candela became leading figures who also contributed to the general interest in creating greater and more exciting structures.

In the Mid-West, contemporaneous with Nakashima's Lumber Storage, Professor William Strode and Donald L. Dean, from the Department of Architecture and Architectural Engineering of the University of Kansas, began their own research using plywood sponsored by Douglas Fir Plywood Association (DFPA). As a consequence of this research, in April of 1956, students of the department built an experimental combination of two hyperbolic paraboloid shells each 20 by 20 feet connected along one edge. Essentially, the shell was a lattice structure that consisted of two layers of 1/4-inch plywood strips nail-glued to a plywood box which created the necessary beam on the perimeter. Three reinforced concrete abutments supported the roof structure.

DFPA continued sponsoring research projects, widely lectured in conferences and symposia, and advocated the use of plywood with technical and promotional publications such as *Exciting New Leisure-time Homes of Fir Plywood* (1958) and *Second Homes for Leisure Living* (1960). This effort accompanied and probably nurtured an increasing interest in plywood as a building material, the use of which became a natural path for Nakashima.

Although there is no documented evidence for affirming that Nakashima knew about all these experiments before building the lumber storage, it is likely the consulting engineer Paul Weidlinger (1914-1999)[10] did. In fact, Mario Salvadori, who began his collaboration with the engineering firm in 1945, had already discussed the overall virtues of thin shells, their various shapes, and suitable materials in a series of three articles in *Architectural Record* in 1954. Nakashima already knew this modern material through Antonin Raymond, who had used plywood for his house in New Hope (1938-39) and earlier works in Japan.

2.3. The Hands-on Approach in the Arts Building: Organization and Hierarchy

George Nakashima's dissatisfaction with the modern practice of architecture in America catalyzed his primary adherence to woodworking, a process that he could control from beginning to end and which demanded an integrated relationship between the processes of design and production. When considering this approach in the context of both the particular conditions in Bucks County and his apprenticeship with Antonin Raymond, why Nakashima did few drawings in comparison to other contemporary architects becomes clear. As the hand drawings portray, Nakashima's sketches are not necessarily empty of details but mirror the hierarchy in the construction process.

10. It is likely that Antonin Raymond recommended Weidlinger, who had collaborated in the Reader's Digest Building (1948-1951), which was built in Tokyo by Raymond and Rado's office.

As Antonin and Noémi Raymond, Nakashima found the New Hope vicinity an appropriate location for establishing his workshop. In fact, since the late nineteenth century, New Hope had been attracting artists searching for both a sense of community and a relatively cheap location in the proximity to New York and Philadelphia. By the time the Raymonds established their farm in 1939, various visual artists, writers, playwrights, and wealthy New Yorkers had been buying and restoring stone farmhouses to settle in the area, which generated a vibrant artistic community.

Within this context, Nakashima adhered to the "model of the solitary craftsman." He began to work in a single studio applying a philosophy that echoed the tenets of Antonin Raymond, who believed that "life philosophy and design philosophy are one thing, and if the fundamental precepts of life's philosophy become confused, so will design in any field of art become confused." Intriguingly, this approach resonated with other craftsmen and designers in the Northeast United States, such as Wharton Esherick (1887-1970) and previously with Henry Chapman Mercer (1856-1930).

Despite Nakashima's aloofness, a successful business demanding new facilities, offered him a chance to apply his hands-on approach in architecture that stemmed from his earlier experiences in India and Japan, which were discussed in greater detail in the previous section.

In Pondicherry, while supervising the Golconde construction, two main factors were instrumental for Nakashima's architectural approach: the lack of training of the disciples of the ashram, who were the only builders for the construction according to the explicit wish of Sri Aurobindo, and the lack of materials due to political disturbances in Europe and Asia. While Sammer was in charge of completing the construction drawings, Nakashima delineated detailed and measured drawings for the construction of concrete formwork to explain and guide the construction process to his spiritual colleagues. Craft became a necessary and unexpected action to solve the details stipulated on these project drawings. The lack of materials stimulated the search of alternative solutions on-site like the construction of a foundry for producing the hardware and evolved in Nakashima a sense that "an architect is at the mercy of materials- that he can design only in set patterns because methods of handling materials are so hard to change."[11]

The difficulties found supervising the Golconde construction probably helped Nakashima to understand even deeper Raymond's respect for Japanese master-carpenters: the craftsmen who control the process and explore the possibilities of the materials, understanding their intrinsic qualities. This approach was connected to the idea of simplicity and honesty in every act of construction.

These attitudes soundly resonated with Nakashima, and rather than acting as a mere designer who envisaged the initial idea and plans, Nakashima conceived architecture as an ongoing process in close collaboration with builders. In fact, during a guest lecture at a school of architecture, George Nakashima offered a clear vision of how the education of an architect ought to be. Opposite to the established academic training, involving mainly theoretical actions, George Nakashima upheld a hands-on approach through the appreciation of the materials and workmanship. For Nakashima, "only with that knowledge can a designer rise

11. Bern Ikeler, "George Nakashima: Tenet and Tools" in *Bucks County Traveler* (December 1951): 45-46

above the status of theoretician and create buildings that in his view successfully synthesize structure and aesthetics, as well as form and function."[12]

In fact, Nakashima more often than not spoke out against a modernist practice focused on questioning meaningless innovation and on drafting at the drawing board. For Nakashima "building is essentially a practical problem, and we must face the hard fact that the fundamentals are tools and not paper."[13] Nakashima felt that the division between designer and craftsman "compromised the aesthetics and the literal foundation of a building."[14] Undoubtedly, Nakashima merged this practice with the Raymonds' principles, earlier discussed, and the appreciation of Daiku; accordingly, he said, "designers should be in the same business as contractors. That is the way the master carpenters of pre-modern Japan operated, and it is a good sound system."[15]

In the case of the Arts Building and the Cloister, various and detailed sketches were delivered to the builders. This action does not contradict the widespread idea that Nakashima was intuitive and produced only few project drawings. This practice agrees with the constant supervision by George Nakashima, and even with his direct participation in the construction process. Known drawings include exterior elevations, plan, and highly defined detailing of architectural elements such as post connections and windows. This collection of drawings reveals the breakdown of the project in a manageable scale depending on the operation, and implicitly aknowledges the existence of a construction hierarchy and the involvement of other actors.

Depreciation books offer a glimpse of the construction chronology. The building permit was paid in March of 1964. In May, procurement of materials inaugurated the construction, which was extended until April of 1967(see 2.2 Construction and Alteration Chronology). One of the actors in this process was Robert 'Bob' Lovett, who had begun his collaboration with Nakashima working at the workshop in the winter of 1946. Bob's brother, Frances, had introduced him to Nakashima after Bob had been temporarily laid off from his regular job. First, Bob Lovett was involved in the furniture making, and eventually, after sporadic collaborations, became the builder of a sequence of buildings at Nakashima's property, among them the Arts Building.

The carefully detailed and measured drawings, which also incorporated basic annotations, were reminiscent of Nakashima's task in Pondicherry: a reflection to show what was to be built. In fact, although builders may have been familiar to Nakashima's architecture and techniques, since the final solution portrayed a high level of craft, the construction process required detailed drawings to communicate the ideas and not mere sketches of the idea, as it happened when the work was initiated and presented to the builders for the first time

12.This was said in occasion of an article related to a shop and exhibition at the Full Circle Gallery (April 27th-May 10th, 1986). Rob Howe, "A Lifelong Dedication to Craftsmanship: George Nakashima's One-Man War with the Ordinary" in *The Washington Post, Washington Home* (April 24, 1986): 19
13. Ibid.
14. Ibid.
15. Charles S. Terry, "George Nakashima, Woodworker" in Japan Architect (February 1963), 59-68

2.4. The Relationship with Ben Shahn and the Minguren Movement



George Nakashima's addition to Ben and Bernarda Bryson Shahn's house. Date Unknown. Source: George Nakashima Woodworker Archives/Archiectural Archives, University of Pennsylvania.

Undoubtedly, Nakashima's friendship with Ben Shahn and his later involvement with Minguren nurtured Nakashima's interest in establishing an association with the arts and craftsmanship that transcended his woodworking activity in New Hope. Both aspects coalesced with Nakashima's spiritual beliefs and personal search for enlightenment, which is arguably fundamental to our understanding of the Arts Building and Cloister.

In the mid-1950s, George Nakashima became a friend of the Russian American artist Ben Shahn (1898-1969). Both men implicitly shared beliefs about the redemptive power of the arts and their ephemerality as well, although they reached their ideals from distinct spiritual paths. This acquaintance eventually resulted in a fruitful collaboration in the arts and architecture. Ben and his wife Bernarda Bryson Shahn acquired various pieces of furniture by Nakashima, and Nakashima designed and built two additions with built-in furniture to the Ben and Bernarda Shahn's house in Roosevelt, New Jersey.

Benjamin Shahn, son of Russian Jewish émigrés , naturalized American,was a famous and resourceful plastic artist who expressed his ideas using different media such as easel paintings, illustration, photography, mosaics, and murals, within a long career amply recognized by museums, critics, and audience. While Shahn attained wide success during the depression period in America, the triumph of abstract expressionism during the post-World War II relatively set him aside in the artistic scene. Nevertheless, MOMA organized Shahn's first retrospective in 1947 and he was selected to the Venice Biennale's American Pavilion together with Willem de Kooning in 1954.

In the late 1950s, Ben Shahn commissioned George Nakashima to design the extension of his house in Jersey Homesteads, a New Deal community now called Roosevelt, New Jersey. The original building was a single-story cinder block structure designed by Alfred Kastner; Louis I. Kahn being the assistant architect in the office.

As in earlier buildings, Nakashima crafted built-in furnishings, ensured quality, and adjusted the project to the human scale through its sensitivity and know-how. Some architectural elements at Nakashima's extension greatly resemble those used at the Arts Building: an exposed beam, a grill, and exterior poles. The beam of poured concrete reposes on and extends beyond a random masonry of roughly dressed stone on the western aisle. This detail is repeated in the structural elements of the Cave at the Arts Building; an interior grill bears high resemblance to the work in the Cloister, and exterior poles preserve a peculiar shape less concerned with a perfect appearance, which echoes the utilitarian and aesthetic Japanese folk traditions.Other elements are usual in earlier buildings such as the Showroom: exposed post and beam structure, a raffia plaster that echoes Japanese wattle and daub technique, and a stone fireplace with a metallic hood.

The second work comprised an addition to the second floor, including a studio for Bernarda, a master bedroom and a terrace. Both the design phase (earliest

alternative schemes are dated October 1965) and the construction occurred simultaneously with the Arts Building.

The Nakashima and Shahn correspondence and written accounts offer a glimpse into the close friendship and professional relathionship between both families. Financial records reveal that Ben Shahn's prints were sold in the woodworker complex as early as 1963, and presumably the year before. It is possible that the idea of building a gallery for exhibiting art was already present.

Unfortunately, Shahn died in 1969, shortly after the Arts Building was completed along with the first exhibition of his artwork. On one of the visits to the property, "Ben noticed that George had designed a wall with a perfect cant for a mosaic."[16] To this end, Ben Shan painted a gouache titled 'The Poet's Beard,' which had to be enlarged 5.5 times and eventually used as the base design for the mosaic.

In 1970, George Nakashima hired the services of Gabriel Loire (1904-1996) through the Société d'Exportations d'Art Religeux and the New York based Loire's agent in the United States. Loire was a well-known French stained glass mural artist based in Chartres, France. Among his commissions were the Main Line Reform Temple in Wynnewood (1960), Saint Thomas Moore Church in Allentown (1969), as well as the large-scale mosaic Passion of Sacco and Vanzetti (1967) designed by Shahn and destined for Syracuse University in New York. Presumably, this last work influenced Nakashima on his choice. Poet's Beard was shipped to New Hope in October 1970 and installed on the exterior of the building in 1971.

In the 1960s, George Nakahshima was also involved in the design and construction of two sacred spaces: the Catholic Church of Christ the King in Katsura (1964-65), near Kyoto, and the Chapel of Christ in the Desert (1964-1967), in Abiquiu, New Mexico. Both projects offered Nakashima an opportunity to address faith through the creation of an integrated environment.[17]

The Japanese commision came trough Father Leopold Tibesar (1898-1970), who baptized Nakashima. The later had been in Japan in the late 1920s and was named Superior of the Maryknoll Missions in Seattle in 1935. Tibesar and Nakashima may have met earlier through Antonin Raymond's office, and when Nakashima returned to Seattle, the Catholic priest allowed Nakashima to use the workshop in the Maryknoll Boys' Club.[18] When a group of Japanese Amerian Catholics wanted to build a church dedicated to the Maryknoll Fathers who supported the Japanese during their internment in WWII, among them Father Tibesar, Nakashima offered himself voluntary.

For Christ the King, Nakashima, with the assitance of his daughter Mira then a student in Tokyo, envisioned a 98 x 50 feet diamond shaped tilted hyperbolic paraboloid to cover an axially planned church. The whole structure, including the supporting walls were expressed in concrete. On its lower end, the roof extended from the entrance to a circular baptistry. Balancing the design, this baptistry supported a tall cross, which was placed opposite to the highest peak of the roof.

While Christ the King related to an urban environment, Christ in the Desert was an answer to the natural character of the Chama Canyon, and the materials available:

16. Mira Nakashima, 187
17. Ibid., 218
18. Ibid., 40

primarily stone, adobe, and wood vigas. Structure relied on the potentialities of these materials, therefore shaping the appearance of the building. The general form was expression of a central plan with four one-story wings of equal length extending from a central double-story glass lanterned nave.

The commission of this chapel came through Father Aelred Wall (1917-1983). George probably first met him while making the furnishings for the Benedictine community of Mount Savior, in Elmira, New York between 1961 and 1963. It is possible conversations with Nakashima happened before Father Aelred's moved to Abiquiu (and even Nakashima presumably had offered his place).

In New Hope, the Cloister probably drew upon this connection to the simplicity of monastic life and to the hospitality in the Benedictine tradition. As the oral history suggests the Cloister was intended to host Japanese craftsmen visiting New Hope. This program was probably related to Nakashima's association with the Minguren Movement.

In 1963, Nakashima became involved with the Japanese sculptor Masayuki Nagare (1923), founder of Minguren, who was in New York for an exhibition of his work at the Staempfi Gallery in Manhattan and supervising the execution of a stone wall of volcanic rock called ‘Stone Crazy’ at the 1964-1965 World’s Fair in New York. Nagare and Nakashima’s first acquaintance became a fruitful friendship that led Nakashima to visit the Minguren group in Japan and to rename the Arts Building as the Minguren Museum as previously described.

In the fall of 1963, Nagare brought a group of seven craftsmen from Shikoku to participate in the Japanese pavilion construction and to recreate the traditional stone masonry of Japanese castles. This pavilion, which intended to embody the best of Japan, combined three buildings that merged traditional and contemporary Nipponese designs, emphasizing the contrast between old and new, both in architecture and content. It offered an overview of the technology, products, and food along with a glimpse of pre-industrial Japan to the World's Fair visitors.

Nakashima probably abhorred the technological purview of the fair. However, the improvised character that Nagare showed during the construction aroused his sympathy. In response, Nagare invited Nakashima, being a craftsman himself, to join Minguren. Nakashima did not hesitate to collaborate with this group, establishing a strong tie that was memorialized when the Arts Building was renamed Minguren Museum. Other material evidence of this to corroborate this connection: Nakashima obtained some black volcanic stones of Nagare’s stone wall, which were used eventually in the construction of the interior masonry wall that supports the cantilevered steps leading to the second story at the Arts Building. Additionally, Nakashima placed a sculpture called ‘Keyhole’ by Masayuki Nagare, initially made for the Japanese Pavilion, near to the entrance.

Along with the architectural projects, 1964 was a hectic year. After preliminary contacts in the 1950s, and probably earlier, Gira Sarabhai invited Nakashima to visit the National Institute (NID), where he became a consultant and supplied designs for furniture. On his way to India, Nakashima visited Nagare in Takamatsu. At his return, the Arts Building and Cloister in New Hope became a natural repository for this renewed transnational interchange, as its collections and use have



George Nakashima and the first Altar of Peace completed. 1986. Neal Boenzi. Source: George Nakashima Woodworker Archives.



George Nakashima's sketch for the Altar of Peace. Note scuplture by
Source: George Nakashima Woodworker Archives.

demonstrated throughout the years. The Arts Building and Cloister bridges art, craft, and education all interwoven with a deep spiritual meaning. As defended by Nakashima, architecture became the expression of an ideal. Besides the events involving the community, this is also a space of retreat and contemplation.

2.5. The Foundation for Peace

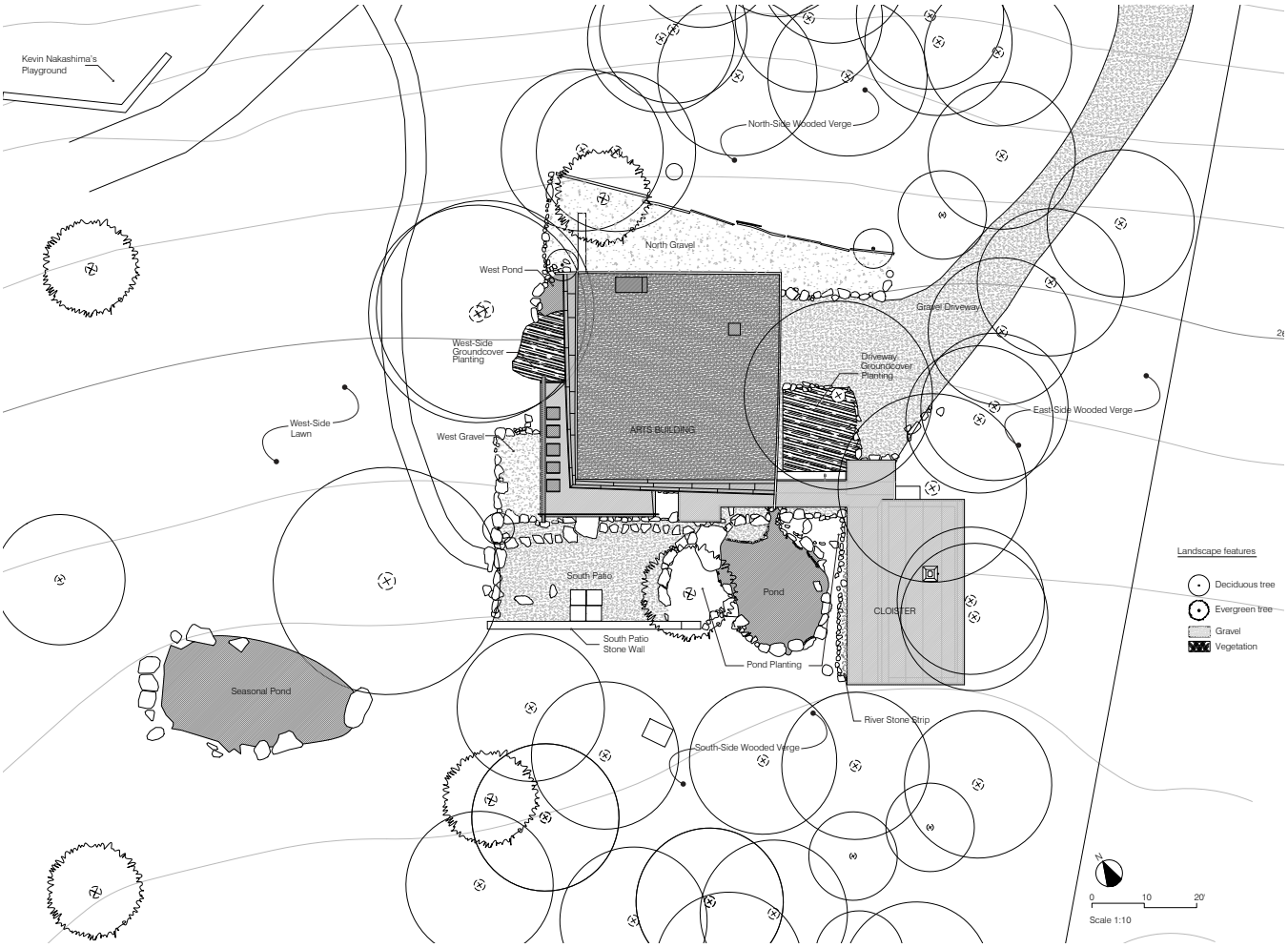
In 1983, Nakashima purchased a large walnut log from his logger, Frank Kozlosky. The log was obtained from a 300-year-old tree in Long Island, 12 feet long, and tapering in diameter from 5 to 7 feet. This extraordinary specimen became the seed for Nakashima's vision of bringing peace "as a genuine expression of nature and an act of beauty... Peace in a tangible form, instead of an abstract idea and an absence of war... the pure spirit of peace for which all people yearn and the world politicians spurn... A shrine for all peoples and owned by no one."[19]

The first Altar, to be installed at the Cathedral of Saint John the Divine in New York City and sponsored by Steven C. Rockefeller and Dean James Parks Morton, was finished in 1986, the dimensions being 10.5 by 10.5 feet. The altar was formed from two walnut boards built on a base, connected by butterfly keys, and engineered to allow expansion and contraction because of thermic loads.

When George Nakashima passed away in 1990, the first Altar of Peace was already placed and there were negotiations to install a second one in Russia.Eventually, this was housed in the Academy of Sciences in Moscow in 2001. In 1996, a third Peace Altar was dedicated in Auroville, an international spiritual community near Pondicherry founded by Sri Aurobindo and Mother Mira in 1968.

The Altar of Peace Project was renamed as the Nakashima Foundation for Peace in 1995, which would set the Altar of Peace Project and the advocacy of related cultural programs as its main goals. Marion Nakashima, donated the Arts Buildings and Cloister to the Foundation in 2003. Besides being the center for a mission committed to peace, the building houses wood boards for crafting new future altars, personal objects gathered through the years by George Nakashima and his family, prototype furniture and archival material, and it is used for concerts and other events related to the Foundation for Peace's goals.

19. Ibid., 236



Arts Building and Cloister site map with character areas.
(See Naka A-01. Site Map and Naka A-02. Ground Floor)

3. Understanding the Landscape

Nicholas Pevzner, Landscape Architect

3.1. Site History

Context and Setting

The Arts Building and Cloister landscape is part of the George Nakashima Woodworker's Complex, a collection of fifteen buildings occupying a south-facing gently sloping site nestled amid patches of residential properties and oak-mixed hardwood forest, in the Lower New England-Lower Piedmont ecoregion, just west of the Delaware River in Solebury Township, Buck's County, Pennsylvania. It is located about two miles south of the town of New Hope, PA.

The Arts Building and Cloister are the southernmost of the buildings on the property, and occupy the relatively flat ground at the bottom of the gentle slope. The landscape around the Arts Building contains a series of carefully designed gardens and plantings, interpreting traditional Japanese landscape design and mediating the Arts Building's relationship to the larger Nakashima property.

The Arts Building and Cloister is surrounded on three sides — north, east, and south — by mixed deciduous forest, and on the southwest by lawn with hay meadow beyond. The landscape immediately surrounding the Arts Building includes a straight stone wall, pea stone patio, and stone-lined pond, with associated vegetation (pond planting). The larger borrowed landscape of the Arts Building includes the individual trees to the west and southwest, and the forested character of the view to the north, east, and south.

Chronology

The immediate site of the Arts Building prior to the 1964 was predominantly forested, with an adjacent clearing that corresponds roughly to today's west-side Lawn. The Swimming Pool and the Pool House had been built three years prior, between 1960 and 1961, and were connected to the rest of the complex' buildings (such as the Conoid Studio, Chair Department, and Finishing Department) via a gravel driveway.

In 1938, an historical aerial photograph shows areas of agricultural land being cultivated amid a forested extension. This was the Bucks County's scenery Nakashima experienced before he purchaded the 3 acres of land from a Quaker farmer.

Early in the history of the George Nakashima Woodworker's Complex, the Pennsylvania Department of Agriculture planted Scotch Pine (Pinus sylvestris) on the southern slope of the property, probably for erosion control.

Prior to construction of the Arts Building, the Seasonal Pond was excavated, lined with a clay bottom and surrounded by boulders and planting.

In the 1960s, George Nakashima planted cryptomeria (Cryptomeria japonica) and Dawn Redwoods (Metasequoia glyptostroboides) along the primary Pool House

Below: George Nakashima Woodworker's Complex before the Arts Building and Cloister was built. 1962. Author: Ezra Stoller, Esto Photographics. Courtesy of George Nakashima Woodworker Archives.













gravel drive, between the Arts Building and the Pool House, in the existing clearing south of the Pool House gravel drive. In the 1980s, just west of the stepping stone path to the Arts Building, George Nakashima planted two rows of flowering cherries, which persist today.

Also in the 1980s, just to the south and east of the George Nakashima Woodworker's Complex property, the forest was cleared and a neighboring house was built. This house is visible today to the south of the Arts Building when looking out across the main Pond.

3.2. Existing Conditions

The Arts Building and Cloister landscape contains a number of primary zones, or character areas. Two main areas that dominate the design are the South Patio and the main Pond. Both echo elements of traditional Japanese garden design, and both are framed by the L-shaped covered walkway that connects the entrances of both the Arts Building and the Cloister. These two areas, along with the stone pavers of the covered walkways, are most directly experienced from within the Arts Building and Cloister, or when arriving.

South Patio

To the south of the Arts Building proper, is a raised pea gravel patio (the South Patio, see A1), which serves as the point of arrival when coming via the stepping stone path from the main Pool House gravel drive. The South Patio grade is two steps up from surrounding grade, flush with the interior floor elevation of the Arts Building. Along the south side it is held by an 18"-thick low dry-stacked stone retaining wall; along the east and west sides the patio is retained by lines of large rocks in linear arrangements.

Along the southern side of the South Patio, there is a sculptural arrangement of two large three-dimensional stones in conversation, plus a composition of four flush square paving stone plates. A slow stepping-stone path leads visitors along the northern edge of the South Patio to a very large flat mica schist stone in front of the entrance. The reflective mica in the schist stone catches the sun when viewed from inside the Arts Building, resulting in a visually dramatic experience when opening the front door (see A2).

A second row of stones, protruding slightly higher from the pea gravel, serves as the northern edge of the South Patio, dividing its fine gravel from the rougher gravel directly below the overhang of the Arts Building roof. A triangular wooden lantern, with a natural stone cap, anchors the eastern side of the South Patio.

Main Pond

The Main Pond (see A3) is a central visual feature of the Arts Building landscape. The main Pond is roughly circular, and is lined with large stones, small stones, lines of wooden posts, and planting. A small waterfall flows into the Pond from the side facing the Arts Building (see A4). The pond uses recirculated water, using a pump housed inside the Arts Building.

There are a number of fairly large stones that feature prominently in the Pond

landscape. One of these, labeled “large stone” on George Nakashima’s drawings, is exceptionally large and noteworthy, and is the focal point of the main Pond. Irregularly shaped and vaguely saddle-like, it predates the construction of the pond and Arts Building landscape, found in-situ, and roughly mirrors the hyperbolic paraboloid shape of the Arts Building roof.

Pond Planting

The Pond Planting areas are lower in grade than the South Patio, enclosed by large stones and featuring bare soil. The vegetation includes small shrubs and one large Eastern red cedar (Juniperus virginiana) tree. The red cedar tree is the visually dominant vegetation in this planting area, which spans both sides of the main Pond.

Gravel Driveway

At the north side of the Cloister and the east side of the Arts Building, the Gravel Driveway (see A5) terminates in a large parking area. For visitors arriving by car, this driveway offers the main arrival sequence. The driveway is framed by woodland trees on both sides, and large rocks framing the edge of gravel. A rectangular patch of groundcover vegetation and a Black Locust (Robinia pseudoacacia) tree occupy the corner between the Arts Building and the Cloister, framed by lines of small- to medium-sized stones delineating the edge of planting. From the parking area, a visitor can pass under the covered walkway between the Arts Building and Cloister, which serves as a spatial threshold, across a large mica schist paving stone, and into the main Pond space.

Also visible from the Gravel Driveway is the heating oil tank adjacent to the Cloister, partially screened by the ash (Fraxinus) tree in front of it.

West Pond, West Gravel, and West-Side Groundcover Planting

The west side of the Arts Building features a small pond and a patch of groundcover planting (see A6), as well as two areas of rough gravel delineated by linear frames of small- to medium-sized stones (see A7). The water in the West-side Pond is not circulated. The pond and planting can be seen from inside the Arts Building through a large full-height window. The rough gravel patch on the southern side of the west façade of the Arts Building stretches just over halfway along the length of the mosaic mural. Flowering dogwood trees are growing from between the framing rocks in two places along this stretch of west façade — in the rocks lining the West Pond and the West Gravel.

South-side Wooded Verge and East-side Wooded Verge

The woods just to the south and east of the Cloister are remnant patches of the woods that predate the construction of the Arts Building (see A8 and A9 respectively). The South-side verge is dominated by a mix of beech (Fagus), tulip poplar (Liriodendron tulipifera), black locust (Robinia pseudoacacia), and ash (Fraxinus sp.). The East-side verge is dominated by black oak (Quercus velutina) and swamp white oak (Quercus bicolor). The South-side wooded verge contains some white pine (Pinus strobus) trees and some stands of bamboo.





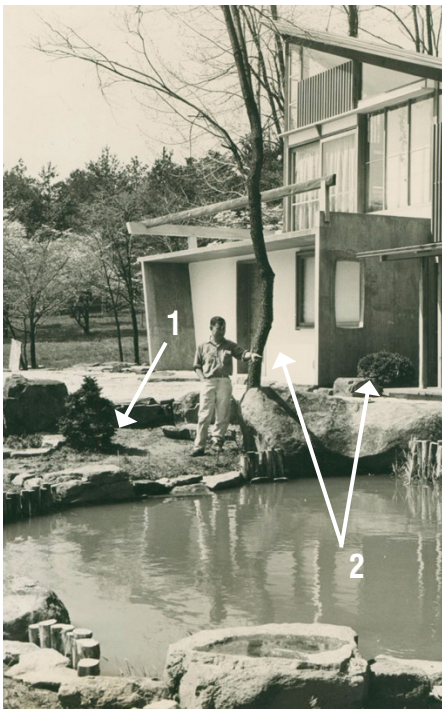






West-side Lawn and Seasonal Pond

To the west of the Arts Building and South Patio is a large expanse of mowed grass with occasional trees. Within the West-side Lawn, a Seasonal Pond acts as a visual point of interest (see A10). This Seasonal Pond is clay-lined, and lined with large stones and vegetation, but the water is not pumped or circulated. A hay meadow extends south beyond the West-side Lawn, immediately to the south of the Seasonal Pond.





South Patio and Pond Planting, Historic (1967) and Current Conditions (2016):

1. Planned vegetation that conveys original design intent, now mature. 2. Formely planted vegetation that conveys design intent that is currently missing.



Source: George Nakashima Woodworker Archives (left). Photo by author (above, right).

3.3. Analysis and Evaluation

This section offers an assessment of the integrity of the landscape immediately surrounding the Arts Building and Cloister, and traces the changes that have taken place in this historic landscape. Where appropriate, this section offers evaluations of the condition of contributing and significant elements of the historic Arts Building landscape.

Vegetation

Vegetation was an important design element for George Nakashima on the property, and this is equally true of the Arts Building landscape. As with all vegetation, the passage of time, and the process of biological growth, continually alter the landscape.

The trees and shrubs around the Arts Building can be characterized as belonging in one of three categories:

1. Those that he planted as saplings have since grown up to be large mature trees, altering the visual character of the landscape compared to historic photographs, but continuing to comply with the landscape's design intent.

2. Those that were present early in the design of the Arts Building, but that have since died and been removed, occasionally resulting in a geometric outcome that now lacks rationale. In this case, the missing vegetation is keenly felt, and its absence adversely impacts the design intent.

3. A third category of trees — those that have self-seeded and have been allowed to remain — may not have been part of the original design intent, but their removal may cause more dramatic adverse impact to design intent than their continued growth. This category of vegetation needs to be evaluated on a case-by-case basis.

South Patio and Pond Planting

The primary example of the first category — small planted trees that have grown up — is the Eastern red cedar that George Nakashima planted next to the main Pond, in the Pond Planting zone. This tree, appearing as a small seedling next to George Nakashima in the historic photo below, has grown to be a full, mature tree in the almost 50 years since it was planted. The mature tree continues to demonstrate design intent.

On the other hand, the missing deciduous tree and small evergreen shrub constitute voids that violate the design intent of the Pond garden. The dominance of the Eastern red cedar and the absence of the formerly larger and more dominant deciduous tree has altered the design intent.

While it would not be advisable to remove or otherwise damage the Eastern red cedar at present (and indeed all attempts should be made to maintain its health), if in the future the red cedar were to die, original design intent through the planting of a large deciduous tree and a small red cedar in their historic relationship could be restored.

West Gravel and West-side Planting, Historic (1967) and Current Conditions (2016):

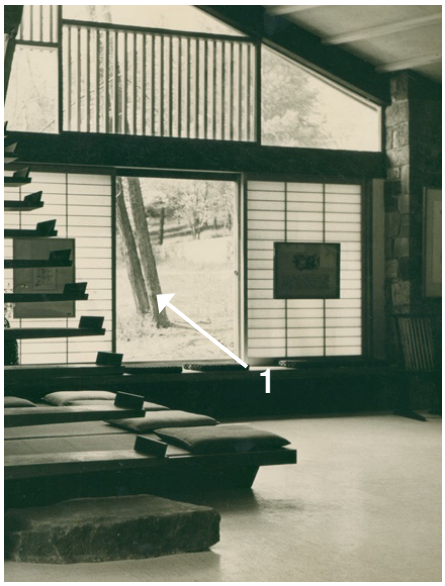
Formely existing trees that are currently missing, adversely impacting the design intent, which should be replanted (2); Self-seeded trees that were not part of the original desing intent but which should be allowed to remain (3).

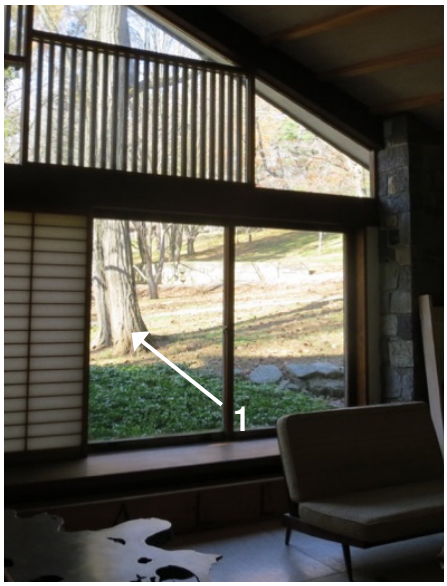




West-side Lawn, Historic and Current Conditions:

Black locust trees visible from inside the Arts Building, contributing to the Arts Building landscape (1). These twinned trees are continuing to grow well.





West Gravel and West-side Planting, Historic (1967) and Current Conditions (2016):

Missing retaining stone(s) at edge of Pond Planing (1). Stone that has moved or been added to the Pond Planting garden, resulting in an unintentional arrangement. Note also the electrical outlet at the base of the South Patio Stone Wall, which is non-contributing and which alters the design intent (2).





Source: George Nakashima Woodworker Archives (left). Photo by author (right).

The small evergreen shrub by the sliding glass door Arts Building entrance could be replaced at any time.

West Gravel and West-side Planting

Along Ben Shahn's mosaic mural wall, is another prime example of the second category: formerly planted vegetation that has since been removed, upsetting the design intent. The rectangular geometry of the West Gravel formerly responded to the presence of a deciduous tree, which is now missing.

West-side Lawn

The two large mature black locust trees just west of the West Pond, visible from inside the Arts Building and still alive and in good health, are an important contributing feature of the Arts Building landscape.

Stone

The Arts Building landscape relies heavily on sculptural stones, stone borders, flush paving stones, and larger pre-existing in-situ stones to organize space, direct movement, and serve as visual compositions. Stone is much more stable than vegetation, and most of the stone around the Arts Building remains in good shape. In several places, however, stones have deviated from the original design intent. These situations can be characterized as follows:

1. Stones that have been removed or displaced, or that have migrated, resulting in an altered design intent.

2. New stones or other elements that have been added, altering the design intent.

3. Stones that have become obscured by soil, turf, or groundcover vegetation, altering the design intent.

South Patio Stone Wall and main Pond Planting:

In the Pond Planting area that currently hosts the large Eastern red cedar tree, comparison with historic photos suggests that a large retaining stone is missing, breaking the clear delineation that historically existed between the South Patio and the Pond Planting zone.

There are also new stones present in the Pond Planting which do not appear in historic photographs, suggesting that they are indeed the missing elements of the stone border, having moved or been displaced.

Along the south side of the South Patio Wall, at the eastern end of the stone wall, an electrical outlet protrudes from the grass in front of the wall. It is a non-contributing feature, distracting from the simplicity of the wall's geometry, and the visual presence of the electrical outlet should be minimized if possible.

For stones that have migrated or are missing, attempts should be made to restore these primary structuring elements, in consultation with historic photographs. Of primary note is the area between the South Patio and the Pond Planting: attempts should be made to locate the missing stone(s) of the retaining wall border be-

tween the two zones, and to reset them.

West-side Lawn

The west-side lawn features an approach path that was recently improved with stone paving. The new paving visually dominates the more subtle paving stones on the South Patio, minimizing the feeling of arrival. The new paving also departs from the design intent for the western approach, which was intended to be much less dominant, composed of separated stepping stones amid grass. This previous version of the approach path is visible in historic photographs.

The new stone paving is non-contributing, and should be rethought as part of a restored approach sequence, which should reference the original path geometry and material.

West-side paving stone approach path as desinged, 1967 (20; current conditon showing overly dominant stone paving, 2016.





Gravel and planting areas around perimeter of Arts Building and Cloister are dotted with instances of the subterranean termite control system (2), which are not part of the original design intent and are non-contributing.



Source: George Nakashima Woodworkers Archives (above left); Photo by author (above right, right)

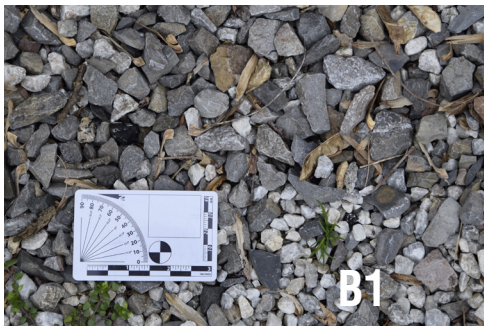
Gravels and Stone Munch

The small, loose paving material that covers up the various surfaces around the Arts Building is important not only for its visual character, but also for the tactile experience it affords, and the sound it makes when stepped on. There are five sizes of gravel present in the Arts Building landscape (coarse crushed gravel, fine pea gravel, coarse pea gravel, larger stone mulch, rounded river stones).

The original gravels are still present, and continue to contribute to the design intent, but the gradual mixing and migration of some of the gravels from their intended locations is slowly eroding the design intent of the landscape. Nakashima did not use steel borders or edging to make sharp distinctions between different gravels, so the division between zones ends up following roughly along the lines set out by linear rows of larger stones.

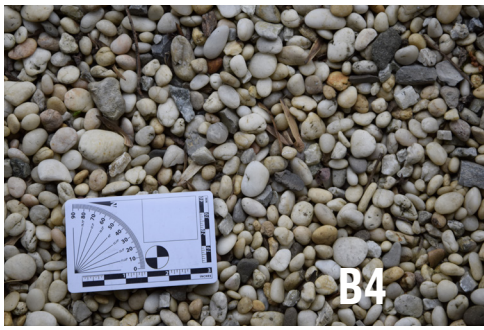
On the right, from top to bottom, the gravels are:

B1. Coarse crushed gravel at the north driveway.
B2. Larger stone mulch as used in the North Gravel and one zone next to the main Pond.
B3. Fine pea gravel used on the Arts Building entrance.
B4. Fine pea gravel used on South Patio and covered walkway.
B5. Rounded river stones as used along the River Stone Strip between the main Pond and the Cloister.











Wooded Landscape Features

There are three primary wooden landscape features in the Arts Building landscape:

1. Wooden posts lining areas along the main Pond.
2. Wooden logs lining the north edge of the North Gravel area.
3. Wooden lantern on the South Patio.

Wooden Posts

The wooden posts at the edges of the main Pond are in an advanced stage of deterioration, with some posts completely missing. They posts are in constant contact with the water; many are rotten at the base and splitting at the top. The posts should be restored or replaced as necessary to maintain their appearance as part of the pond perimeter.

Wooden Logs

The wooden logs at the north edge of the North Gravel area separate it from the North-side Wooded Verge beyond. This is the only example of logs being used to separate character areas. The date of these logs is uncertain. Follow-up interviews with employees at the wood shop and at the tree maintenance company that manages the woodland for George Nakashima Woodworker should be conducted to determine whether the logs are contributing or non-contributing features of the Arts Building landscape.











Wooden Lantern

The wooden lantern is of a design that appears in several other locations on the George Nakashima Woodworker's Complex property, and is an important contributing element of the Arts Building landscape. The lantern on the South Patio was recently remade, following George Nakashima's original design, by craftsmen in the wood shop.

Views

The primary view that extends the Arts Building landscape beyond its immediate surroundings is the view from the main gallery space of the Arts Building to the south, across the pond, towards the South-side Wooded Verge (see C1 and C2). Historically this view would have consisted of a solid wall of forest immediately beyond the Arts Building clearing, enhancing a feeling of seclusion and focusing attention on the pond garden landscape.

In the 1980s, the neighboring tract of forest just beyond the eastern property line was bought and a house developed. Much of the forest around this new house was cleared and replaced with lawn. This resulted in the forest to the south and southeast of the Arts Building, instead of extending as a solid wall of vegetation, to instead be transformed into a thin strip of porous woodland. This visual porosity is especially evident in the winter, when the deciduous trees lose their leaves, distorting the design intent of the pond landscape.

Other contributing views of the Arts Building landscape are the views to the west from the main gallery room through windows in the western elevation (see C3), and to the west from the South Patio across the Seasonal Pond (see C4 and C5). The north and east elevations of the Arts Building are solid and offer no views. The potential for the nearby East-side Wooded Verge and North-side Wooded Verge to be contributing features should be studied further.





Wooden Posts, Historic (1967) and Current Conditions (2016): Pond post at edge of main Pond, with arrow highlighting missing posts.



Balloon Photo with arrows showing the logs separating the North Gravel area next to the Arts Building, from the North-side Wooded Verge at the left of the photo-graph. Clearly visible is a stump from a freshly removed mature tree, next to one of the balloon operators dressed in red.





Wooden Lantern, Historic (1967) and Current Conditions (2016)

Source: George Nakashima Woodworker Archives (left); Photo by author (right)



Aerial view of George Nakashima Home, Studio, and Workshop complex.
Source: Pennsylvania Imagery Navigator/Delaware Valley Regional Planning Commission.

Gravel driveway from Conoid Studio to northeast parking area.

Approach













Departure













3.4. Visual Corridors

Photographs taken during a site visit in late October 2016.

The left group illustrates the sequence approaching the Arts Building from the Conoid Studio through the driveway on the eastern limit of the site.

The group on the right illustrates the opposite direction.



Aerial view of George Nakashima Home, Studio, and Workshop complex.
Source: Pennsylvania Imagery Navigator/Delaware Valley Regional Planning Commission.

Gravel driveway from Conoid Studio and visitor pathway leading to the Arts Building.

Approach













Departure







Photographs taken during a site visit in late October 2016.

The left group illustrates the sequence approaching the Arts Building from the Conoid Studio through the driveway leading to the Pool House and visitor pahtway.

The group on the right illustrates the opposite direction.



Aerial view of George Nakashima Home, Studio, and Workshop complex.
Source: Pennsylvania Imagery Navigator/Delaware Valley Regional Planning Commission.

Gravel driveway from Conoid Studio to the Pool House.

Approach













Departure











Photographs taken during a site visit in late October 2016.

The left group illustrates the sequence approaching the Pool House from the Conoid Studio through the driveway diving the group of residences, workshop and studio from the lawn.

The group on the right illustrates the opposite direction.



Aerial view of George Nakashima Home, Studio, and Workshop complex.
Source: Pennsylvania Imagery Navigator/Delaware Valley Regional Planning Commission.

Views from and to other locations on the site

1a. 

1b. 

Views of the Arts Building from the Conoid Studio (1a) and from the Chair Department (1b), respectively.

2. 

3. 

View of the large lawn on the southwest (2) and the Conoid Studio (3) from the Arts Building terrace.

4. 

5. 

Views of the Arts Building from the Conoid Studio (1a) and from the Chair Department (1b), respectively.

6. 

7. 

Views of the Arts Building from the Conoid Studio (1a) and from the Chair Department (1b), respectively.

8a. 

8b. 

Views of the Arts Building and sorrounding woodland from the west side of the lawn.

9a. 

9b. 

Views of the Arts Building and sorrounding woodland from the south lawn.

3.5. The Arts Building and Cloister Site Boundaries

The Arts Building and Cloister stands apart. Faithful to his principle of creating integrated environments, George Nakashima carefully designed the immediate surroundings of the compound. Natural features found their proper place in a progression from a selected arrangement of pavements, plantings and ponds to the wildness of nature. Exceptional in its ability to make the visitor feel peace, this environment still imparts an idea of retreat.

In legal terms, the place is comprised of two components: the Arts Building and Cloister understood as all the associated fabric within its boundary walls, and Limited Common Elements, which are the exterior architectural elements and the associated landscaped and planted areas. These limits are described in the Minguren Condominium bylaws. As a part of her estate planning, Marion Nakashima created this condominium association and divided George Nakashima Home, Studio, and Workshop property into three units. Within the Condominium, the Foundation owns the Arts Building and Cloister and has responsibility to assure the Limited Common Elements are kept in a state of good repair and condition. In its respective percentage interest and to the extent established by the bylaws, the Foundation shall contribute to the administration and burdens of the common elements, which include elements such as driveways, pathways, and parking stalls, as well as the Pool House, the Swimming Pool, and the Reception House.

The strict interpretation of the bylaws helps to limit the components described above to the fabric and the immediately surrounding designed landscape. However, the management of the place as a cultural resource compels one to embrace a broader extension. This extended area would consist of the south and east side wooded verges, as well as the views towards the west side, including but not limited to the lawn and the seasonal pond.

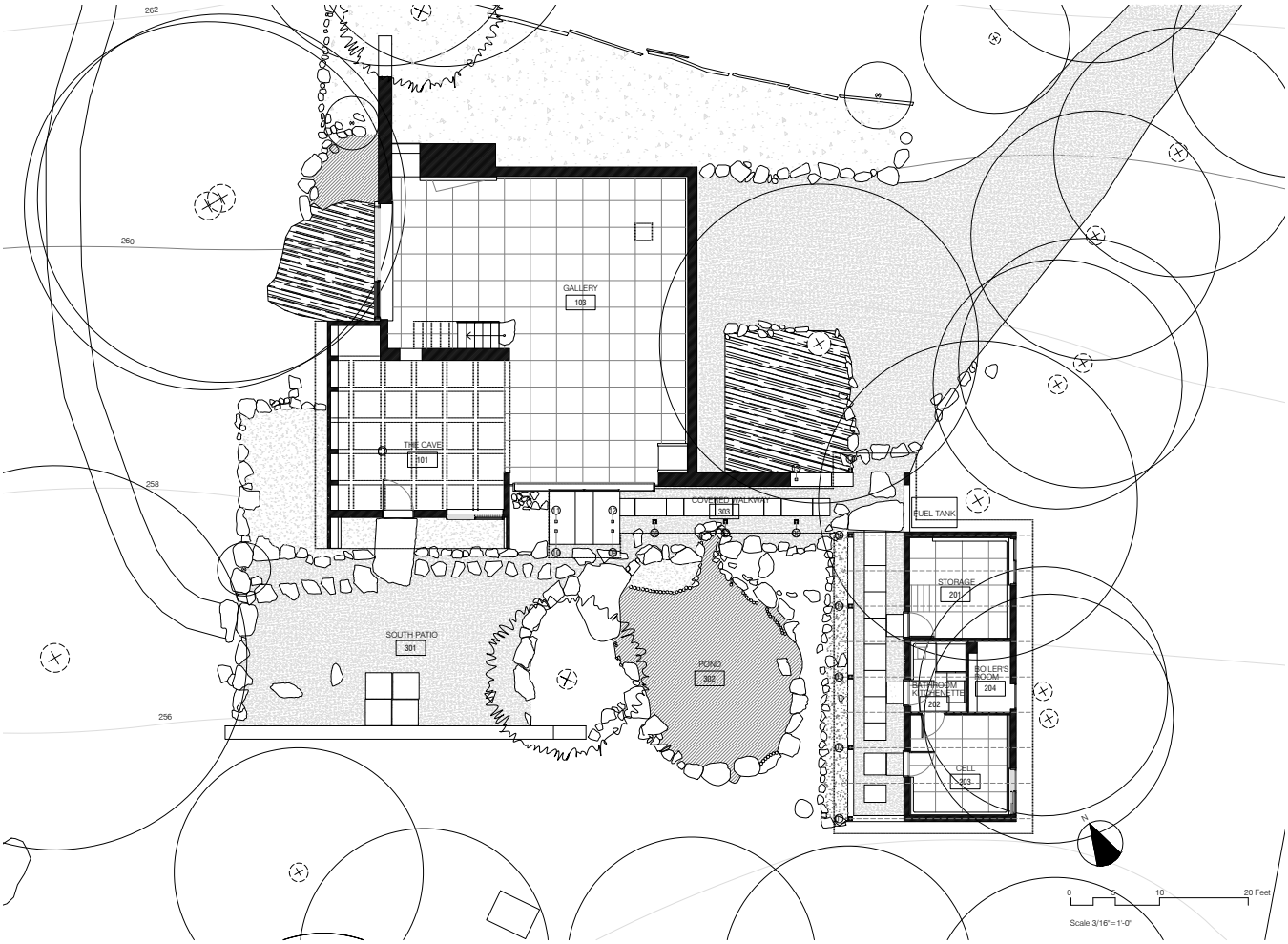
This setting contributes to the distinctive character of the Arts Building and Cloister and is integral to George Nakashima's intent. In interpreting the visual approach and departures from the place, it has been possible to define a perimeter which draws on the concept of a buffer zone. In addition to the codes and ordinances compliance, in cultural planning terms, changes within this area must be assessed regarding their impact on the spatial scale, approach and departure sequences, including the visual relationship with the rest of buildings situated on the woodworking complex.

Towards the east, south, and west, this perimeter is limited by the Minguren Condominium property boundaries. Surrounding land on the south side of Aquetong Road is enrolled in the Agricultural Security Area program. This enrollment does not guarantee that land -as is- will be permanently preserved, but provides a series of benefits that may discourage further scattered development.



Proposed buffer zone and legal boundaries

- • • • • George Nakashima House, Studio and Workshop site - Minguren Condominium
- Arts Building and Cloister - owned by the Foundation
- Limited common elements
- Proposed buffer zone
- Agricultural Security Area



Arts Building and Cloister site map with character areas.
(See Naka A-01. Site Map and Naka A-02. Ground Floor)

4. Understanding the Building

4.1 Architectural and Material Description

Visitors walking down the path from the Conoid Studio soon recognize the expressive Arts Building with its tilted hyperbolic paraboloid roof that contrasts with a restrained and smaller attached Cloister. Both buildings stand apart in an isolated wooded area on the eastern limit of the property, where the slope flattens out. As described earlier, the compound displays Japanese and Bucks County influences, which are recognizable through the use of typical architectural elements that are merged in a new way of expression. In this building, it is possible to find a combination of traditional materials, such as stone and different woods, with innovative twentieth century materials, such as plywood and concrete block.

The Arts Building is a two-story structure about 23 feet high, nearly 36 feet by 40 feet in plan, intersected by a tilted hyperbolic paraboloid that has a lower peak on the northeastern corner[1], about 9 feet high above the finish floor, and a higher peak soaring vertically approximately 14 feet on the southwest. Obliquely rising from two 18 inch-thick random rubble masonry abutments in the west and the south, the Arts Building opens entirely towards the south and west* through the interplay of structural wooden elements and single and double-glazing infill. Conversely, two load-bearing reinforced concrete block masonry walls enclose the space towards the east and north and secure the lower edges of the roof.

A reinforced concrete volume, just above 8 feet height, with a waffle slab and inclined west wall, projects outwards on the southwestern corner of the building. This volume gives form to four functions: to anchor the higher peak of the roof using an Eastern white pine post connected to a standing beam; to announce the main entrance; to serve as an exterior terrace; and to act as Ben Shahn's mosaic support. Upon this volume, an interconnected combination of wood and poured concrete handrails limits the terrace.

Connected to the Arts building by an L-shaped covered walkway and porch, the Cloister is a simple one-story construction about 11 feet tall and measures approximately 19 feet by 39 feet in plan. The Cloister structure is comprised of exposed concrete block masonry walls pierced by two windows and a door on its east elevation, and by three doors on the west elevation.

Interior spaces

In the main entrance, the transition between the exterior and the interior is formally expressed through a single ample door inserted in a white rendered 12 inch concrete block unit masonry wall, which stands recessed under the south side of the terrace. The door leads to a compressed space known as the "Cave", which is the vestibule of the Arts Building.

This vestibule is delimited by the mentioned exterior wall on its south side, an inclined wall reinforced with concrete ribs on the west side, and a stone masonry wall on the north side. The east side remains open to the main exhibition area.

* In the description, the author uses the architectural north. The building is skewed about 15° clockwise from the north-south axis.

Stone slabs of various sizes and shapes form the flooring, which is heated by a radiant heating system. A lower waffle ceiling, which consists of a six by five reinforced concrete grid, emphasizes the compressing effect. On the northwestern corner, hidden by a folding door, there is a bar with water supply. Five skylights with fixed shoji screens and a window with sliding shoji screens provides a filtered light to this space.

The exhibition area reads as a flowing, variable-height large room, divided into two sections: a large exhibition area and a sitting area around a fireplace. Reportedly, the north and east wall are plastered with Structolite™. The flooring is of vinyl asbestos tiles simulating travertine produced by Amtico. Referencing the exterior materials, the fireplace is constructed of uncoursed random rubble stone masonry. The firebox back is partially constructed with firebrick, and the front hearth is polygonal flat sandstone. On the left side of the fireplace, a casement window with a fixed pane of glass, which terminates directly into the stone wall, provides light, ventilation, and views to the north side of the building.

A second sitting room is placed on the second floor, accessed via cantilevered steps, the shape of which echoes Nakashima's earlier milk table design. This loft overlooks the main space of the gallery and has direct access to the exterior terrace through an opening with sliding doors. A walnut floor, built-in spindle-back settee (a Conoid bench with double back), and built-in shelves enriched with a variety of different connections characterize the space. For ventilation, there are two single paned casement windows with a crank handle.

Sliding windows and doors establish a clear relationship between exterior and interior on both elevations, progressing from a controlled environment to the woods, passing through a landscaped ground area that combines organic forms, such as the pond surrounded by rock arrangements, and with rectilinear elements such as a stone masonry fence to create an exterior foyer.

The Arts Building is further screened by Japanese-inspired hinged cypress grills and shoji screens. The varying combination of glazed spans and grills generates different degrees of privacy while offering shade and controlled view of the surrounding landscape.

Providing exterior shelter for visitors moving from the Arts Building to the Cloister and vice versa, the pathway structure incorporates a light interplay of ipe posts, beams, 1 inch thick plywood, and a granule-surfaced waterproof skin. The pavement is comprised of reddish fieldstone flat slabs directly placed upon the ground and with gray gravel, which covers the rest of the pathway.

Below: The Arts Building's exhibition space. Notice the cantileverd steps leading to the mezannine. November 2015.



The austere geometry of the Cloister is reinforced by the modesty of its materials. While the front of the Cloister opens up to the landscaped yard with the pond on a different level, in the rear, the Cloister walls directly meet the ground level.

Divided by concrete block partition walls, the Cloister layout is comprised of four spaces: a storage room, now used to house archival material, a service area with kitchenette and bathroom, a room for the heating system, and a small-sized multifunctional living/sleeping area. The front elevation reveals the access to the main spaces, while the rear houses the access to the room that contains the boiler.

Douglas fir wood plates rest upon the concrete block walls, and provide the necessary connection between rafters and walls. Rafters support a decking of tongue and groove fir boards, probably 2 by 4-inch. Like the covered walkway, the roof is finished with a granule-surfaced waterproof membrane. The presence of a plywood substrate as indicated in George Nakashima's sketches is unknown.

In the rear elevation, openings house sliding windows. The concrete lintels mimic those used in other buildings such as the Workshop and the New Lumber Storage. Indoors, a shoji screen diffuses the light; outdoors, a utilitarian metallic screen protects from insects.

On the front elevation, doors, which are an interplay of wood and glass covered with paper, give access to the interior spaces. As in the Arts Building, the flooring is vinyl tile simulating travertine. In the living/sleeping area, three walls are covered with Structolite™.



Above: Craftsmen placing the first plywood layer in the Arts Building. Author unknown. Source: George Nakashima Foundation for Peace.

The Hyperbolic Paraboloid Roof: Plywood, Copper, and Impervious Materials.

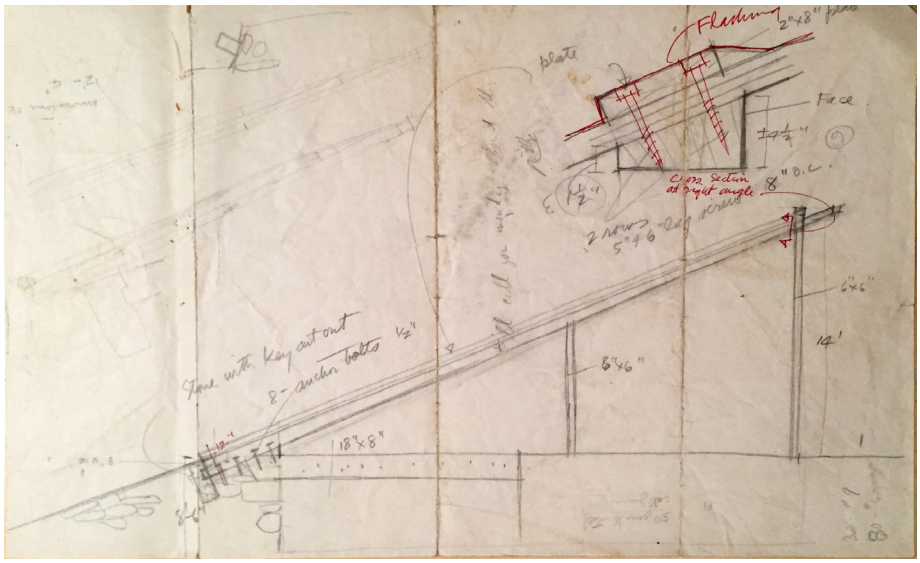
For the Arts Building, Nakashima reproduced the plywood shell roof first developed for the Main Lumber Storage (1958). However, the intentional display of visible craft at the Arts Building required carefully designed ribs and joints, and the application of a delicate white translucent finish on the exposed face of the plywood.

The New York engineering firm of Paul Wiedlinger Associates suggested the use of three layers of 1/2-inch plywood, shifted ninety degrees to overlap joints, and nailed with twelve 6d nails per foot. Hand measuring revealed that each panel is 5/8-inch thick, and 4’ wide and 8’ long, which was a common standard in the plywood industry since the early 1930s. Therefore, the as-built thickness shows an excess of 3/8-inch compared to the initial design.

Regarding the construction, Robert “Bob” Lovett, one of the builders, revealed that the three layers of plywood comprised 160 sheets, which needed to be trimmed, screwed, nailed, and glued together. Opposite sides are laid on the ribs and opposite ends, which appear not to be glued, abut to the adjacent panels. Available hand drawings show that plywood boards were fastened with 2 rows of staggered nails at the panel edge placed on the ribs.

This plywood shell was connected to tapered edge beams on two sides, and to warped plates installed on the load bearing walls. Archival photo documentation suggests that the plates were fastened with two rows of staggered bolts spaced 8 inches on center. The bolts were embedded into a poured concrete bond beam capping the concrete block masonry. Part of the bolts were countersunk to secure the plate to the bond beam. A number of them, approximately each two feet, extended beyond the plate plane and were used to join the three layers of plywood and an upper 2x8-inch plate.

The latter was installed all around the plywood shell perimeter. A sketch by Nakashima shows a cross section at right angle through the assembly on the west elevation. The plate was screwed to the beam with 2 rows of 5-inch and 6-inch long screws spaced 8 inches on center.



Cross section at right angle through plate and edge beam by George Nakashima.N.d. George Nakashima Collection, James A. Michener Arts Museum Archives. Gift of Mira and Kevin Nakashima.

The sketch also shows the structural configuration. The edge beam is supported by an upright on the upper end, at a middle point, and assembled to a notched stone at its lower end. 1/2-inch anchor bolts secured the edge beam to the masonry below. Although as built upright sections differ from the annotations, the arrangement is a fairly faithful reflection of this scheme.

Beyond the perimetric structure, the plywood shell projects to form wide eaves, which taper towards the roof's upper corner. The lower layer of plywood sets back and projects only about two feet. Currently soffits are painted opaque white. Flashing trims and fascia, reportedly made of cypress, protect the edge of the eaves. The fascia is comprised of different segements, probably because the wood was not available in the required length as well as because of later alterations. Scarf joints were used in the south and west elevations, whereas in the north and east elevations the fascia appears to be abutted and screwed to the plywood shell.

The covered walkway and Cloister's porch shows a similar fascia. An inset detail by Nakashima shows a 1 1/8-inch thick wooden strip notched to receive and house the plywood panel, whereas on the walkway an inset detail depicts a 1 3/4-inch by 5 1/2-inch cypress fascia. Therefore, these components perform a double function: they protect the edge and stiffen the border, which has more proclivities to deterioration. In the case of deterioration, they can be replaced without affecting the plywood deck.

According to Bob Lovett, the roof was finished with two layers of 3/4-inch Celotex™[20], asphalt saturated felts, and eight tons of marble chips on top of the asphalt lining. In the case of the Arts Building, the asphalt coating acted as the waterproofing coat as well as the adhesive material to maintain the white marble chips in place. These bituminous coatings may involve liquid bitumen with asbestos fibers admixed.

The hyperbolic paraboloid roof eaves are covered with copper sheets, which are overlapped and present sealed joints. The outer edges of the outward sheets are bent over an edge nailer. The outer edges of the inward copper sheets turn up to

20. Usually, Celotex™ was an insulating fiberboard which could be used as ordinary sheathing in walls and cealings. The board had a waterproofing treatment. Roof sampling will offer the opportunity to investigate and identify the type and the properties of the material.

form a gravel stop that contains the built up roofing. This assembly creates a wide channel to carry water towards the gutters. Expansion joints are not recognizable.

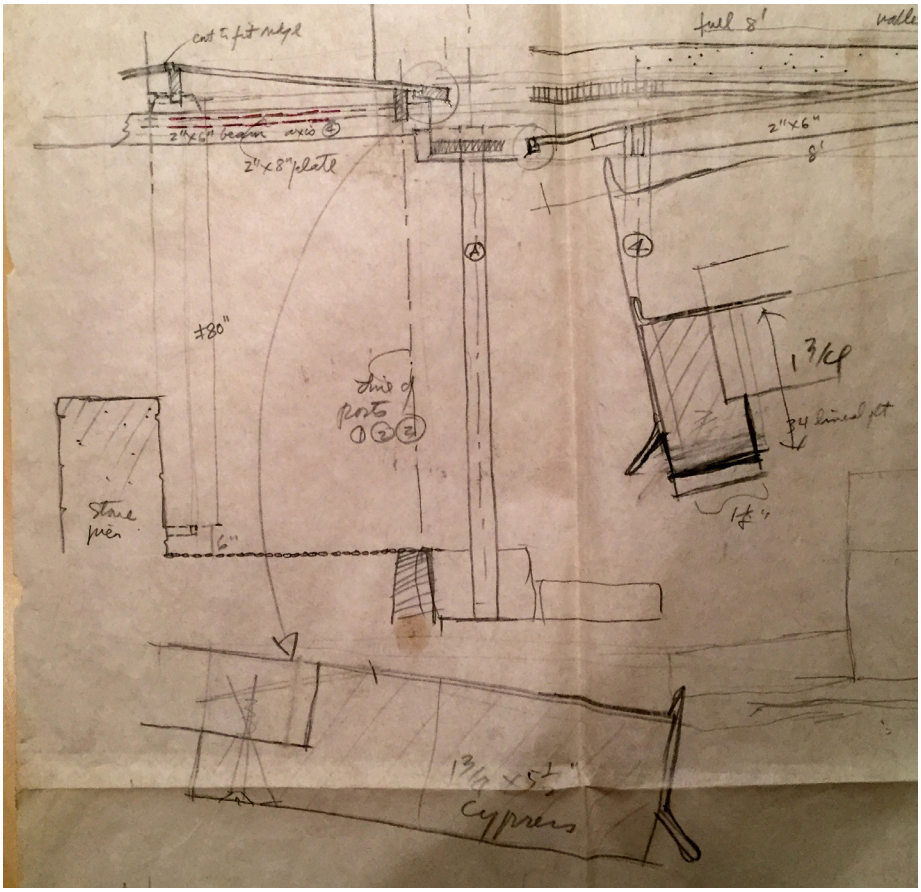
Box-style copper gutters (approximately 3 1/2" x 3 1/2") are directly fastened along the drip edge of the eaves in the north and east elevations. Instead of outlets and downspouts, the gutter ends are open and extend beyond the eaves' limits to drain the rainwater directly to two ponds strategically situated on the west and south patio. Gutters appear to be custom made, manufactured from 0.250" patinated copper sheet and the sections assembled by overlapping and nailing their ends. Numerous hidden copper hangers help to preserve the squared section shape and to connect the gutters to the gravel stops, also crafted with copper sheets.

A canopy, a deviation from the original design, protects the window seat on the west elevation. Copper sheets are connected using standing seams. Seams and edges appear to be adequately sealed. Copper is also used on the flashing of the stone masonry chimney and in the patinated copper flashing trims installed in the covered walkway, which connects the Arts Building and Cloister, as well as in the Cloister's roof and porch.

The Envelope

Stone

In the Soul of a Tree, Nakashima praised the Bucks County barns and admired the



Sketch depicting two types of fascia by George Nakashima.N.d. George Nakashima Collection, James A. Michener Arts Museum Archives. Gift of Mira and Kevin Nakashima.

stone masonry traditions of the English Quakers, thus suggesting his recognition of and reference to local materials and traditions. Nakashima admired the durability of stone masonry stating, “There is a wonderful feeling to be had in erecting a stone wall. There is a sense of order and permanence. A good wall will last for generations and even millennia.”[21]

Nakashima’s craft of stone masonry is evident in most of the buildings throughout the property, first in his residence, and then in the Showroom, the Conoid Studio, the Arts Building and Cloister, and the Reception House. In the case of Nakashima’s House, the family collected most of the stone on site and the vicinity. In the case of the Arts Building, Nakashima used a massive uncoursed random rubble masonry technology to construct load-bearing 18-inch thick abutments. The provider was Delaware Quarries.[22]

The stone masonry is comprised of a variety of stones of distinctive type, size, and color: volcanic stones (gift of Masayuki Nagare), granite, yellow sandstone, brownstone, argillite, granite, Pennsylvania black limestone, diverse colored sandstones, and possibly diorite, basalt, siltstone, and shale.

In the abutments, the stones are arranged in a random pattern with some regular courses interrupted by large stones, a technique which is reminiscent of the Bucks County stone masonry barns. Overall, shapes are irregular, from more rounded to more squared stones. Stone finishes comprise slightly dressed rubble, which include some work on face, beds, and joints. Quoin stones are squared, and are placed either as headers or stretchers; other stones act as bond stones. Special stones are carved and interlocked with the lower end of the tapered beams, creating a joint that involves both wood and stone.

Unlike the abutments and the stack, the chimney is a mixed rubble masonry with predominately roughly squared units, particularly in the corners. The cap consists of a flat stone slab resting upon concrete bricks.

The stones are laid with a lime-cement mortar, the color of which ranges from light brown to gray, a quality that is likely related to the aggregate employed. Joints range from half an inch to one inch and a half and are irregularly recessed from the stone faces approximately one inch.

Concrete Building Blocks

A genuine material of the twentieth century, the history of the concrete block dates back to the last decades of the nineteenth century. In detailing the Cloister, Nakashima annotated the use of 8" Waylite[23] on the east and west elevations.

The Cloister stands tight to the technical recommended restrictions for construction with concrete blocks. Its greatest height is around 11 feet and its maximum width approximately 12 feet. The interior partitions walls, which are keyed to the load-bearing walls, are disposed perpendicularly to the Cloister’s length, contributing thus to stiffening and stabilizing the building structure against lateral loads.

A magnetometer confirmed the presence of horizontal reinforcement on the bed joints. Vertical arrangement is unknown. If the Cloister load-bearing walls were reinforced by grouting the CMU cores is unknown. Data obtained through IRT

21. George Nakashima, *The Soul of a Tree*, 71
22. Delaware Quarries was founded by Joseph Busik in 1946 after buying a company that historically operated on the banks of the Delaware River. Busik expanded the business and diversified the stone offer under an agreement reached with other quarries, becoming thus a stone yard. The origin of the stones at the Arts Building is pressumably diverse.
23. Waylite is a type of lightweight block that was develope commercially in the 1930s.

camera inspection was not conclusive. In the east elevation, lintels, which are reminiscent of those used at the Workshop and the Main Lumber Storage, are made of reinforced concrete. Footings dimensions and arrangement are unknown.

The as-built conditions reveal the use of stretcher units and single corner units, the faces of which are on plane. Unit nominal dimensions used at the Cloister are 8 by 8 by 16-inch for the load-bearing walls, 4 by 8 by 16-inch for the partitions, and 8 by 4 by 16-inch for the top row in the plinth. At the Cloister, two types of concrete blocks that vary in color have also been identified. A dark gray color was used in the wall foundation at the southeastern corner, while a lighter concrete block, the Waylite, was used for the rest of the masonry.

The bond follows the typical running bond pattern, which at some point is replaced by a stack bond construction in the plinth.[24] It is noticeable that the mortar joint profile is concave, very likely produced with a rounded jointer, probably 5/8 inch. This joint was recommended for exterior walls because it easily sheds water.

In the case of the Arts Building, the CMU masonry walls are rendered with a white stucco. A magnetometer confirmed the presence of horizontal reinforcement on the bed joints. Presence and arrangement of vertical reinforcement are unknown. The stucco was applied as a two-coat system. The scratch coat is 3/16 inch thick, and the finish coat is 1/8 inch thick. On the interior, panels of Styrofoam™, placed between the CMU masonry and the lath provides insulation.[25] As a finish, Nakashima selected Structolite™, a ready-mix base coat plaster, that resembles vernacular clay wattle and daub plaster.

Glass

Glazing infill in casement and sliding windows, as well as sliding doors is single glass. Pressumably the weight influenced this decission. Insulated glass is used for the infill in the window walls except for the lower panes in the corners, and the niche close to the terrace. Both types of glass are original to the Arts Building. Nakashima selected traditional Japanese elements to establish grades of transparency and translucency in the carefully designed west and south elevations. Hinged grills characterize the exterior while sliding shoji are recognizable in two locations: the window seat on the west elevation and the sliding window at the side of the main door. On the south elevation, casement fabrics filter the light coming through the sliding doors at main gallery and the loft.

Infill wall

The Arts building infill panels are 2 inches thick and are comprised of six different layers. From exterior to interior: white cement stucco, scratch coat with wire mess, two 1/2 inch Celotex™ fiberboards, scractch coat with wire mesh (7/16 inch), and finish coat (1/16 inch). Both the exterior and interior finish is troweled smooth.

White Translucent Finish

To the interior, the plywood deck is painted white a translucent finish. SEM-EDS spectrum indicates the presence of titanium (Ti), calcium (Ca), sulfur (S), zinc (Zn), magnesium (Mg), silicon (Si), and minor traces of aluminum (Al), phospho-



Typical infill wall. Arts Building, West elevation.

24. The running bond is a concrete masonry bond having successive courses of overlapping stretcher units with head joints falling in the middle of the unit in the previous row. In the stack bond, the overlap is less than 1/4 of the unit length.
25. Reported by Aram Dadian, who participated in the roof repairs in the early 1990s.

rus (P), and potassium (K). These chemical elements suggest that the pigments can be titanium dioxide plus calcium sulfate. Presumably with addition of zinc oxide, as well as magnesium silicate as extender. CCD Raman analysis confirmed the presence of titanium dioxide and calcium sulfate. The complexity of the spectra suggests that the binder is a combination of different oils, which have not been identified yet. Alkyd is excluded.

The Use of Reinforced Concrete

Recalling traditional Japanese coffered ceilings, George Nakashima chose a waffle slab to cover the wide space of the vestibule in the Arts Building. The extant framing is a six by five grid of identical squared spaces. In the row next to the inclined wall, the spans were substituted by openings to house five skylights.

Essentially, the waffle slab is is a reinforced concrete monolithic two-inch thin slab integral with six by six-inch tapered joists. It is supported by exposed concrete walls on the east and west elevations, and by a stone masonry wall on the north. The wide span on the east is possible due to an upturned beam. This structural arrangement exhibits Nakashima's mastery to craft the creative and aesthetic aspects of the structure, while controlling technical aspects.

Although the as-built reinforcement is unknown, during a visit to the Michener Museum in March 2015, a frame plan by Paul Weidlinger shows the typical reinforcement for the joists and the slab. It was recommended to install two #4 rebars in the upper section and one #9 rebar in the lower section of each joist, and #4 rebar at 12 inches between joists. All concrete walls below the grid slab had to be 8 inches thick with #4 rebar 10 inches each way in each wall. Rebars in the joists in the north are bent and anchored into the wall.[26]

In the early 1990s, the framing experienced a significant deformation that caused cracks providing an easy path for rainwater. This condition prompted an improvised solution and resulted in the installation of a vertical wooden log. This support, located in the intersection of two joists becomes a vertical continuation of the upright that bears the higher peak of the hyperbolic paraboloid roof.

Flooring materials

A combination of traditional and modern flooring materials establishes an interrelationship between the interior and the landscape. The Cave floor is laid with local stone slabs of different sizes and shapes. The main gallery space floor is laid with vinyl flooring, which was also used to cover the Cloister floor. In the loft, a raised walnut floor partially covers the exposed concrete.

On the exterior, different sizes of stones add visual interest while at the same time accomplish a functional purpose. Overall, walkways are made with irregular flagstone, but in the covered pathway, where the flagstone shows a more regular and square shape; pea gravel completes the path. A dark river rock band is used to cover the ground that receives the water runoff from the Cloister roof.

Nakashima selected artificial Amtico™ Travertine tiles of 36 by 36-inch size with 1/8-inch thickness installed upon a smooth concrete base, the adhesive being unknown. This dimension exceeds the standard 12 by 12 inches; 3/32-inch gauge

26. The original framing plan, projected by Paul Weidlinger Consulting Engineering, suggested a six by six grid of identical squared spaces.
27. American Biltrite Rubber Company, which still exists, was founded as Ewell Rubber Company in 1908. The company first produced shoe heels and soles entering into the flooring material industry in the first decades of expansion. In 1961, American Biltrite acquired Bonafide Milles, Inc., a manufacturer of vinyl-asbestos and asphalt coverings, which doubled the production abilities of its Amtico Rubber Flooring division, which produced solid vinyl and rubber floor coverings.

Amtico Rubber Flooring, a subdivision of American Biltrite Rubber Company[27], commercialized under the vinyl-asbestos travertine tiles type.

The fact that Amtico produced such a diversity of flooring materials implies that the tiles used by Nakashima might be free of asbestos since 36 by 36 inch was a standard within the solid vinyl tiles.

Building Mechanical Systems and Installations

Building mechanical systems and installations in the Arts Building and Cloister include heating, electrical installations, telecommunications installations, plumbing, and sewage collection systems.

Heating is based on a central system that feeds pipe radiations. Each radiator is a welded steel pipe with steel radiating fins and is connected to the following radiator by the pipes. These elements are mounted along the east and north elevations, as well as under the window seat and concrete curb on the west elevation. The radiatiors are integrated into the architecture by housing them under a wood board that reads as a baseboard all around the main gallery. Pipes installed below the stone paving heat the Cave.

The boiler is housed in the Cloister, in a utility room with access from the east side. The fuel tank stands outdoors on the north side of the Cloister, partly hidden by the concrete block masonry and a wood grill. Thermostats strategically placed in the interior assist in regulating the comfort level. During the site visits in the fall and the winter, heating was operative.

Although not original, artificial lighting is occasional and strategically located, enhancing the architectural experience. Kent Hall and desk, as well as Noguchi-style lamps, are used in the interiors, providing an indirect and filtered warm light. The lights in the skylights in the Cave are not longer functional. There is a light fixture inside the wet alcove. The skylights have adequate electrical installations for housing lights. However, in their current configuration they do not allow space for a bulb. Outdoors, there is a tri-legged lamp installed on the south patio and two aluminum sconces on the Cloister.

There is no air-conditioning system. However, the casing windows strategically placed in the loft area and sliding windows and doors allow enough interior natural ventilation.

A water pipe system distributes water to a faucet and heater installed in the bar at the Arts Building, and to a kitchenette, shower, and toilet housed in the Cloister. The design and sizing of the sanitary sewage system, installed below grade, is unknown.

Ben Shahn's Mosaic Mural

As described earlier, prior to his death, Ben Shahn painted a gouache cartoon, "Poet's Beard", that served as the design for a mosaic mural to be ultimately installed in the Arts Building. The location, the angled concrete wall on the northwest elevation, was described by Nakashima as follows:

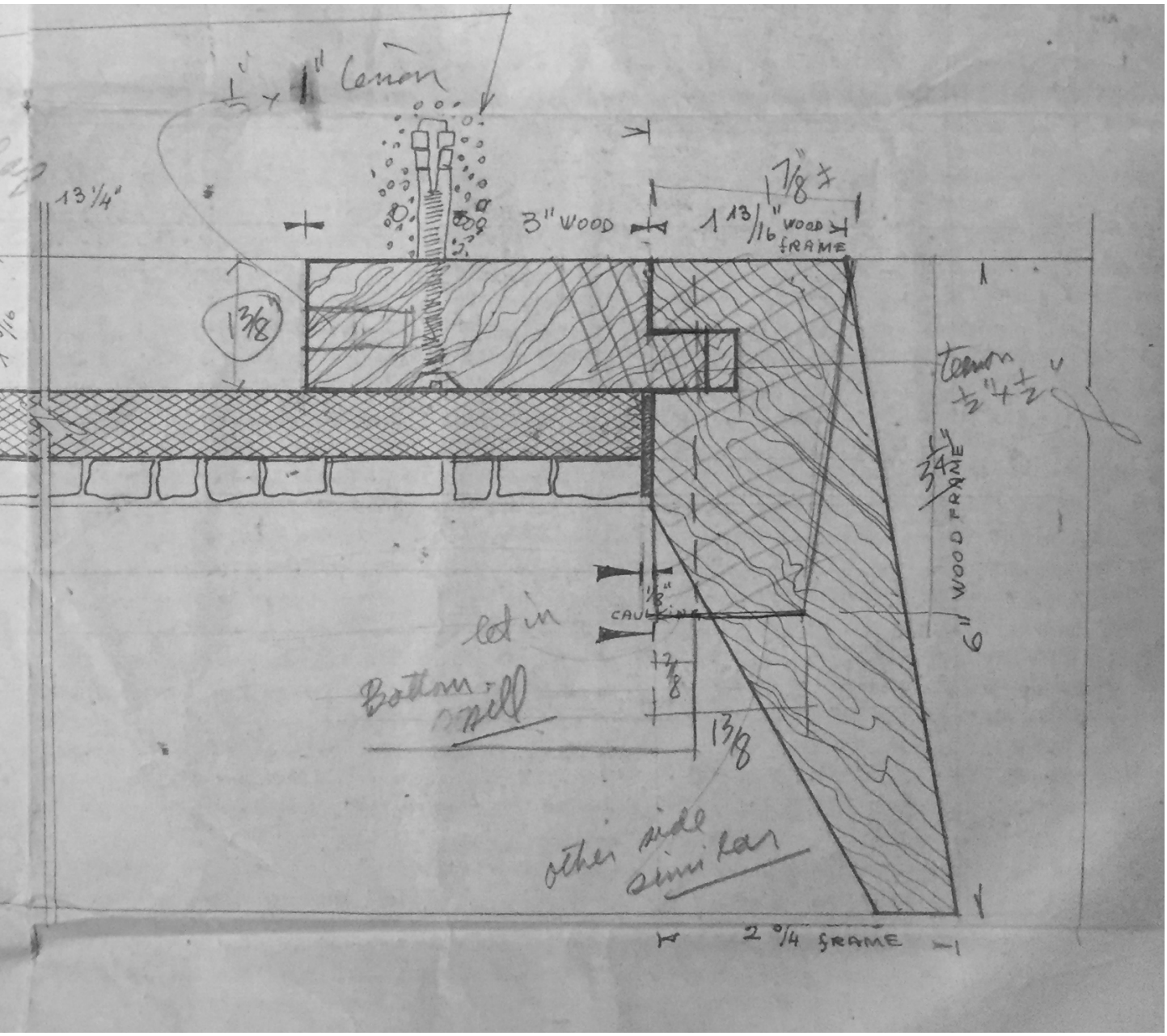


Fig. 4.1. Detailing for installation of the mural mosaic.
Provided by Gabriel Loire, June 1970, with corrections by George Nakashima.
Source: George Nakashima Collection, James A. Michener Art Museum Archives.
Gift of Mira and Kevin Nakashima.

> It is somewhat forward at the top and slopes back, so that it is well protected from the weather. There is almost no rain that falls on this wall and it does not freeze, so we feel that it would be very favorable for a mosaic of this kind (…)
> It will be principally black and white, with a few areas of brilliant color. We think it is very beautiful and it is at one end of a large field, with a few small trees in front of it. The vista to the mural is quite long; it can probably be seen from something like 300 feet away.[28]

The seven feet high by approximately twenty-three feet wide mural was manufactured in eight panels by Gabriel Loire in Chartres, France and shipped to New Hope during the fall of 1970. The mural was divided into eight panels that were mounted together during the process of manufacture to control and minimize as much as possible the visual impact of the joints. Together with the panels, Gabriel Loire delivered detailed plans and instructions for the installation. Although the archival documentation does not contain information about the materials employed for the manufacture, Jacques Loire reported the use of marble tesserae (which can be an highly metamorphed limestone), tesserae made of glass paste from Venice, and slab glass (French: dalles de verre, which is thicker than the common stained glass). These tesserae were cut with a hammer in the studio and positioned with a mortar of epoxy resin on plywood boards.[29]

External visual investigation reveals that the panels are screwed to a hidden frame. The correspondence between Pierre Massin de Miraval, the art agent, and George Nakashima are a very illuminating source and explain the process of how the panels had to be installed. Additionally, the detailed drawings of construction with hand corrections also provide useful information to understand the elements that were probably installed in order to maintain the mural in place. The joints between panels were designed to show the minimum possible. For this purpose, the mural was completely mounted and demounted at Gabriel Loire's workshop.

A letter signed October 13th, 1970, indicates that eight bags were provided together with the panels. Each one containing nineteen numbered tesserae corresponding to the locations of the screws to be covered. The explanation was clear, "when the screw is screwed, you have to cover the screw head with the numbered piece of mosaic for that screw with epoxy. You can easily understand that this way, the screw heads become invisible."[39] It appears that the final solution was to employ a type of elastomer adhesive, although it could be a repair treatment where the epoxy failed.

Nakashima modified the detailing proposed by Gabriel Loire. A wooden frame was intended to house completely the mosaic. However, Nakashima excluded the upper rail from the final installation. In addition, the tapered sill section was changed to a squared one, in which Nakashima would ultimately use a Japanese- inspired joint. A grid of dimensional lumber screwed to the concrete wall was proposed to serve as the backing for supporting the panels. A total of 24 strips were used. Seven 4 by 1 3/16 inch strips, wider to receive a screw, placed each 35 1/4 inch center lines, and 10 3 by 1 3/16 inch strips regularly arranged in between.

28. Letter from George Nakashima to Gabriel Loire, January 26, 1970. George Nakashima Collection, James A. Michener Art Museum Archives. Gift of Mira and Kevin Nakashima.
29. Jacques Loire. Email to the author. December 16th, 2016.
30. Letter from Pierre M. de Miraval to George Nakashima, October 13th, 1970. George Nakashima Collection, James A. Michener Art Museum Archives. Gift of Mira and Kevin Nakashima.



Fig. 5.1. View of the west elevation from the north. Note the original gutters, the original head in the sliding window, and the skylight domes. The concrete floor of the terrace is exposed.
Source:
George Nakashima Woodworker Archives



Fig. 5.2. Northwest elevation view. Date: December 2104. Note the new gutter system, the copper canopy , and the new flat skylights. The copper patina is indicative of new and old flashing campaigns. The concrete floor of the terrace exhibits a waterproofing coating painted in white. Landscape features have been changed overt time.
Source:
Architectural Conservation Laboratory

4.2 Architectural Archaeology

This section presents the research findings regarding the alterations to the building. Methodology employed the direct observation of the building itself, the comparison of archival images to the as built conditions, the recollection of maintenance and accounting records, and interviews. The following individuals reported their memories of past repairs: Mira Nakashima, Kevin Nakashima, John Lutz, and Aram Dadian.



View of the Arts Building under construction. Note the flashing sheets covering the north overhang. An upturned fascia board is visible on edge. This configuration creates a wide channel to carry off rainwater and snow melt to the ponds at the west and the south. Courtesy of George Nakashima Foundation for Peace.

Water Disposal System

The collection and disposal of rainwater and snow melt are a critical aspect for any building. In the Arts Building, eaves and gutters are the principal means of carrying water off the roof, which ultimately protects the building. In the case of the Cloister, a shed roof drains towards a band of river stones laid out adjacent to the porch.

The photographs taken during and shortly after construction reveal a different material and configuration on the lower eaves of the hyperbolic paraboloid roof. Forming a continuum with the roof, the flashing protecting the eaves along with an upturned fascia creates a wide gutter.

Reportedly, failures on the design of this experimental detailing facilitated moisture infiltration that eventually caused rot and prompted the replacement. Pressumably performed in the early 1990s, the repair involved the replacement of deteriorated plywood underneath the eaves, new flashing, a new built-up roof and the installation of the current box-like gutters. Although this design deviates from the original intent, it appears to function better.

In 1994, another major alteration to the exterior was the repair of the window on the west elevation. This repair included the installation of a copper canopy designed by Mira Nakashimal, which would conceal both the white eastern pine lintel and the head of the original window (see figure 5.1.).

To control leaks, the original exposed concrete terrace was waterproofed with a fiberglass membrane in a first campaign and painted white with an epoxy based coating in a second campaign. This intervention disrupted the original finish and aesthetic qualities of the exposed concrete, although it provided a watertight seal that protects the interior from moisture penetration.

The Covered Walkway and the Cloister Roof

In the south elevation, the black locust bearing posts of the covered walkay and the porch were replaced in two different repair campaigns in early 2000s. The intervention also altered the original finish of the plywood soffit in a large area of the porch.

The original posts stood directly upon the concrete block masonry in the porch area and upon concrete bases in the rest of the walkway. These posts were reminiscent of the details of traditional Japanese farmhouses. The model for the post was the menkawa, a post with four planed sides, and four unplaned surfaces that are left with the natural contours.



Above: views of the Cloister from the terrace and the south patio. Note the ballasted roofing and the gravel stops. Courtesy of George Nakashima Foundation for Peace

A Japanese-inspired cross-shaped open mortise is cut in the top of each post to connect three joist members on three faces of the post: two porch girders and a roof rafter, which pass through. The joint works like a triple plug-connecting joint. The first two elements to be connected are the two girders, which have a tenon of the same length that projects half the distance of the post section. The second part of the assembly is the roof rafter, which is perpendicular to the other two girders, placed over them securing the connection in its upper part.

Unlike the original configuration, the new uprights rest upon ipe Japanese-inspired bases, which are a truncated square pyramid. This detail was modified presumably to discourage rot at the post base. Upper connecting joints were replicated to join new and original members.

Girders and roof rafters appear to be the original in the porch area; however, although the plywood sheets appear to be the original, they have been relocated and painted with an opaque white paint different from the earlier translucent white 'stain' used by Nakashima. Furthermore, on the north side, where the parking area is located, two joists have been replaced by machine made members, one of which is a glue-laminated joist.

Replacement has involved roof waterproofing and new copper flashing. However, as the archival images show, the sheds were a ballasted roof. Gravel stops are visible on the perimeter and on the Cloister roof recognizing the footprint of the living space underneath.

The Exterior Envelope

Regardless of the canopy addition on the west elevation, the Arts Building and Cloister's exterior envelope possess a high level of integrity. Subtle repair occurred as elements deteriorated, usually in kind.

On the upper level, the wooden rail support appears to have been replaced in kind. In addition, the sliding window sill was replaced because it was rotten.[31] Above it, the thin wall was cleaned and repaired with a similar finish. (Fig. 5.3)

Repairs to the stucco on the main entrances were done as well. As reported by Aram Dadian, the proportions were two parts white Portland cement, one part lime, and three parts white sand. On an area around the northeast corner, a whiter cementitious mortar was used for filling cracks, resurfacing spalled areas, and repairing chipped edges.

In early 2000s, the five acrylic sky domes observed in Fig. 5.1 were first replaced in kind, and ultimately, by customized skylights. The earlier sky domes consisted of a fiberglass dome installed in an aluminum frame. The new installation was thought to facilitate water seepage and eventually were substituted by functional skylights, which were manufactured by Aram Dadian with wood and polymethyl methacrylate sheets.

31. This intervention took place after George Nakashima died. The contractor found some difficulties in replacing the original element because of the craftsmanship-inspired details, and he stated that the building was "like a cabinet" because its members were interlocked.

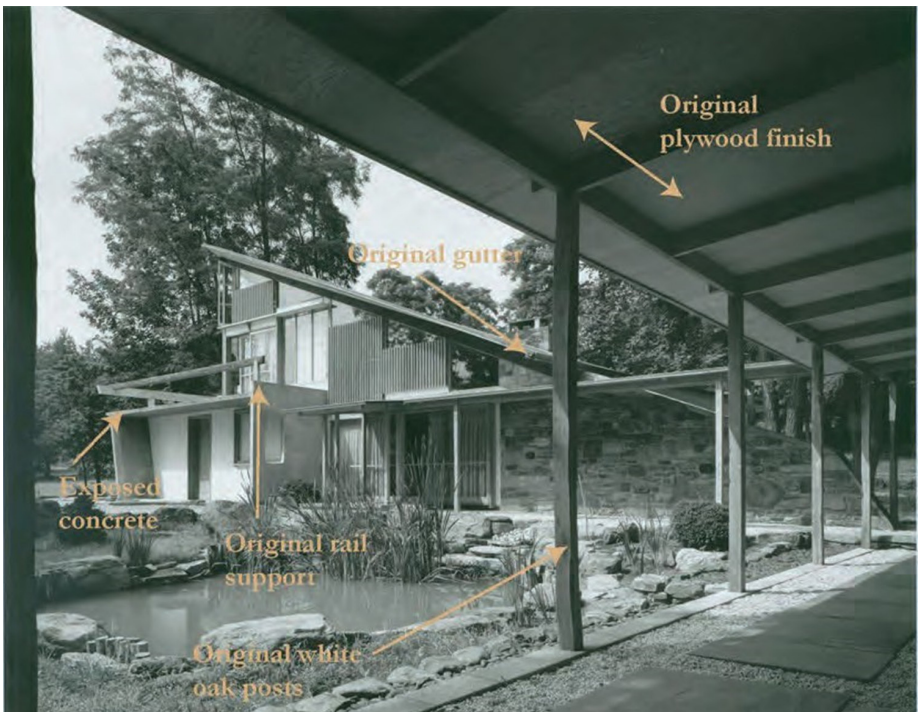


Fig. 5.3. South elevation view. Date: 1965. Note the original black locust posts, plywood soffit finish, rail support, and gutter. Source: George Nakashima Woodworker Archives.



Fig. 5.4. South elevation view. Date: December 2014. Note the new gutter system, the new ipe posts upon ipe bases, and the opaque white paint covering the plywood soffit. As shown in Fig. 5.1, the concrete floor of the terrace has been waterproofed.



Interior of the Cave from the Gallery. Courtesy of George Nakashima Foundation for Peace

Interior

An early photograph of the Cave reveals that panels covered with Japanese paper were installed on the niches between the concrete stub walls. The wider middle niche was Japanese bark paper.[32] The adjacent niches show two other different patterns. Three shelves inserted between the spans, were located at different heights and projected slightly. *Shoji* screens, which diffused natural light from the skylights, were flush in the lower face of the concrete grid. At least three systems have been used to hide the wet alcove: a divider, a curtain, and, eventually, a folding door.

In the early 1990s, a wooden column was installed to support the waffle slab, which had a noticeable deflection that compromised the structure and the building tightness. In the area, surrounding the post base, removal and reinstallation of the floor stone is recognizable. Original stone slabs were removed, probably to place the footing for the wood column and cut later as they were adjusted to the column perimeter. A change in the color of the cementitious mortar used for the joints is noticeable.

Reportedly, leaks deteriorated the finishes of the inclined wall. Panels and shelves were removed, and the wall was rendered with a white plaster with a rough finish. Ghosts on the sides of the stub walls indicate the original position of the former shelves. Mira Nakashima recalls that when the wood shelves shrank, because of the hygroscopic nature of the wood, they became loose and usually fell out.

Above the fireplace, the lintel was replaced as a consequence of carpenter ant activity. Repair occurred to the adjacent window as well. Below, a 1967 photograph (fig. 5.5) partly shows the original lintel over the fireplace. As the wood was cut parallel to the grain direction and tangent to the growth rings, a wavy plain grain characterized this beam.

The grain figure of Nakashima's original fireplace lintel was undoubtedly selected in relation to the heavily patterned exposed plywood ceiling, which is still visible. Although the replacement lintel reveals a sensitive repair, this visual relationship is now lost (fig. 5.6). Reportedly, the plywood deck along the north wall was replaced and repaired in kind to mend the deterioration caused by leaks. During this intervention, the skylight was also covered in the same manner as those in the exterior terrace.

In summary, failures related to deterioration from moisture have compelled specific alterations to the Arts Building and Cloister over time. Changes have ranged from sensitive in kind replacement such as the fireplace lintel and window to repairs that have modified the visual appearance and presumably improved the functionality of certain details such as the replacement of the posts in the covered walkway. In 2016, repairs include the refinish of the loft floor, the replacement in kind of the south black locust railing, and repointing of the stone masonry chimney.

32. Mira Nakashima. Email to the author 01/28/2017.

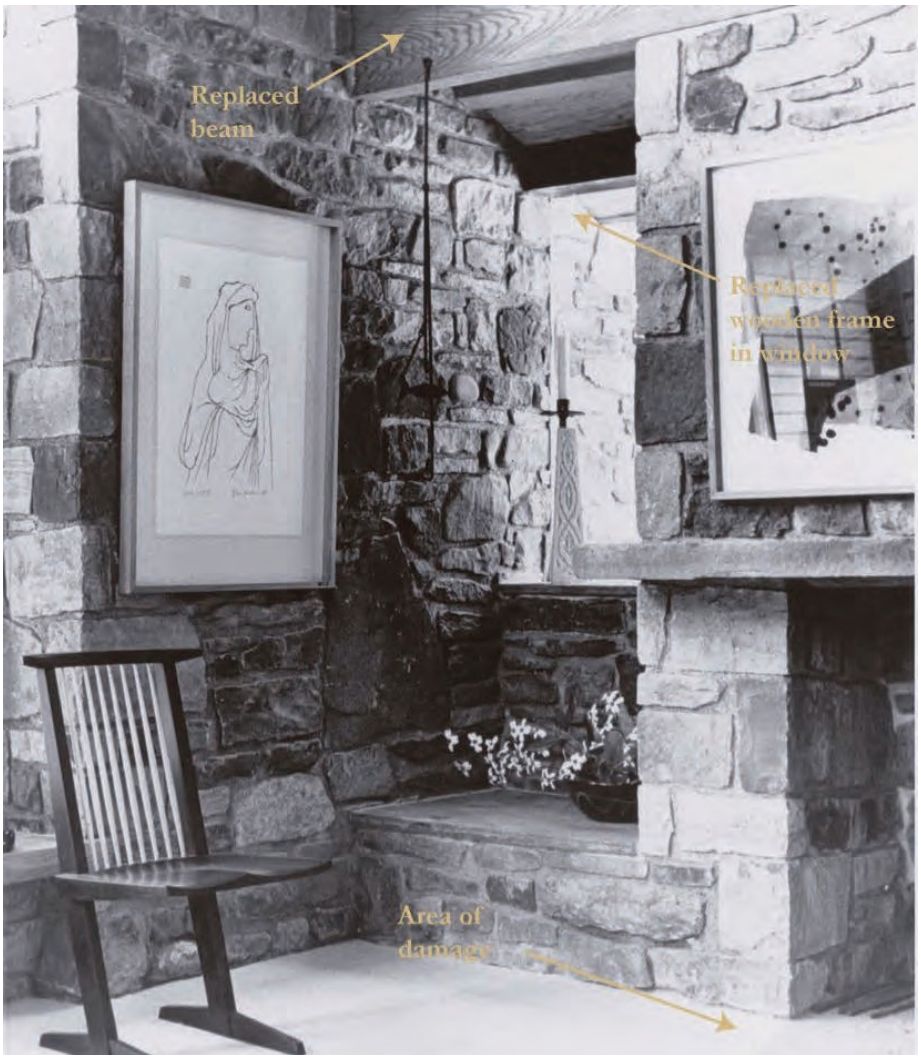
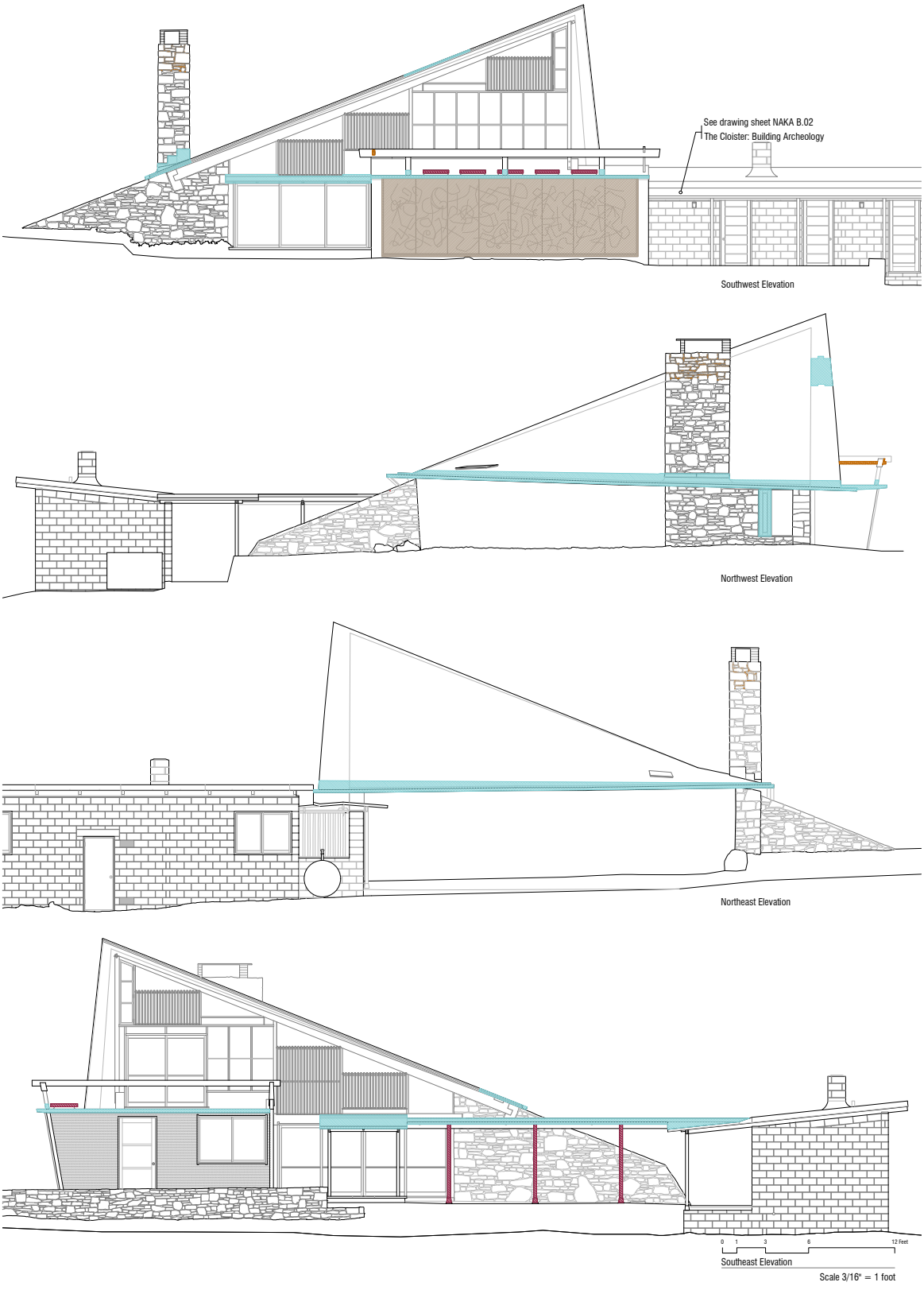


Fig. 5.5. Fireplace corner. Date: 1967. Author unknown. Source: George Nakashima Woodworker Archives.



Fig. 5.6. Current state of the fireplace corner. Date: November 2014.

Alterations to the Building Fabric



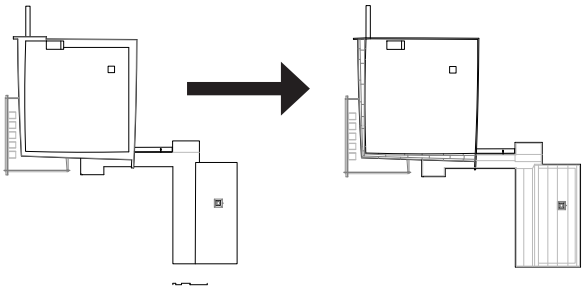
1967



1970s



"The Poet" mosaic mural is installed.



East and north eaves were repaired and the water disposal system modified.

1990s



2000s



Black Locust *menkawa* posts are replaced by Ipe straight uprights.

2010s



Repair works on the chimney stack.

4.3. Conditions Assessment

This section identifies the primary processes of deterioration observed at the Arts Building and Cloister. Conditions are recorded by building element and location. They are discussed regarding the original material and subsequent alterations and maintenance, as well as their environment. In the following section, the consultants provide an assessment based on their respective areas of expertise. Note that the climatic and situational contexts are described in section 5.6. Envelope and Interior Assessment by Michael C. Henry.

Preliminary visual survey took place during two field visits in February and March 2015. On February 15th, 2016, César Bargues conducted investigation with an IRT Camera to detect failures in the building envelope. On November 4th, 2016, the condition assessment was reviewed.

Conditions were noted and categorized according to standards such as the ICOMOS ISCS: Illustrated Glossary on Stone Deterioration Patterns, ACI Concrete Terminology, and the National Park Services' Preservation Briefs. Additional categories were created to cover all identified conditions not included in these documents. As a result, specific terms are defined in an illustrated glossary that is organized by categories depending on the building parts: roof, stone masonry, CMU masonry, reinforced concrete structure, wood frame, mosaic, interior finishes, and flooring.

Findings

A. Arts Building

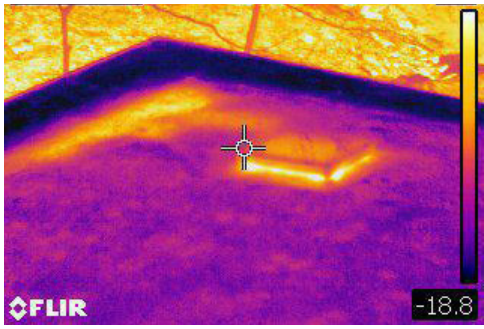
Hyperbolic Paraboloid Roof

The investigation of the building envelope with an IRT Camera revealed a thermal anomaly on the north end of the hyperbolic paraboloid roof. Roof probes, approximately each two feet square, demonstrated the presence of moisture entrapped below the asphalt underlayment. The fiberboard insulation is saturated and the outer face of the plywood deck was visibly wet but not deteriorated. The area of damage is about 9'x14'.

Pressumably, this condition is associated with a leak detected and repaired in the summer of 2015. This leak was caused by a roof puncture close to the north side of the skylight, where the ballast layer was unevenly distributed.

The removal of the ballast for repair revealed that the asphalt lining is in overall good condition. Embedded aggregate or loose stone ballast upon the asphalt lining slows down their rate of aging. However, where marble gravel was washed out for long period of time, the exposed asphalt lining shows alligatoring[33].

Service performance of roofing asphalt depends upon chemical and mechanical characteristics. Chemical changes resulting from exposure to light, heat, and oxygen facilitate oxidation and produce progressive embrittlement. Therefore, service stresses, which include the gravity loads depending on the inclination, and thermal expansion and contraction can cause alligatoring and eventually failures







From top to bottom:
A. Infrared image of the northeast end of the hyperbolic paraboloid roof. February 15th, 2016.
B. Cutting plugs to investigate the roof. May 9th, 2016.
C. Saturated fiberboard insulation and wet surface of the plywood deck.

33. Exposure to UV light result in composition and moisture content as a roofing asphalt ages in service. The shrinking of the surface results in an appearance that resembles cracks.

where the moisture can migrate.

On the eaves, the flashing elements show different rates of weathering, accordingly with the replacement and repairs done in the past. A greenish patina covers the eaves, while the more recently installed flashing and gutters remain dull brown with green staining because water carries the corrosion products of both eaves and earlier elements.[34] Typically, a discrete crack is visible on the flashing sheets contiguous to a flashing juncture. This condition is related to the design and the restriction imposed to thermal expansion and contraction. In a number of locations, sealants are failing and show a lack of adhesion. In the south elevation, the lower end of the flashing covering the edge is loose.

The copper gutters show crevice corrosion and galvanic corrosion in all the junctures because of direct contact between dissimilar metals: the steel nails and the copper sheet. If this type of corrosion continues, current leakage in the junctures will be expedited. Furthermore, there is noticeable damage because of impact to the gutter edges; a section has been deformed probably by fallen branches. The base exhibits damage by marble chips carried off by the snow melt and rainwater.

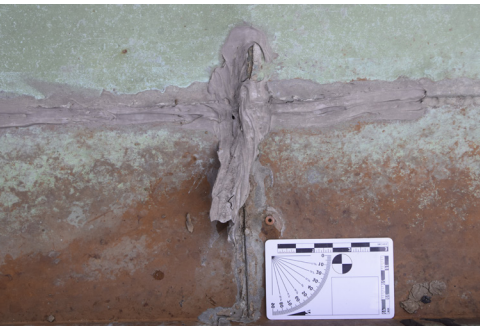
During the site visits, tree litter and moss patches were visible covering the ballast on some locations. Marble gravel washed out from the roof and leaves were clogging the gutters. This condition can allow the rainwater to overflow directly to the ground by one side and on the eaves' edges on the other side. This worsens the moisture-related problems on the north and east walls and contributes to faster decay of the fascia.

Regarding the roof plywood shell, the assembly is exposed to interior and exterior conditions. While the ceiling in the interior is in excellent condition, on the exterior, the plywood shows rot and minor damage from animal activity. A number of baldcypress ribs show moisture stains caused by a past leak not longer active or conditions during the construction process. Such stains are minor visual alterations that do not affect the wood structurally.

Both on the exterior and the interior, the plywood sheets show minor microchecks, which appear on the surface in the form of multiple hairline cracks or slightly open superficial parallel splits of different lengths. Particulary on the exterior, under severe moist and dry conditions, according to the technical guides, these checks may in time become cracks penetrating virtually the full thickness of the face.

Causes of these checks are found in the chemical properties of the wood and the plywood characteristics as a composite material. On one hand, the wood cell wall is largely made up of cellulose and hemicellulose, and the hydroxyl groups on these chemicals make the cell wall hygroscopic. Conversely, the differential moisture conditions to which ply faces are exposed create differential stresses that compromise plywood performance. In fact, under high humidity conditions, the outer face of the exposed veneer expands, while the inner face is relatively fixed because it is glued to the next ply, which is placed crosswise. Fibers in the exposed face then create compression stresses against one another. When the fibers dry out and shrink, they pull away from each other, creating checks of different intensity. This phenomenon can be more severe under rapid drying than

34. When exposed to atmospheric conditions, a conversion film turns the initial light reddish-brown copper from light brown to darker colors and then to greenish turquoise over the years. This patina makes copper resist further corrosion. The patina can be copper oxide or sulfides when the products are red or black, and copper carbonate hydroxides (basic copper carbonates) or copper chloride hydroxides polymorphs when the products color range from blue to green. Other corrosion chemical compounds include copper hydroxide nitrate (basic copper nitrates), copper acetate monohydrate (neutral verdigris), and copper acetate hydroxide (basic verdigris).





Above: Failing sealant and crack adjacent to a flashing juncture at the hyperbolic paraboloid roof eave on the west elevation. Below: Fascia and gutter at the hyperbolic paoraboloid roof eave on the east elevation. Gray stains on the bottom of the gutter indicate water flowing between the gutter and the fascia. The fascia connection is rot, as the plywood edge. Note crevice corrosion and galvanic corrosion in the gutter juncture.

under slow drying because wood has a plastic behavior.[35]

Areas of the plywood sheets adjacent to the chimney stack are rotten. In addition, on the east fascia, a plywood sheet shows rot affecting the exposed first ply. It appears that the glue is acting as a barrier to prevent further decay.

Terrace

Regarding the concrete terrace, a fiberglass membrane was installed to solve leakage problems in the past. It appears that this solution was not enough, since water penetrated at the lap splices. A white epoxy coating was applied covering the entire surface and the vertical joint creating an impervious continuous film. Conditions before fiberglass installation are unknown. However, in the interior, holes in the plaster covering the ceiling and rust stains are the effect of the earlier rainwater penetration.

Concrete

Concrete conditions were recorded to describe possible causes as well as to estimate their possible effect upon the performance, service life, and safety of the structure as recommended by ASTM.

Long-term loading and insufficient support caused deflection and visible cracking in the waffle slab. It is necessary to point out that this slab is not uniformly loaded. On the south elevation, loads from the interplay of wood and glazing directly set on a joist that has the same section as the rest. On the northwest, the white eastern pine upright supporting the tapered beams rests upon an upturn concrete beam. This beam, which is monolithic with the gridded slap, had no support underneath.

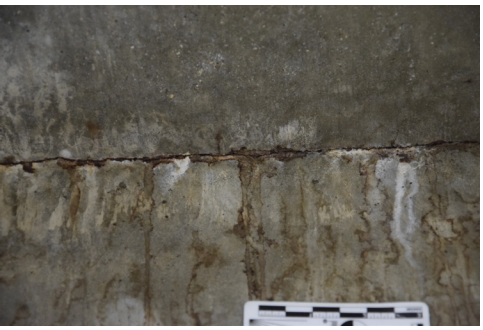
In the early 1990s, this deflection was corrected with the addition of a wooden column, which was installed at the intersection of two joists providing additional support. Rust staining indicates that moisture infiltration through the cracks has affected the rebars.

Regardless of this episode, exposed concrete surfaces are in good condition with minor problems of aesthetic nature. Imperfections as a result of an improper placing of concrete are visible. Flaws include honeycombing, bugholes, and uneven edges because of joints between the formwork panels. Surfaces also show impact damage, scratches, efflorescence, superficial erosion, soiling, and biological colonization. After visual examination and sounding with a hand-held hammer, no incipient spalling and blind delamination is recognizable.

In the interior of the building, various hairline cracks are visible on the waffle slab spans. Cracks are primarily random, with a variable length and a width around 1/16” or less. Generally, whitish leaching deposits fill in the cracks, and a brown stain can be observed surrounding some cracks.

These deposits are a consequence of water-soluble compounds leached out of the concrete by infiltrated water and precipitated by reactions such as carbonation or crystallization by evaporation. Carbonation occurs because the calcium hydroxide present in the concrete has combined with carbon dioxide once it reaches the

35. Nelson S. Perkins, Ed. Plywood: *Properties, Design, and Construction.* (Tacoma, WA: Douglas Fir Plywood Association, 1962), 91





Above: Corrosion products and leaching caused by moisture infiltration in the past. Below: Hairline cracks visible at the intersection between an electrical conduit and the concrete.

exterior surface of the concrete. In the areas where moisture interacts with the rebar, corrosion products accompany the deposits.

There is no visual evidence to conclude the existence of active corrosion in the embedded rebars, which could ultimately cause further cracking. Corrosion measurements can be taken using copper-copper sulfate half-cell tests or linear polarization techniques to determine the probability or rate of active corrosion of the reinforcing steel.

Regarding surface defects, bugholes are small irregular cavities, usually not exceeding 5/8 inch in diameter, which result from entrapment of air bubbles of formed concrete during pouring and hardening. This defect is observable in some surfaces on the exterior, and in the interior in the soffits, and lower faces of the joists together with entrapped fallen leaves, which were not removed before pouring the concrete.

Honeycombing[36] was noticed in different locations in the interior and the exterior: in one of the concrete ribs, in soffits and joists, in the concrete rail of the stair landing, and in the lower section of the wall at an angle close to the access. Generally, honeycombing is a condition that ranges from a moderate to severe problem in concrete structures because the affected areas are weaker and more permeable that sound areas. Technical literature recommends patching these areas as early as the form is retired, the greener the concrete the better. However, now, the difficulty in achieving a good match may suggest accepting these flaws, particularly in the interior. Additionally, it confers a particular and more organic character to the hardened material, which might be desirable if performance is not compromised.

On the skylight openings, hairline cracks are visible both in the slab thickness and on the soffit following the direction of the electrical pipes. This cracking could be related to corrosion of the electrical metallic pipes, or to the expansion and contraction of this material because of thermal loads, or to both causes.

Damage by mechanical impact and hooks are present on the bond beam capping the stone masonry wall. The use of the metallic hooks perforating the concrete should be avoided. Minor scratches are visible elsewhere.

On the exterior surfaces, different rates of superficial erosion on the unprotected surfaces were observed. This erosion is characterized by the loss of the outer layer of cement paste causing the exposure of the aggregate. In some areas, inadequate drip grooves and drainage caused this deterioration that is generally accompanied by moisture stains, which are a minor problem. Along with erosion, on the north and west elevations, which remains most of the time in shade, concrete surfaces show biological colonization, mainly comprised of algae and lichens.

At the soffit on the entrance area, hairline cracks with leaching deposits are visible. The rest of the concrete surfaces shows good condition, except for some small areas that show chipped edges and impact damage.

36. Honeycombing, also known as rock pockets, are areas of voids because of failure of the paste to fill effectively the spaces between the gravel. This can be produced by poor mixing, segregation during pouring, or leaching out of the mortar at a leak in the form.Vibration during concrete placing might have prevented both honeycombing and trapped air bubbles. However, the relatively small section of the described elements probably made vibration of the concrete mix difficult once poured.

East and North Wall Assemblies

On the exterior, the stucco covering the CMU masonry is original except for a few areas of repair, particularly around the northeast corner. Setting into an area of drainage adjacent to a slope, the north wall shows a higer rate of deterioration than the east wall. In the upper third of the former, horizontal cracking parallel to the bed joints is visible. Cracks range from 2 1/2 feet to nearly 18 feet long with an approximate width of 1/32 to 1/16 inch. Carbonate calcium deposits cover this cracking. Typically, these types of longitudinal cracks are caused because the net axial tension, such as that due to wind uplift on a roof connected to a masonry wall or the overturning effects of lateral loads, exceed the capacity of the masonry wall.

On the rest of the surface, discrete hairline cracks follow the perimeter of the masonry units. Darker areas are visible along the line of these cracks, along with efflorescence. Surface loss through disaggregation around these areas is visible This is likely due to crystallization of soluble salts in surface pores. Salt sources could be the soil, the foundations, the concrete blocks, or the cement mortar. Microchemical spot testing revealed small traces of sulfates, no chlorides or nitrates.Two large calcium carbonate deposits occur between 3 and 4 feet high. Water dripping from both deposits was noticed.

It appears that moisture chiefly migrates through the mortar joints, which may have higher permeability compared to the concrete blocks. Causes of this dampness can be rising damp, condensation within the wall assembly, or rain penetration. If raising damp is occuring, moisture migration through the wall masonry is likely due to the lack of a waterproof membrane or through-wall flashing on the foundation. Moisture sources could be the water table below grade, and the water surface from rainfall and snow melt. X-ray diffraction analysis revealed the presence of small traces of copper on a sample taken from the large carbonate calcium deposits. Pressumably, this would confirm the roof as a source of moisture. Reportedly, a French drain was installed. Its performance is unknown.

The northeast corner is slightly out of plumb at the level of the wall plate, which might involve the whole masonry section, and display hairline cracks. On the east side, the lower part of the wall shows a hairline crack as well. This area has been repainted in the past, but now is open again. This condition might be indicative of a slight settlement, structural deformation, or both.

Infrared imaging revealed the existence of thermal bridges on the interface between CMU and stone masonry. Areas of the CMU wall are slightly colder than others forming vertical bands.

Stone Masonry

The various types of stones that comprise the stone masonry are causing an uneven rate of deterioration, especially in the abutments. Superficial erosion, soiling, mechanical damage, blistering, flacking, hair cracks, and efflorescence are all visible. Overall, biological colonization is also present.

As explained in the previous section, efflorescence is due to the evaporation and crystallization of salts in solution transported by moisture infiltrated in porous



From top to bottom:
A. Infrared image showing the presence of a thermal bridge in the interface between the CMU wall and the stone masonry on the north elevation. The photograph was takenat 7:32 am on February 4th, 2016. The building was heated during the night.
B. Close up to the darker areas and hairling crack occuring at the concrete block perimeter.
C. Overlaid infrared image on the previous photograph. Note how the darker wet areas are warmer. The photograph was taken at 6:04 am on November 4th, 2016. The building was heated during the night.





Above: Close up photograph of the "step cracking" above the mantle on the fireplace. Note efflorescence.
Below: Typical moisture stains on the wood frame

materials. Efflorescence was visible on the following locations:

- On exterior surfaces below the gutters at the west and south elevations.
- On two areas of the right side of the fireplace: below the mantle and below the lintel. Note that the masonry behind the lintel comprises concrete blocks as well.

On a limited number of stone units, the surface has erupted into blisters and is flaking. These conditions are primarily related to processes of granular disintegration because of moisture infiltration and salt crystallization.

Hairline cracks between stone units and the mortar were noted throughout the masonry. On the interior, above the fireplace, a "step cracking" is visible. It becomes wider towards the top of the masonry with a thickness equal to 1/16-inch. On the exterior, along with hairline cracks the lower ends of the buttresses show failing joints.

Algae, lichen, and mosses pervasively cover the stone in the areas exposed to rainwater or ground water splash. Algae is also visible on the firebox right return and floor. Biological activity varies across the seasons. During the fall, moss covered large areas, which were reduced during the colder winter. Additionally, areas of soiling varying in tone were observed on areas where previously algae had grown. Biological colonization contributes to moisture retention in the fabric slowing down evaporation and furthering greening thus. Although the decay mechanism is slow, some lichen species will disintegrate the substrate by chemical action.

Wood Frame

Overall, exposed wood displays a gray appearance, which is due to the slow degradation of the material caused by various factors in combination, including sunlight and UV raditation.[37] Mildew growing on exterior surfaces was noticed as well.

Unaesthetic repairs with epoxy are visible elsewhere. Damage caused by squirrels, birds, and insects is present. Squirrels have damaged wood surfaces by gnawing and scratching elements, such as the grills installed on the elevations or the plywood. Woodpeckers have pecked looking for insects, possibly attracted by carpenter bee activity. Holes made by the latter are visible on the fascia. The site is protected against subterranean termites by bait stations.

On the fixed glass panes, the weather stripping consists of cypress stops exteriorly mounted and nailed to the wood frame. On a few places, traces of a deteriorated sealant was visible. On the south elevation, at the side of the sliding door, the lower wood stop is deteriorated and needs replacement.

On the interior, wood frames and built-in shelves show discoloration and moisture stains. While discoloration is caused by exposure to daylight and UV radiation, moisture stains are the result of a single wetting or of periodic wetting and drying cycles. Cause can be active or inactive. Sources of moisture can be water vapor that condensates, rainwater penetration, or both. This phenomenon possibly damaged one *shoji* screens originally housed on the shelves in the loft.

37. Of these, it is the UV portion of the solar spectrum that initiates weathering, which together with moisture advances the degradation process. UV radiation is limited to the range of 295 to 400nm and represents the 6.8% of the total radiation. It causes the photo oxidation and photochemical degradation of the wood surfaces. First, the exposure produces a color alteration, because of a chemical change in the wood extractives. Then, UV radiation degrades the lignin, which is the polymer that bonds cellulose and hemicellulose, therefore, weakening the wood cellular structure and ultimately causing the slow erosion of the wood fibers from the surface. Eventually, colonization of microorganisms, commonly mildew, occurs. The rough and grey appearance of surface is a symptom of this degradation process.

Generally, windows and doors are in good condition, although their shrinking and swelling seasonally reduce their operability. Isolated conditions include two mechanical impacts to one of the lower panes of the sliding door at the south elevation. A sliding door leaf is lifting. In this location, the gap between the door leaf and the window frame accumulates dirt.

Prefabricated plastic skydomes installed with an aluminum frame were thought to be a source of leaks; consequently, new skylights with wood frames and methacrylate panes were manufactured to replace them. Now, some condensation occurs, as revealed by moisture stains in the wood frame.

Infill Walls

On the south elevation, the interface between the infill wall and the concrete surface shows a gap running vertically. This condition allows moisture infiltration and heat loss. Similarly, on the west elevation, the joint stands open. The interface between infill walls and stone masonry show a vertical hairline crack. Stains because of past dauber wasp nest are visible.

Interior Finishes

Discontinuities between the stone masonry and the concrete block masonry, and between those systems and the openings' frame have been causing moisture infiltration, which ultimately has led to damages to the plaster as evidenced by staining and efflorescence.

In the Cave, efflorescence and color alterations are visible in the window jamb and the area below. Particularly in the right corner, it is recognizable an area that ranges from light ochre to light pink. Some of the plastered soffits in the gridded slab, which stand directly below the terrace area, are perforated and stained because of hidden leaks that appear to be no longer active.

On the left side of the window seat, the stucco shows color alteration, disgregation and material loss. Efflorescence is visible on the upper part of the jamb. Pressumably, water is penetrating either through the interface between the adjacent wood frame and the concrete structure, the stone masonry and the concrete, or both.

The walls plastered with Structolite™ show corrosion products in the form of small spots. The spots are tipically reddish and display a whitish deposit on its center. SEM-EDS spectrum indicates the presence of aluminum (AL) and small traces of iron (FE) on the plaster. Pressumably, the corrosion products could be related to the oxidation of these metallic constituents. SEM-EDS indicates also the presence of sulfur (S), calcium (Ca), and silicon (Si), typical elements present in the Plaster of Paris (CaSO4. 2H2O) and Quartz. Small traces of other chemical elements include phosphorus (P), potassium (K), magnesium (Mg), chlorine (CL), and sodium (Na).

The curtains need to be woven and re-hung on the curtain track. The fabric, which is a casement, is in good condition.



From top to bottom:
A. Efflorescence and color alterations below the window sill. Source of moisture is likely water vapor that condensates on the window glass.
B. Moisture stain and color alteration on the left jamb of the window seat.
C. Disintegration and material loss visible in the stucco on the left side of the window seat.
D. Corrosion products on the plaster.





Above: View of the Cloister roof.Note moss growing on the granule surface membrane.
Below: Typical alligatoring visible on the sealants.

Flooring Materials

The vinyl tile flooring system is in moderate condition. In the gallery area, many Amtico™ travertine tiles show total or partial lack of adhesion to the concrete subfloor. The causes can be moisture migration through the concrete subfloor, the glue has reached the end of its service life, or both. As the technical literature indicates, if moisture migration can permeate the underlying concrete slab at a higher rate that it can permeate the vinyl tile flooring system, failures will occur. This failure can occur between the adhesive and the subfloor or between the tiles and the adhesive. Moisture source is likely to be water below grade. The presence of vapor barriers below the concrete slab is unknown.

The tiles display shrinkage. a contraction probably related to the sunlight (infrared radiation) exposure. This condition has led to uneven joints, discoloration, and ultimately can also cause embrittlement. The weight of the wooden specimens leaning on the concrete wall have deformed the tiles. On the left side of the fireplace hearth, damage by fire is recognizable. The adjacent stone slab shows scaling.

On the Cave, stains and scaling are noticeable in some units of the stone floor. Missing and failing joints are visible as well.

B. Cloister

Covered Walkway and Cloister Roof

The granule-surfaced waterproofing membrane is in good condition. However, on some locations sealants are deteriorated and show alligatoring. Tree litter and areas of biogrowth are visible. Scratches are visible on the plywood soffits and of frame elements. Also, the plywood sheets show moisture stains and rot on the edges adjacent to the fascia. The third and fifth rafters, beginning from the southern side, show evidence of rot above the west CMU masonry wall. Above this wall, the wood stops show deterioration as well. Material loss and rot is visible on the wood stop between the fourth and fifth rafters. Between the third and fourth rafter, the wood stop is broken. Plywood soffits are paint opaque white, which is a deviation of the original intent.

As in the Arts Building, the wood elements show damage caused by woodpeckers and carpenter bees. Condition of the posts are extensively explained in the following section. Unaesthetic epoxy repairs are also visible. The finish of the wood elements has darkened considerably. Possible causes are:

- photo degradation (cross-linking /oxidation) darkens oil
- polymer degradation (cross linking / oxidation) darkens oil
- dirt compounded into macro-morphology (can turn a linseed oil coating black)
- mold-fungi action[38]

The concrete block masonry is in good condition, with a few minor problems such as dark stains with efflorescence, biological colonization, hairline cracking on the perimeter of the blocks, and dirt covering the lower section of the walls, particularly on the south and east elevations. One CMU unit below the wooden grill shows a vertical hairline crack as a result of differential thermal movement

38. Andrew Fearon, e-mail message to authors, December 9th, 2016

between walls. While the rainwater runs into a gravel path on the west elevation, the south and east masonry is completely exposed to the rainwater splash transporting soil particles.

Dust, spider webs, remnants of a dauber wasp nest and corrosion products are present in the aluminum lighting fixtures. On the east elevation, the door was cut and repaired during the summer of 2016. The door sill has been modified.

Concerning the interiors, the wood frames of the windows facing east show discoloration and moisture stains. These moisture stains are probably produced by water vapor condensing on the glass pane, by rainwater penetration, or both.

When the indoor air is humid, and the outdoor air temperature is below the dew point temperature of the indoor air, condensation of the water vapor occurs in the glass panes, which are the colder surface in relation to the wooden frame. Water leaks and soaks the wood frame causing the moisture stains as it dries.

During the last visual survey in November 2016, the cell in the Cloister was in use. The water vapor condensation on the window glass worsened and water dripped onto the plaster at the sides of the window sill. Environmental monitoring should be implemented to execute a comprehensive study of the interior conditions to understand further when and where condensation occurs, and to engineer a solution.

In the shower, the paint coating is peeling off. The vinyl flooring is in good condition, some lack of adhesion was noticed.

C. Ben Shahn's Mosaic

Although the mosaic shows a high level of physical integrity and good condition, the following were recorded: color alteration, missing tesserae, granular disintegration, failing substrate, biological colonization, and superficial erosion. While most alterations are limited in extension, the biological colonization by micro flora along the lower section of the mosaic is affecting various panels.

Discoloration is due to the use of epoxy resin to adhere the tesserae and hide the screw heads, which fasten the mosaic to a wood substructure. This application has stained the tesserae covering the screw as well as the surrounding tesserae altering their appearance. Discoloration was noticed on the joints between panels.

The presence of dark grey deposits covering the lower areas of the panels reveals the existence of micro flora probably associated with higher moisture content. Sources of moisture for this biological colonization are rainwater splash and accumulated snow in winter that is retained in the irregular interstices between tesserae, which are partly embedded in the bedding layer mortar. Curiosly, this condition is stressed in front of a row of large stones placed perpendicularly to the mosaic. While on the rest, the existent gravel diminishes the effect of the water splash.

Missing tesserae may be due to a weak assembly, since some of them have lost adhesion to the bedding layer or, occasionally, the epoxy. The granular disintegration, which appears to be active deterioration, occurs in various specific locations.





Fifth (above) and fourth (below) rafters are easily penetrated by an awl. Note horizontal checks and material loss in the first wood stop.



On the right, the plywood shows delamination of the outer face as well as checks. Note the constrast between the original translucent finish and the opaque white coating on the left.

This loss of stone is not uniform. Firstly, the original stone surface forms a hardened layer, while the subsurface experiences a process of granular disintegration. Ultimately, there is a process of detachment that generates an abraded coarse surface.

Lastly, the wood frame surrounding the mosaic exhibits sign of damage from animal activity in association with epoxy repairs. Various sections of the mortar that fills the upper joint between the mosaic panels, and the inclined soffit of the concrete eave are deteriorated. There are signs of mud daubers nests that have been removed. The condition of the wood substructure is unknown.

The vinyl flooring in the Cloister is in good condition. *Shoji* screens along with minimum use have protected the tiles.

Summary

Water penetration, associated with failures or damage in the waterproofing, the roof design, and the water disposal system, is a persistent problem. Addressing these issues in the past has required different intervention campaigns that have affected the fabric integrity.

Surrounding trees must be considered as a contributing cause in the case of roof puncture, particularly when the ballast has been washed out and the asphalt lining is exposed. Also, soil and debris accumulation provide a suitable substrate for biological colonization, which might exacerbate the problems noticed in the roof; while, at the same time, it suggests the presence of excess water.

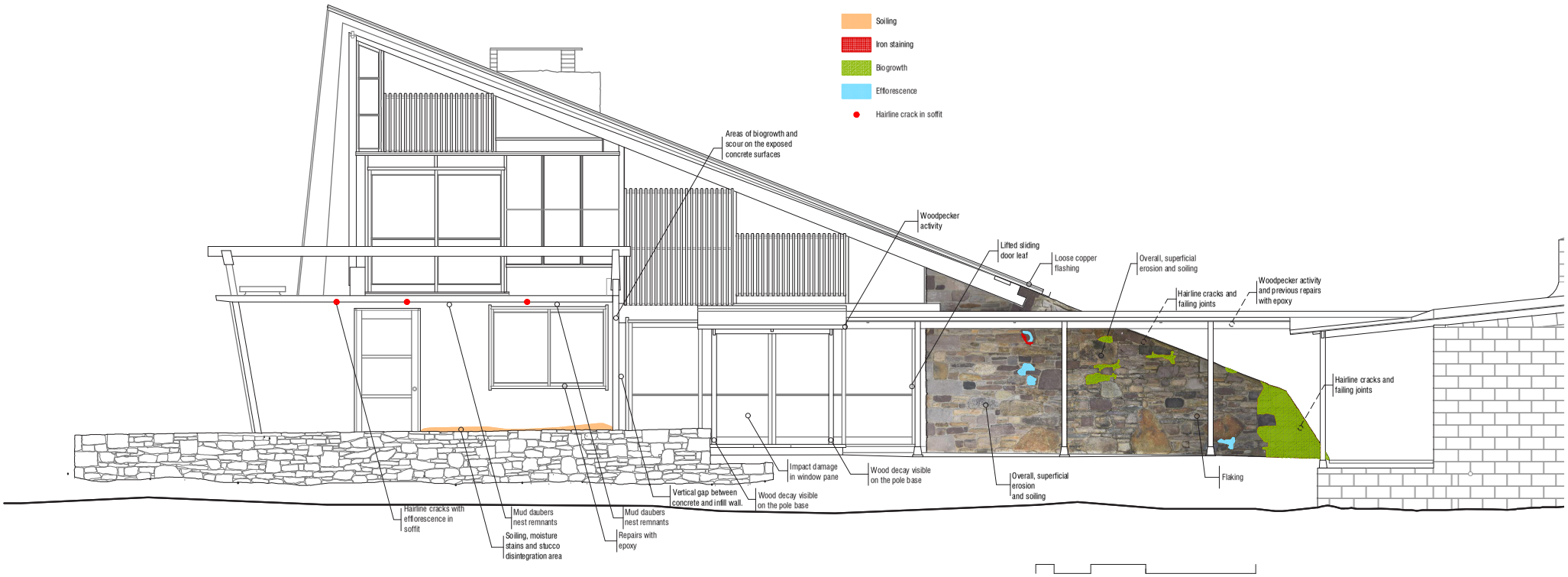
The consequences of melting snow must be also considered where icicles and ice dams form at roof eaves and clog the gutters. Water that is retained behind the ice dams could ultimately penetrate through failures in the waterproof coating or may rise above the flashing, therefore, causing leaks in the future.

Structural damage incudes the horizontal cracking on the north wall. However, moisture is speeding the deterioration of the exterior stucco and is an active force in salt migration. Along with hairline cracks, efflorescence and surface disgregation is recognizable.

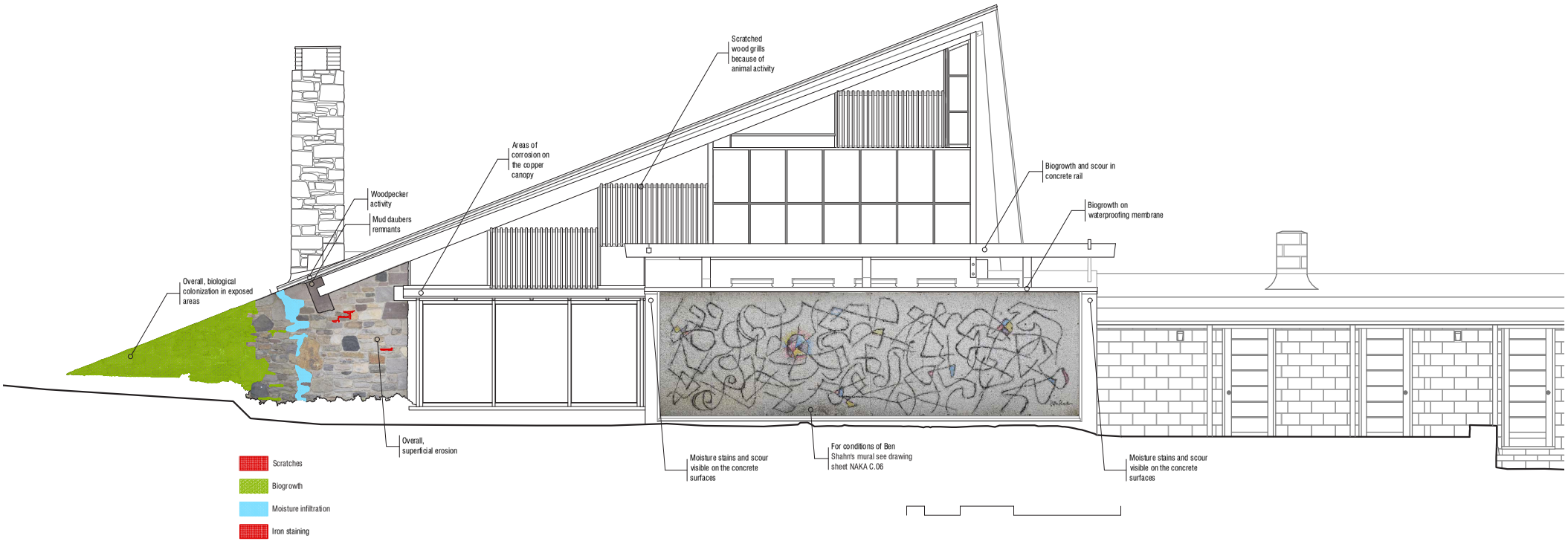
Although in overall good condition, the stone masonry shows a variety of deterioration mechanisms due to the composite nature of the stones. Cracks on the chimney stack and fireplace need to be monitored.

Condensation of water vapor, rainwater penetration or both, along with daylight and UV radiation, are factors of deterioration of the wood elements. Damage by squirrels, woodpeckers, and carpenter bee are visible elsewhere.

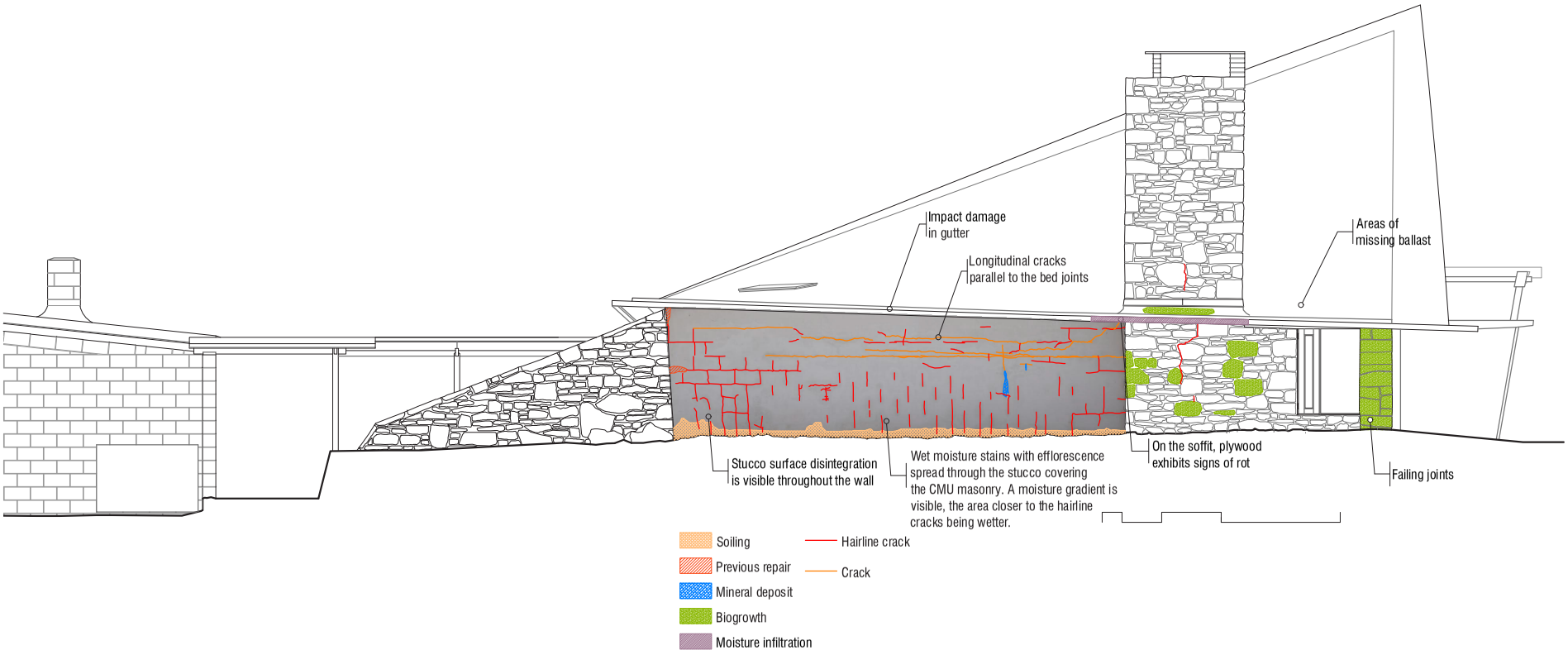
On the interior, the vinyl flooring is close to reaching its service life and will require attention soon. Prior to any repair on the finishes, further research of the assemblies and monitoring of the environment needs to be carried out. As revealed by the infrared imaging, thermal bridges are recognizable in almost every interface between disimilar materials and assemblies.



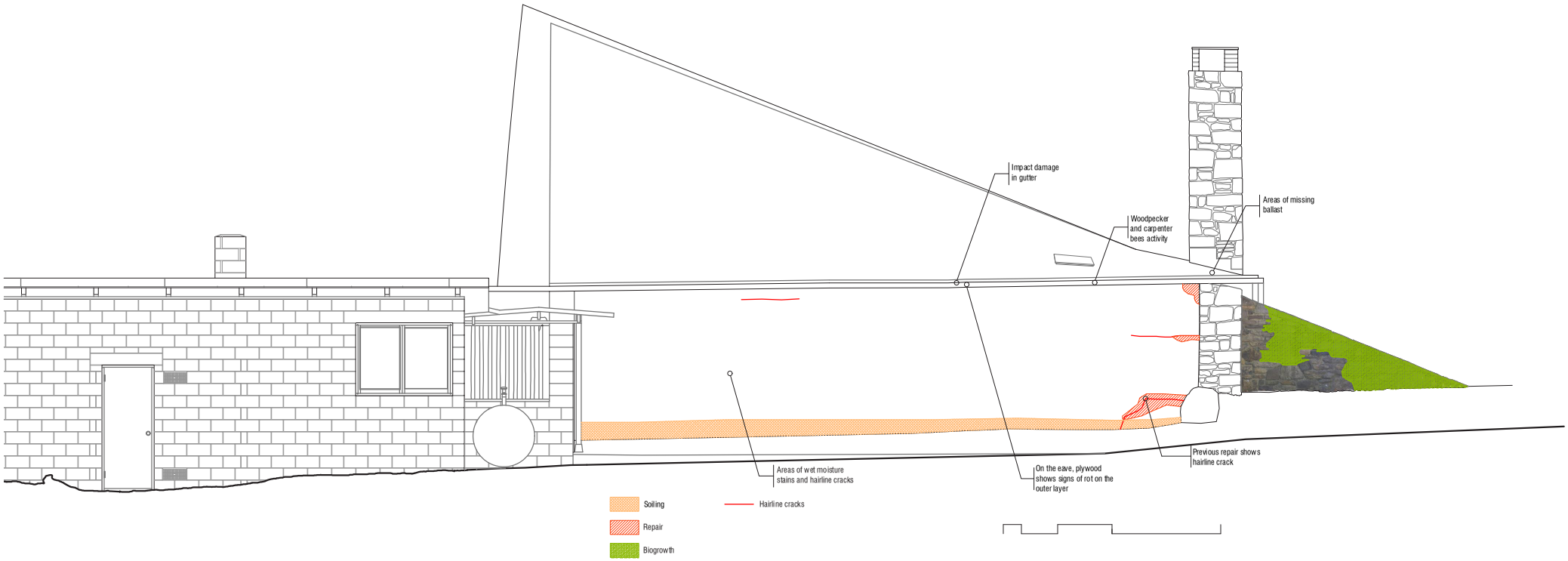
NAKA C01 - SOUTH ELEVATION



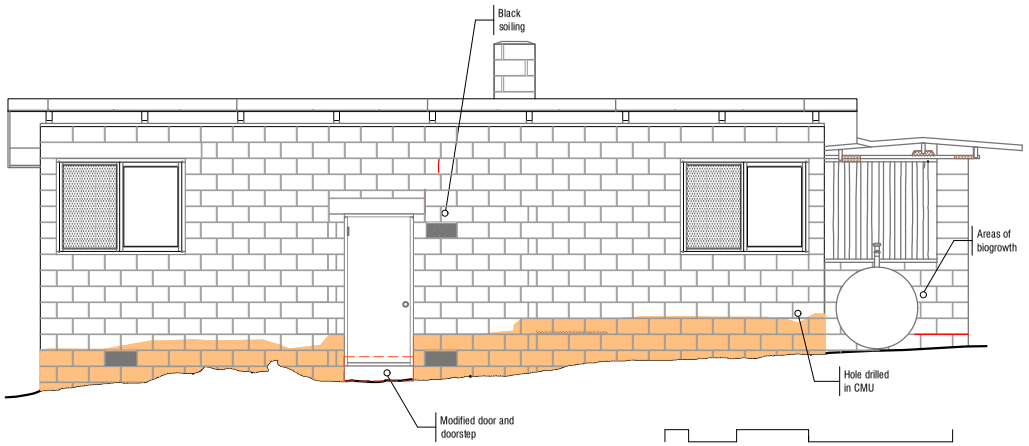
NAKA C02 - WEST ELEVATION

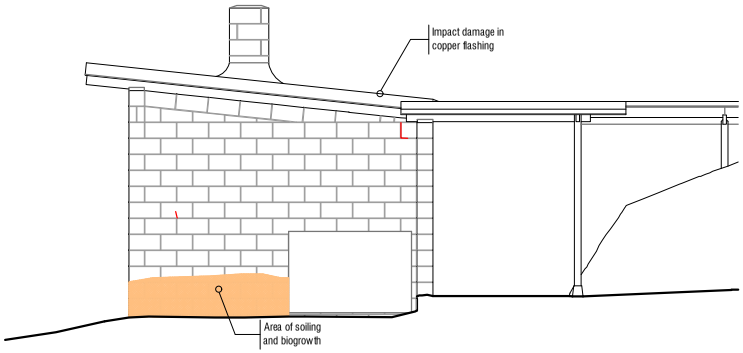


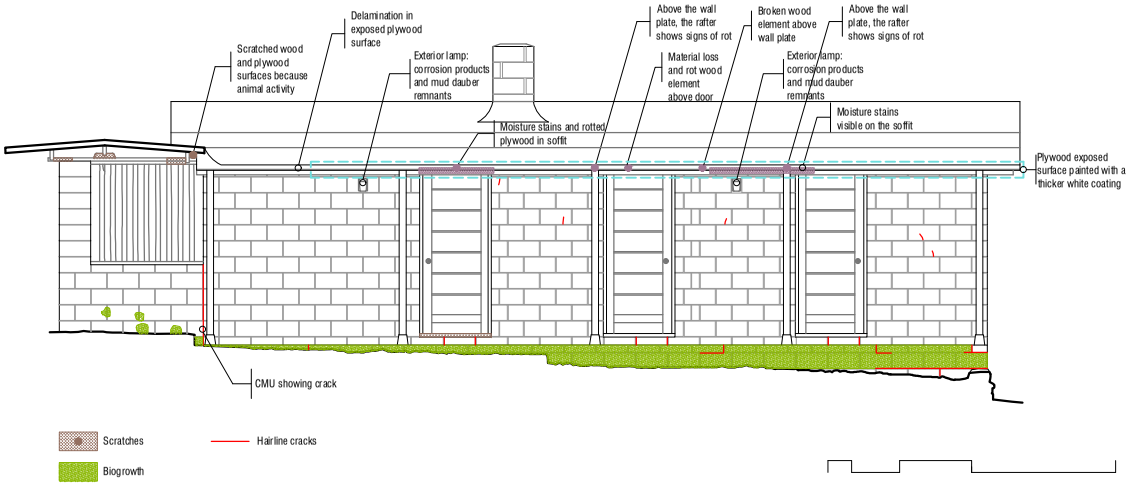
NAKA C01 - NORTH ELEVATION

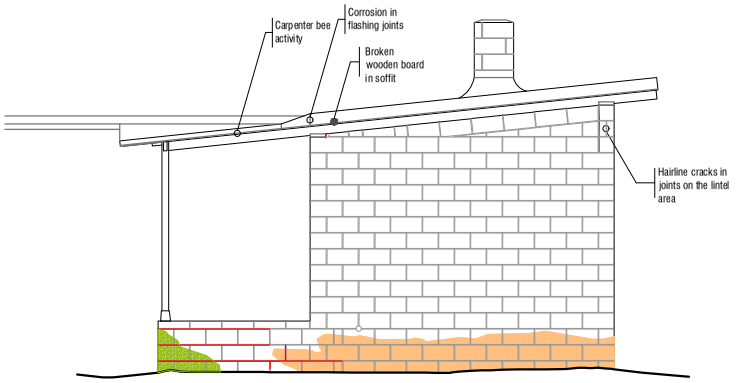


NAKA C02 - EAST ELEVATION



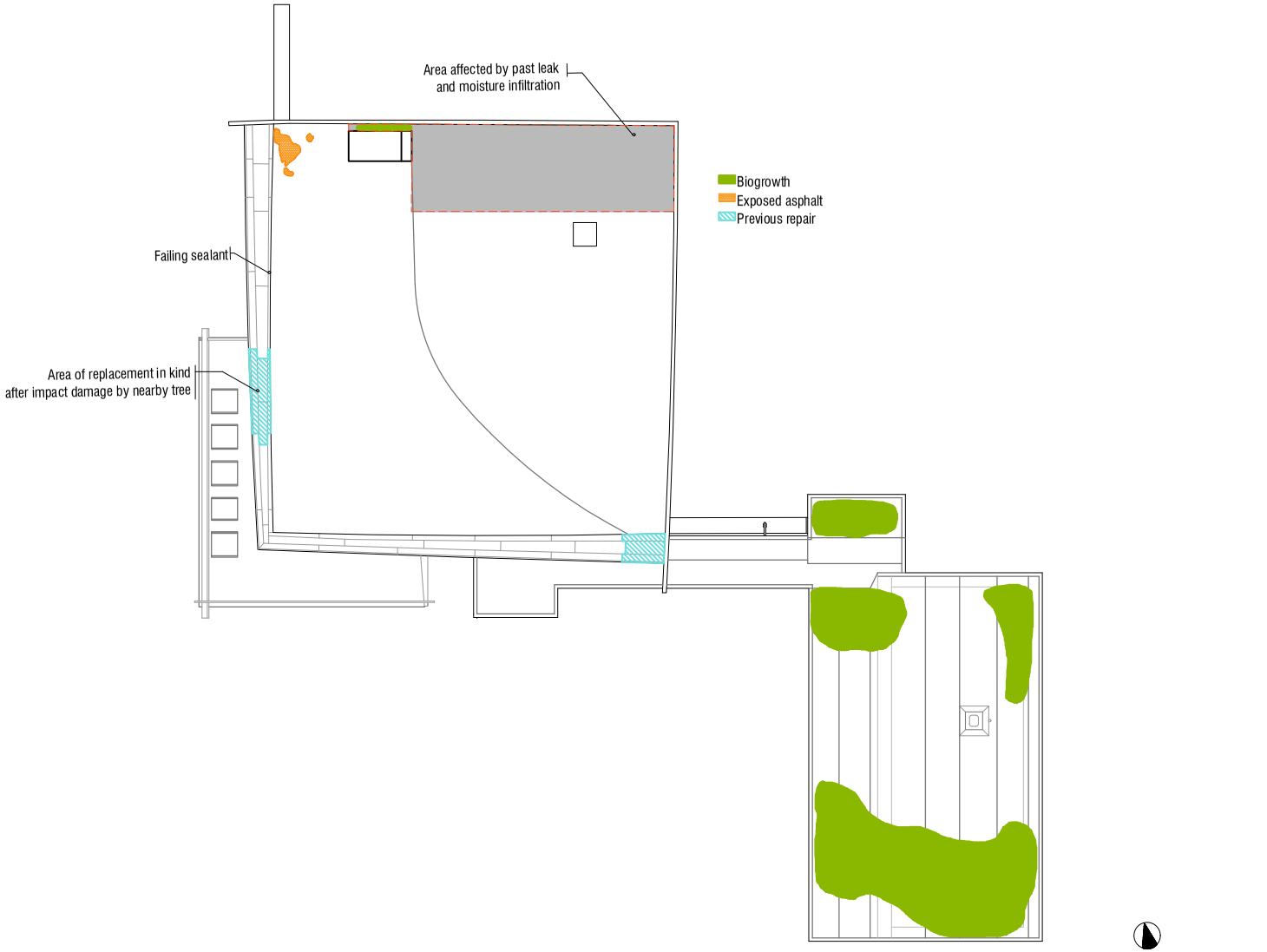






Scratches
Hairline cracks
Biogrowth
Moisture infiltration
Soiling
Rot wood

NAKA C05 - CLOISTER ELEVATIONS

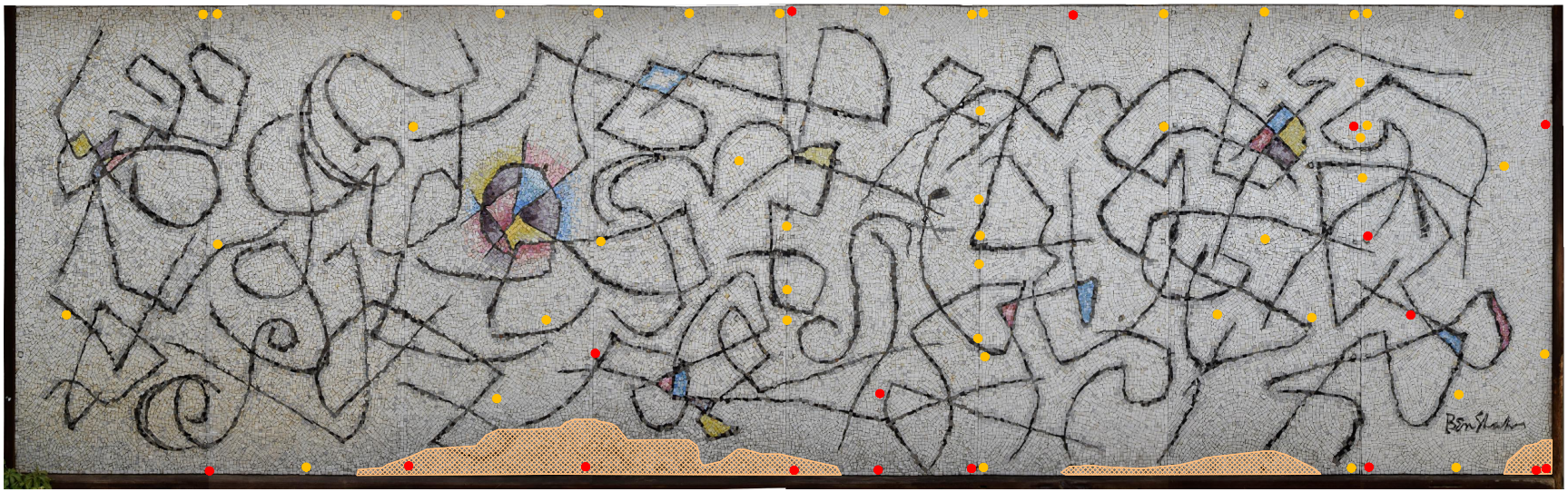


NAKA C06 - ROOFS

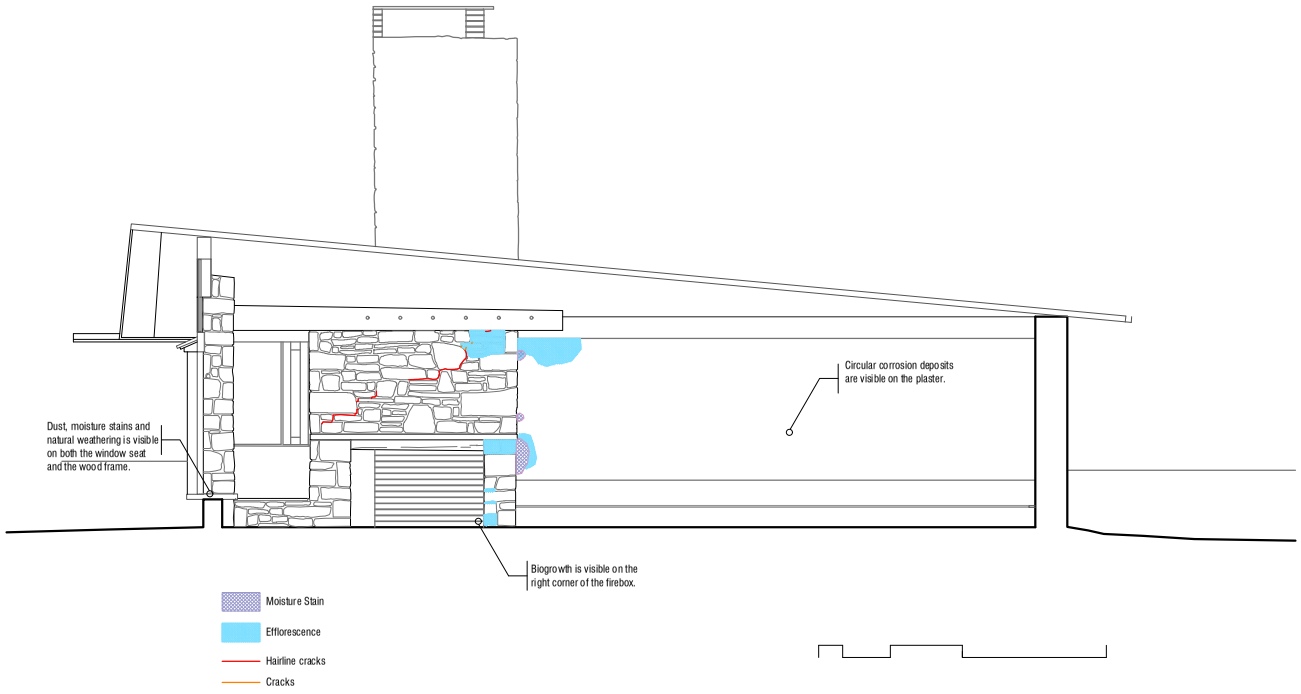
Soiling

Missing tesserae

Color alteration



NAKA C07 - BEN SHAHN'S MURAL MOSAIC



NAKA C08 - INTERIOR NORTH ELEVATION

4.4. Wood Assessment
Anthony & Associates, Inc.

Of the twenty-one buildings that are part of the George Nakashima Woodworker National Historic Landmark site, the Arts Building and attached Cloister are perhaps the most architecturally significant. Built between 1964 and 1967, the Arts Building was designed by Nakashima to be a museum and art gallery, while the Cloister was to house visiting craftspeople. The two and a half story Arts Building has walls constructed of concrete block, poured concrete, and stone, large windows on the west and south elevations, and numerous wooden elements in the roof, exterior and interior of the Building.

Architectural and artistic features of note in the Arts Building include the hyperbolic paraboloid roof, the cantilevered floating staircase and the tile mosaic on the west elevation. The hyperbolic paraboloid (saddle-shaped) roof is composed of plywood covered with asphalt. The free-standing wooden staircase has no outside rail and no risers, with the ends of the steps anchored in the adjacent stone wall. The tile mosaic, seen on the front cover, was designed by Ben Shahn, the artist whose works were to be displayed in the Arts Building when it was initially built.

Scope of Work

The work is intended to provide answers to questions raised by the project team about the condition and /or allowable structural grade of specific wood elements in the Arts Building and the Cloister.

The scope of work was intended to focus on the following elements:

1. Edge beams supporting the south and west roof lines
2. Southwest corner post supporting the edge beams
3. Four original load-bearing posts on the south elevation
4. Wood railings on the terrace
5. Plywood roof diaphragm
6. Plywood used in the Cloister soffits

Field Procedures

Ron Anthony, wood scientist for A&A, conducted the assessment of the wood elements of the Arts Building and Cloister on April 6-7, 2016. Cesar Bargues Ballester of the University of Pennsylvania School of Design assisted with the survey. To accomplish the scope of work listed above, the assessment included removing samples for species identification, visual inspection, probing, moisture diagnostics, and deterioration quantification. The methods used are described below.

Species Identification
Identifying wood species makes it possible to determine material properties, such as resistance to decay, and to identify compatible material for repair of historic



From top to bottom:
Figure 1. Sample removal location from the southwest corner post.
Figure 2. Fungal growth on the underside of the north railing.
Figure 3. Probing with an awl to determine the extent of deterioration in the plywood soffit on the Cloister.
Figure 4. Resistance drilling to identify the condition of an original porch post.

35. American Wood Council, 2015, National Design Specification for Wood Construction, Washington, D.C.
36. American Society for Testing and Materials, 2015 Annual Book of Standards, Vol. 04.10. ASTM, West Conshohocken, Pennsylvania.
37. Western Wood Products Association (2011). Western Lumber Grading Rules. Portland, Oregon.

fabric, if necessary. Wood species were identified by removing samples from selected member types of interest to the project team, from which the species or species group were determined under microscopic examination (Figure 1).

Visual Inspection and Probing

Visual examination of the wood allows for identifying components that are missing, broken, or in an advanced state of deterioration. Missing components are those which have been removed or have fallen away because of deterioration, structural failure, or vandalism. If missing components were intended to provide structural support or protection from the elements (i.e., to prevent moisture intrusion), their replacement may be essential to prevent long-term damage to the structure. Visual inspection also allows for the detection of past or current moisture problems, as evidenced by moisture stains on the exposed surface of the wood. Further, visual inspection enables detection of external wood decay fungi or insect activity as determined by the presence of decay fruiting bodies, fungal growth, insect bore holes or wood substance removed by wood-destroying insects (Figure 2).

Internal decay and insect damage are often difficult to detect due to the lack of evidence on the exposed surface of the wood. Probing the wood with an awl enables rapid detection of voids in the wood just below the surface that may or may not be visible (Figure 3). It can also indicate the approximate depth of the deterioration. Visual inspection and probing provide a rapid means of identifying areas that may need further investigation or repair.

Moisture Content Diagnostics

Prolonged exposure to moisture can produce undesirable conditions and long- term maintenance issues for wood in a structure. Excessive shrinkage or swelling, checking, loose connections, and decay are typical problems. Limited moisture diagnostics were conducted to identify potential sources of moisture intrusion that could result in premature deterioration of the wood and to determine whether further investigation of potential areas of decay was warranted.

Deterioration Quantification

In addition to the inspection of wood members using a combination of visual observations and moisture measurements, limited resistance drilling was conducted to determine loss of material due to wood decay or insect attack. Resistance drilling is a quasi-nondestructive technique for determining the relative density of wood (Figure 4). It is best suited for determining internal problems in wood members that do not show obvious signs of deterioration, such as surface decay. Any internal void or early stage of decay at the location drilled can be detected by determining the relative density of the wood. The relative density is printed on a strip of paper as a small diameter needle penetrates the wood. The technique is very reliable for quantifying the extent of voids when used in combination with other techniques to rapidly locate areas of probable deterioration.

Visual Grading

Structural timbers and lumber used in new construction are intended to comply

Below: Figure 5. Knots and slope of grain (indicated by the seasoning check) on the south edge beam.



with the relevant building code for that jurisdiction. For wood construction, structural engineers rely on design values referenced in the building code to determine an acceptable species, size, and grade for a particular load condition. The design values given in the building code for solid wood products are established by the American Wood Council[35] and published as the *National Design Specification for Wood Construction*. The published design values are based on test data and procedures published by the American Society for Testing and Materials (ASTM) that demonstrate the engineering performance of the material.[36] Wood products are graded in accordance with procedures promulgated by one of several forest products industry associations, such as the Western Wood Products Association (WWPA).[37]

For existing buildings the engineer often relies on available species and current standards to determine the adequacy of the wood members to remain in service. Since many historic buildings were built before building codes or design values for wood products were established (and, thus, before grade stamps were used), engineers are often in a quandary when determining what design values are appropriate. The edge beams and southwest corner post do not have any grade stamps. Frequently an assumed species and grade are assigned, only to show that the wood members are structurally deficient. The result is often an overly conservative estimate of design values and unnecessary replacement and repair decisions with the associated unnecessary project costs.

Timber grade is determined by species, size of the member(s), and growth

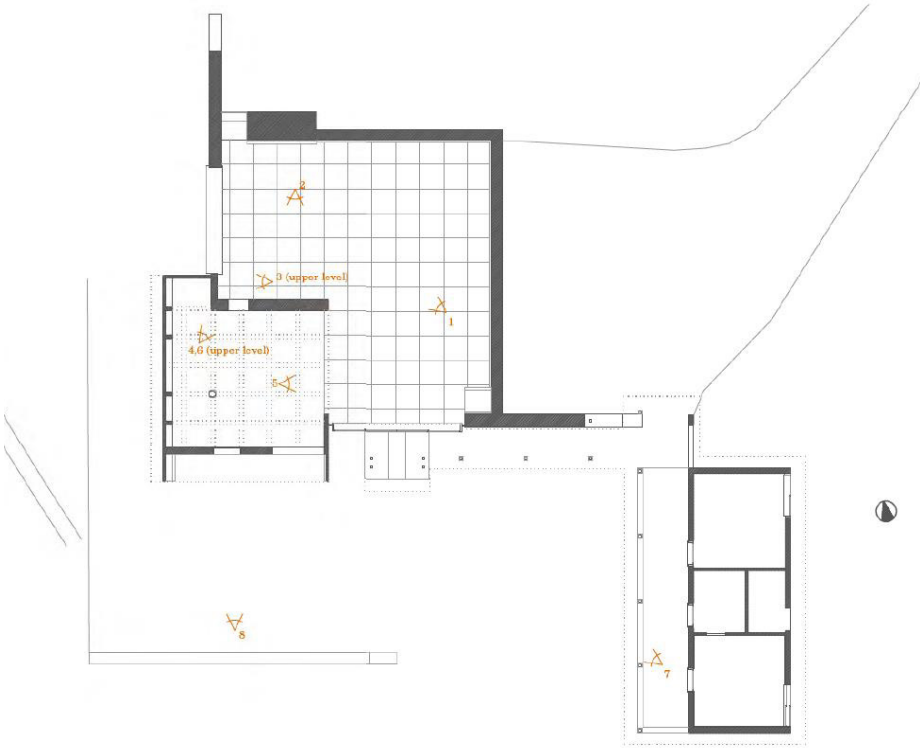


Figure 6. Plan view shoing the Arts Building and Cloister.









Fromt top to bottom:
Figure 7. Inconsistent depth of gravel.
Figure 8. Patches of moss on the roof.
Figure 9. Moss in-situ, with awl for scale.
Figure 10. Moss overturned with the awl in approximately the same position as Figure 9. Note that the gravel is largely disconnected from the root

characteristics such as knots and slope of grain (Figure 5). Knots and slope of grain tend to be the grade-limiting characteristics for lumber and timber in older buildings. Measurement of knots and slope of grain provides an indication of the allowable lumber grade for a given wood species. The visual grade provides essential data for structural analyses to assess the ability of the members to support current or future loading conditions and provides information critical for determining the extent of any necessary repairs. Visual grading was done on the west and south edge beams and the southwest corner post.

Orientation

The Arts Building is oriented with the entrance on the south elevation and a covered walkway connected to the Cloister situated to the southeast of the Arts Building (Figure 6). The hyperbolic paraboloid roof slopes towards the northeast corner of the Arts Building and is supported on the west and south elevations with large timber edge beams that are tapered until they meet at a post at the southwest corner of the Building. A terrace at the second level on the west and south elevations incorporates wooden and concrete railings at the terrace perimeter.

The porch roof of the Cloister uses slender wooden replacement columns to support plywood soffits below the roof covering. Similar replacement columns also support the covered walkway to the Arts Building, except at the landing by the sliding doors, which are original columns.

Findings

Species Identification

Based on microscopic characteristics of the wood, the samples removed from various wood members indicate that several species were used in the construction of the Arts Building (Table 1). This is consistent with George Nakashima's approach to building construction. The west and south edge beams were identified as Douglas-fir (*Pseudotsuga menziesii*) while the post that supports the edge beams at the southwest corner was identified as eastern white pine (*Pinus strobus*). A sample removed from the lintel on the south elevation was also identified as eastern white pine. The edge beams and lintel were reported to be white oak. Douglas-fir and eastern white pine have been widely used for structural purposes. While old-growth timber of both species is considered to be moderately durable, the age of the Arts Building would likely not incorporate old-growth timber; therefore, these structural members should be monitored to ensure that deterioration is not causing a loss of structural integrity. Other species identified in the Arts Building would not be considered commonly used species and, no doubt, reflect the intent of Nakashima to use a variety of species in his work to present the beauty of wood as a building material.

Table 1. Wood Species Identification, Arts Building

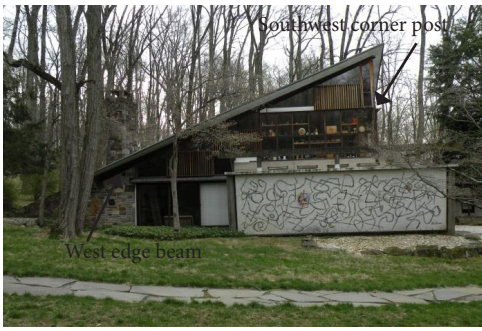
Member	Location	Species
south edge beam	south elevation	Douglas-fir (Pseudotsuga menziesii)
lintel	south elevation	eastern white pine (Pinus strobus)
rib	ceiling rib at east wall	Baldcypress (Taxodium distichum)
southwest corner post	south/west	eastern white pine
north railing	terrace	black locust (Robinia pseudoacacia)
south railing	terrace	Douglas-fir
west edge beam	west elevation	Douglas-fir
original porch posts	south elevation	black locust
roof diaphragm plywood	roof	Douglas-fir and sugar pine (Pinus lambertiana)

Wood Condition – Roof Covering
Although not constructed of wood, the condition of the roof covering directly impacts the condition and longevity of the wood elements below the roof, particularly the plywood diaphragm. An examination of the roof revealed that the gravel depth protecting the membrane was not consistent across the roof. In some areas, the gravel was missing and the membrane was exposed, leading to potential degradation due to exposure to ultraviolet light (Figure 7).

Several patches of moss were growing on the roof (Figure 8). Any biological growth on a roof is a concern due to moisture entrapment that can lead to breakdown of the membrane and roof sheathing due to root penetration, and result in leaks into the interior space. However, other than moisture entrapment, this is not the situation with the moss growing on the Arts Building roof. Several patches of moss that appear to be well-attached to the roof were found to only be loosely connected to the gravel without any attachment to the roof membrane. These patches could easily be overturned without even disrupting the gravel (Figures 9 and 10). The patches of moss should be removed periodically to prevent them from becoming established to the point where they gain roof penetration through the membrane and into the diaphragm below.

The north and east elevations of the Arts Building have wide eaves that show the overlapping plywood sheets making up the roof diaphragm/decking (Figure 11). The top wall plates on the north and the east walls extend slightly beyond the exterior walls, exposing the end grain, although they are well protected from the elements by the overhang.









From top to bottom:
Figure 11. Northeast corner showing the layered plywood used in the shell and the lumber used for the wall top plates.
Figure 12. West elevation.
Figure 13. West edge beam below the eave, as seen from below.
Figure 14. Close up of the south edge beam at the east end. Note the notch detail into the stone is the same as the west edge beam seen in Figure 13.





Left: Figure 15. South edge beam showing the depth of the eave that protects the edge beam.
Right: Figure 16. Insect next on the surface of the south edge beam.





Left: Figure 17. Southwest corner post where the south and west edge beams connect.
Right: Figure 18. Close-up of the connection between the south and west edge beams and the corner post.





Left: Figure 19. Base of corner post.
Right: Figure 20. North wooden railing of the terrace.





Left: Figure 21. North railing at the west wall of the Arts Building.
Right: Figure 22. North railing at the interior face of the concrete railing showing biological deterioration on the side and upper surfaces.





Left: Figure 23. North railing at the interior of the concrete railing, view from below showing biological deterioration on the lower surface.
Right: Figure 24. North railing at the exterior face of the concrete railing showing deterioration. Note the use of a wooden tusk to lock the two railings.

Wood Condition and Structural Grade – Exterior Wood Structural Members of the Arts Building

The roof of the Arts Building is complex in design (the hyperbolic paraboloid roof) but simple in terms of the number and type of members supporting the roof. Three layers of plywood sheathing are used to provide the roof shape with the north and east edges of the roof being supported at the wall top plates and the west and south edges being supported by tapered Douglas-fir beams that span from the wall at the lower edge to the highest point at the southwest corner post (Figure 12).

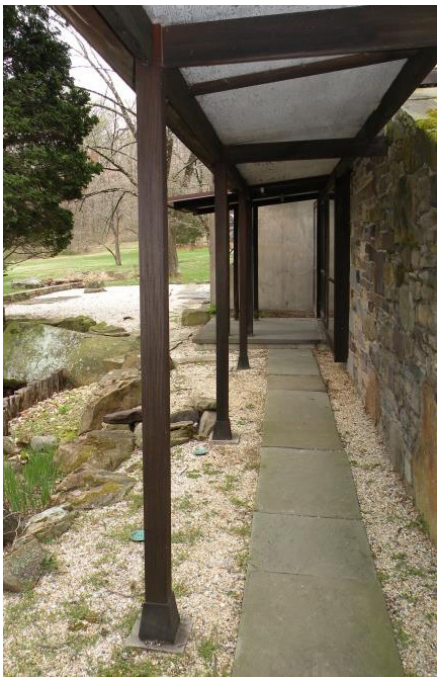
The lower end of the tapered edge beams are notched into stones at the walls (Figures 13 and 14). Based on observed defects in the edge beams, there are no defects that would preclude them from being classified as Douglas-fir Select Structural, Beams and Stringers, in accordance with the Western Lumber Grading Rules (2011) published by the Western Wood Products Association. For allowable design values, the classification in the National Design Specification for Wood Construction would be Douglas fir – Larch Select Structural Beams and Stringers. The west edge beam has an unusual seasoning check (as opposed to a through-split) near the lower (north) end that is likely due to growth of the tree or milling of the beam and has not appeared to affect the performance of the beam over time.

A large eave or soffit extends the roof beyond the edge beams affording some level of protection from the effects of precipitation and, to a lesser degree, ultraviolet light (Figure 15). There is evidence of minor deterioration of some minor wooden elements by insects or insects nests were observed on the Arts Building, including on the south edge beam (Figure 16).

A 4-inch by 6-inch eastern white pine corner post supports the tapered ends of the two edge beams at the southwest corner of the Arts Building (Figure 17). Based on observed defects in the corner post, there are no defects that would preclude the corner post from being classified as Eastern White Pine Select Structural, Structural Joists and Planks in accordance with Standard Grading Rules for Northeastern Lumber (2013) published by the Northeastern Lumber Manufacturers Association, with the corresponding allowable design values published in the National Design Specification for Wood Construction. During

the wood assessment, heavy rain made inspection of the top of the corner post and the connections to the edge beams unsafe to access without use of equipment such as a boom lift. Visual inspection of the connection from below did not reveal any sign of deterioration that would compromise the connection (Figure 18); however, the lack of redundancy in the roof supports suggests that the connection and wood condition be assessed to ensure that the structural integrity of the members has not been compromised.

The base of the corner post is secured in poured concrete but the west face is exposed (Figure 19). Resistance drilling through the west face near the base of the post revealed no internal voids. Additional resistance drilling near the casement





Left: Figure 29. Walkway and supporting posts along the south elevation of the Arts Building.
Right, above: Figure 30. Base of an original post at the landing outside the sliding doors on the south elevation. This post is in good condition.
Right, below: Figure 31. Base of the southeast original post at the landing outside the sliding doors on the south elevation. This post is in fair condition at the base, but in good condition 8 inches above the base.







Left: Figure 32. Close up of the base of an original post at the landing outside the sliding doors on the south elevation. This post has deterioration at the base. Note the metal pin that holds the post to the landing.
Right: Figure 33. Base of a replacement post with wood trim attached.





Left: Figure 34. Cloister showing biological growth on the roof, west elevation.
Right: Figure 35. Plywood soffit of the Cloister, easily penetrated by an awl.





Left: Figure 36. Ant bait adjacent to the Cloister.
Right: Figure 37. Plywood layup visible at the skylight.

window also revealed no internal voids. This post is in excellent condition.

There are two wooden railings on the terrace; a longer one on the south elevation and a shorter one at the north end of the west section of the terrace. The north railing extends from the west wall of the Arts Building through the concrete railing at the west edge of the terrace (Figure 20). The railing is in good condition where it penetrates the wall of the Arts Building (Figure 21). However, it has visible fungal growth and deterioration at the interface with the concrete railing (Figures 22 through 24). The north railing fully penetrates the concrete railing and is secured at the outer face of the concrete with a wooden tusk.

Although there is deterioration where the railing is in contact with the concrete, the good condition noted along the length of the railing and at the west wall of the building is likely due to the use of black locust, a naturally durable wood species. Although black locust is naturally durable, it can succumb to wood decay if moisture is trapped for prolonged periods of time at connections, penetrations through other materials or members, and at the base of columns where water is not adequately drained.

The railing on the south side of the terrace is made of Douglas-fir (Figure 25). The ends of the railing use different connection details to attach the railing to the terrace (Figures 26 and 27). The railing is weathered and has biological growth on the surface, but the growth is not decay. The weathered appearance is the result of long-term exposure to precipitation, ultraviolet light, and wind-blown debris (Figure 28). While the biological growth (moss and lichens) are not deteriorating the wood directly, their presence provides for a favorable environment for wood decay fungi by trapping moisture at the surface. As such, the biological growth could be removed periodically (not using pressure methods). The weathered appearance is often a desirable look for exposed exterior woodwork and does not need to be treated along its length, other than to remove the biological growth. If there is concern about deterioration at the connections, remedial preservatives, such as borate rods, could be inserted to retard the action of wood decay fungi or insect attack.

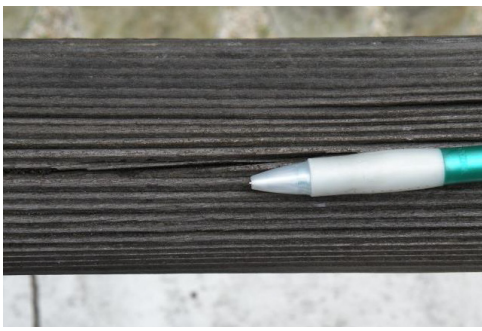
A covered walkway on the south elevation of the Arts Building connects to the Cloister. The walkway is supported by nominal 4-inch by 4-inch wooden posts (Figure 29). Most of the original posts supporting the walkway and the porch of the Cloister have been replaced, reportedly with Ipe (*Tabebuia spp.* aka *Handroanthus spp.*). Four original black locust posts, in place at the landing with the sliding doors into the Arts Building, have experienced various degrees of minor deterioration at the base. These posts are better protected from the elements (weather) than the walkway posts and are, generally, in good condition with only minor deterioration at the base (Figures 30 and 31).

One original post has more extensive deterioration at the base and is suitable for a hidden repair to prevent further deterioration of the wood (Figure 32). The post does not need to be replaced. The deterioration at the base of this post is likely similar to the deterioration that was present in the walkway posts that led to their replacement. The posts (at least the southeast landing post) are attached to the



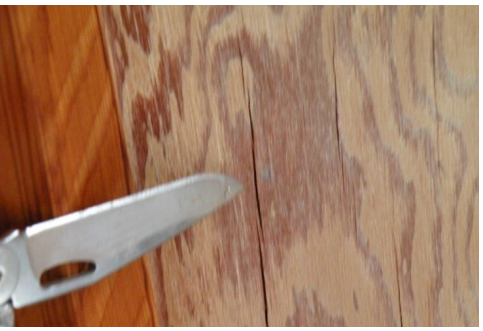






From top to bottom:
Figure 25. South railing on the terrace.
Figure 26. East end of the south railing. Note connection details between the notched railing and the vertical post and the base of the vertical post embedded in the concrete toe-kick on the terrace.
Figure 27. West end of the south railing.
Figure 28. Weathered surface color and texture of the upper surface of the south railing on the terrace.









Fromt top to bottom:
Figure 38. Narrow micro-check in surface veneer of the ceiling plywood.
Figure 39. Larger micro-check in the surface veneer of the ceiling plywood.
Figure 40. Boat patch in the surface veneer of the ceiling plywood.
Figure 41. Router patch in the surface veneer of the ceiling plywood.

stones with a metal pin.

The bases of the replacement posts have been encased with wood trim, although the original posts did not appear to have any trim (Figure 33). The trim may have been attached under the assumption that it would protect the bottom of the posts from moisture. That is not the case. It is recommended that the trim be removed to the original configuration, which will allow for the posts to dry when they get wet. Use of a spacer at the bottom of the post would prevent the end grain of the post from absorbing water under most circumstances.

Wood Condition – Exterior Elements of the Cloister
The Cloister is a simple building constructed of concrete block walls and a low-pitched roof. The soffit, or porch roof, on the west elevation is supported by 4- inch by 4-inch wooden posts (Figure 34). The plywood used to construct the soffit is in poor condition due to wood decay where the Cloister roof has allowed for moisture penetration through the roof covering. The visibly deteriorated plywood was easily penetrated with an awl, particularly at the outer edge (Figure 35). In general, due to the poor condition of the Cloister roof, the plywood in the soffit has two conditions: plywood that has deteriorated, and plywood that will deteriorate. The Cloister roof should be repaired and maintained.

One other observation related to the exterior of the Arts Building and Cloister – there has been a history of ant damage in the buildings at the George Nakashima Woodworker National Historic Landmark site. For some period of time, a program based on bait and traps has been in place to limit attack by insects (Figure 36). Based on this wood assessment, the bait appears to be working at the Arts Building and Cloister and should be continued, unless an alternative preventative program is implemented.

Wood Condition – Interior Wood Elements of the Arts Building
The hyperbolic paraboloid roof of the Arts Building relies on a plywood skin for structural stability. The intent at the time of the wood assessment was to remove a small area of the roof covering and membrane to expose the plywood. Due to heavy rain, opening a probe area was not advisable and deferred to a later date when the structural engineer could examine the plywood.

The edge of the plywood diaphragm layup was visible at the skylight near the northeast corner of the Arts Building (Figure 37). The plywood skin consists of three sheets of 5-ply plywood, each sheet approximately 5/8“ thick. The face veneers on the upper sheet of plywood are thinner than the inner plies; however, this could be due to different fabricators supplying the plywood for the project. The veneer thickness seemed to vary between and within the three panels but this could be due to either manufacturing or installation, rather than differences in panel types. More information on the diaphragm material and construction would be beneficial in understanding the structural performance of the roof as well as potential durability issues.
It was not possible, by visual inspection, to determine if the three sheets of plywood are bonded together with an adhesive. Verification of the use of adhesives to bond the three layers of plywood is paramount if the plywood

layup is assumed to behave as a single composite within the diaphragm. While historical documents suggest that the plywood panels were bonded, the practicality of gluing entire panels that are off-set from one another within the three layers is questionable because of limited assembly time before the adhesive would cure and the lack of means to apply pressure necessary to form a structural bond (clamping). Mechanical fasteners (e.g. screws) attaching the plywood panels together were not visible, but assumed to be hidden beneath the wooden ribs on the ceiling below. The spacing of the ribs likely was intended to cover the edge joints of the plywood. End joints between plywood sheets are visible and, in some cases, have opened slightly with visible misalignment.

Considering structural properties, the plywood sample was determined to have Douglas-fir face plies (assumed to be from the Pacific Northwest rather than the lower Rocky Mountains); that qualifies it for classification as a Group 1 species, which dictates material properties. The cross plies are sugar pine, which is Group 4. The veneer grade for the plies is unknown, although the exposed bottom face ply exhibits patches of measurable size and frequency. It is reasonable to assume the top ply is the same grade. It is not possible to determine the grade of the core plies without deconstructing a large section of several panels (which is not recommended). Also unknown is whether the panels conform to Rated Sheathing, their span rating, or the adhesive used and whether is qualifies as Exposure 1 or 2. These, and other, variables affect the material properties.

Based on the information obtained during this project, the appropriate document for the plywood properties is APA Plywood Design Specification Y510. There is a newer version but some of the properties were changed because of recent changes in the panel layup. Based on industry technical data, ¾-inch 5-ply plywood with Douglas-fir face and back veneers and sugar pine cross plies made in the 60s is essentially the same product that would be made in the 90s. Thus, Y510 seems to be a good source document for material properties.

The underside of the plywood visible from the interior of the Arts Building appears to be free of defects and blemishes. However, close examination of the veneer shows that micro-checks of various widths and lengths are present, as well as patches that replaced defects during the manufacturing process (Figures 38 through 41). The micro-checks are the result of either lathe checks that were present in the veneer after it was rotary cut from the log or due to drying after installation. In either case, the micro-checks are of no consequence for either structural performance or general appearance of the interior space. The patches are placed in the veneer to replace defects such as knots during the manufacturing process. Two types of patches were observed. Most common were boat patches (football-shaped) 4.5 inches long and 2 inches wide. Less common were router patches (with parallel sides and rounded ends) 2 inches long and 1 inch wide. Both patch types are difficult to see on the plywood ceiling without close examination due to the precision of installing the patches to try and match the grain pattern and the whitewash coating that masks the patches. Baldcypress ribs extend between the east and west walls (Figure 42). The ribs are spaced 24 inches on center and, as mentioned earlier, cover the end joints of the plywood. The ribs are not continuous, but are connected with a splice

Above: Figure 42. Baldcypress ribs extending between the east and west walls.
Below: Figure 43. Failure at the joist in the rib along grid line 6.





secured with a single screw. Very minor moisture stains are visible, mostly at the perimeter of the interior space; however, moisture content readings indicated that the wood has a moisture content of approximately 10 percent. The rib along grid line 6 has a split at one splice (Figure 43). The split, or failure, appears to be cosmetic and so would not affect the structural integrity of the ceiling and roof.

Summary

The findings of the assessment can be summarized as follows:

- The Arts Building makes use of a variety of wood species, including Douglas-fir (Pseudotsuga menziesii) for the edge beams and south railing on the terrace, eastern white pine (Pinus strobus) for the corner post and lintel, Baldcypress (Taxodium distichum) for the ceiling ribs, and black locust (Robinia pseudoacacia) for the north railing on the terrace and the original porch posts on the south elevation.

- There are patches of moss and debris on the roof that can reduce the service life of the roof covering and structure below.

- The west and south edge beams, and the southwest corner post, are in good condition; generally free of any deterioration.

- No defects were observed that would preclude the west and south edge beams from being classified as Douglas-fir Select Structural, Beams and Stringers.

- No defects were observed that would preclude the southwest corner post from being classified as Eastern White Pine Select Structural, Structural Joists and Planks.

- The north railing on the terrace is in good condition where it penetrates the wall of the Arts Building; however, it has visible fungal growth and advanced deterioration at the interface with the concrete railing on the terrace and should be repaired.

- The south railing on the terrace is weathered and has biological growth on the surface but is in good condition. The biological growth could be removed periodically and remedial preservatives, such as borate rods, could be inserted at the connections to retard the action of wood decay fungi or insect attack.

- Four original posts in place at the landing with the sliding doors into the Arts Building have experienced various degrees of deterioration at the base. The southeast original post has the most deterioration at the base and is suitable for a hidden repair to prevent further deterioration of the wood. The post does not need to be replaced.

- The supporting posts on the walkway between the Arts Building and the

Cloister, as well as the posts supporting the Cloister porch/soffit, have been replaced. It is recommended that the trim at the base of the replacement posts be removed to the original configuration, which will allow for the posts to dry when they get wet. Use of a spacer at the bottom of the post would prevent the end grain of the post from absorbing water under most circumstances.

- The plywood used to construct the Cloister soffit is in poor condition due to wood decay where the roof has allowed for moisture penetration through the roof covering. The Cloister roof should be repaired and maintained. The plywood soffit should be replaced.

- Due to heavy rain, opening a probe area to assess the plywood diaphragm was not advisable and deferred to a later date when the structural engineer could examine the plywood. More information on the diaphragm material and construction would be beneficial in understanding the structural performance of the roof as well as potential durability issues.

- Baldcypress ribs extend between the east and west interior walls of the Arts Building and are, generally, in good condition, except for a joint failure in the rib along grid 6 and minor moisture stains along the perimeter of the interior space.

Table A1. Drilling log for Nakashima Arts Building.

Drilling Number	Area	Member ID	Drilling Direction	Location	Comments
D1	South elevation	SE landing post	W to E	8” above base	no void
D2	South elevation	NE landing post	W to E	8” above base	no void
D3	South elevation	SW landing post	S to N	$8^{1/2}$” above base	no void
D4	South elevation	NW landing post	N to S	8” above base	no void
D5	SW corner post	post	N to S	at casement window	no void
D6	SW corner post	post	W to E	$5^{3/8}$” above base	no void
D7	West terrace	North railing	S to N	$2^{1/2}$” from wall, 1” from top	no void
D8	West terrace	North railing	S to N	2” from concrete rail, mid-depth	mostly void
D9	South elevation	SE landing post	W to E	2” above base	check in center, visible deterioration at base
D10	South elvation	NE landing post	W to E	2” above base	no void
D11	South elevatoin	SW landing post	W to E	2” above base	no void
D12	South elevation	NW landing post	W to E	2” above base	no void



Figure A1. Drilling locations on plan view, Arts Building.



Figure A2. Southwest corner post drilling locations, Arts Building.

4.5. Structural Assessment
David Biggs, P.E., S.E.

Introduction

1. Scope of services:

- Provide an initial structural assessment of the exposed roof structure of the Arts Building based upon visual observations.
- Identify structural issues and needs.
- Present recommendation for the management plan.

2. Two site visits were made along with project architect, Cesar Bargues Ballester on November 12, 2015 and May 9, 2016.

3. Funding was unavailable in the Getty Foundation grant for analytical work or computer modeling. However, I was able to incorporate some analytical work and to interest SAHC into providing a master's student to perform computer modeling.[39]

Background

The Arts Building was constructed from 1964 to 1967. The roof structure is a hyperbolic paraboloid composed of three layers of 5/8 inch thick plywood. The full description and history of the building are provided in the section 5.1. and 3.2. respectively.

The hyperbolic paraboloid roof structure on the Arts Building is a rarity for the United States. There are two additional, slightly smaller hyperbolic paraboloid roofs at the site on the Lumber Storage. The first pre-dates the Arts Building (1958-1959) and the second is dated 1961. George Nakashima clearly experimented with the hyperbolic paraboloid before undertaking the Arts Building.

The development of timber hyperbolic paraboloids is attributed to Great Britain from approximately 1957 to 1975[40]. Those designs included timber boards for roof decking. In the United States, the West Coast Lumberman's Association adopted standards[41] for timber hyperbolic paraboloid roofs. No search was done to determine how many structures exist that were constructed with this standard.

Observations/Comments

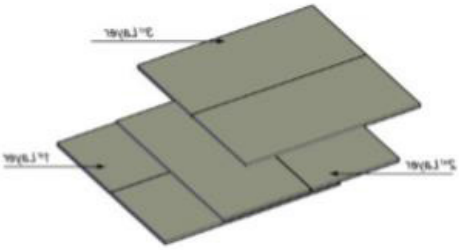
1. Building

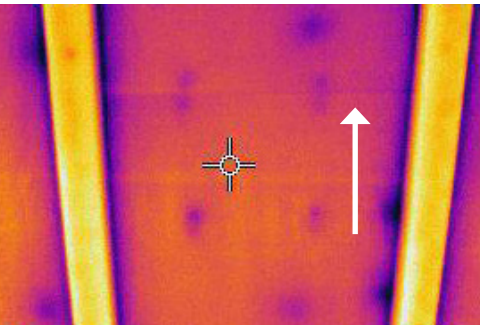
a. Roof Structure

• The underside of the plywood roof structure is visible along with wooden ribs (Figure 1). The underside of the roof structure has noticeable sag. Measurements will be provided later.
• Overall, the joints between the plywood panels are tight with few gaps.
• The three layers of plywood have overlapping joints (Figure 2). The design details required nailing between layers. There are no original construction reports of any glue being used.
• Figure 3 shows an infrared thermography scan from the underside provided by

39. A. Troci, *Modeling and Analysis of Plywood Plate Structures*, Master's Thesis for Advanced Masters in Structural Analysis of Monuments and Historical Constructions (SAHC), Czech Technical University in Prague, 2016.
SAHC is an Erasmus Mundus masters course, co-funded by the Erasmus Programme of the European Union.
The objective is to offer an advanced education program on the engineering of conservation of structures, with a focus on architectural heritage.
40. L. G. Booth, *The design and construction of timber hyperbolic paraboloid shell roofs in Britain: 1957-1975*, The Construction History Society, Construction History, Vol. 13. 1997.
41. West Coast, *Construction and analysis of simple hyperbolic-paraboloid shells of West Coast lumber*, West Coast Lumbermen's Association, Portland, Ore., 1900.









From top to bottom:
Figure 1. Underside view of the hyperbolic paraboloid roof.
Figure 2. Plywood layout.
Figure 3. Infrared scan.
Figure 4. Cracked rib.

Cesar Bargues Ballester. The scan shows several nail locations and the joint at the first plywood layer (arrow Figure 3). We can't be certain which layers (2 or 3) the nails belong to without performing a removal.

- The joints of the ribs are screwed together and are generally tight.
- The ribs themselves primarily hide the longitudinal joint between the exposed plywood panels. They effectively offer minimal structural capacity and are ignored in the analyses.
- Minimal structural distress is evident. Figure 4 shows one cracked rib likely due to excessive deflection.
- There are a few locations where previous condensation and/or roof leaks are evident. Reportedly, there are no active leaks.

b. Edge beams and posts

- The edge beams have no noticeable bowing or warping. Although they are exposed on the exterior, no noticeable deterioration was evident. See 5.3. Wood Assessment [42] for an assessment of the materials.
- Some of the posts have slight water deterioration at the bases.

c. Walls

- The exterior walls are unreinforced concrete masonry with a cement plaster coating.
- The buttresses are faced with rubble stone.
- There is horizontal cracking along the exterior of the north wall.

d. Roofing - wetness

- Samples roof cuts were made by a contractor during my second visit to determine if the plywood panels were wet. Roof leaks caused previous damage. There is a concern whether the leaks were actually stopped or whether the areas adjacent to the repairs were ever dried out.
- A significant area near the skylight was wet; the insulation was saturated and the plywood were wet also. Recommendations were immediately made to replace this area of roofing. Temporarily roof vents were installed to assess whether the vents would be an effective way to dry and maintain the plywood under the roofing.

e. Previous repairs

- Reportedly, a section of roof plywood was replaced due to water damage. There is no indication the roof structure was shored during the repair work.

Measurements

1. Survey readings to the underside of the roof were provided by the Architectural Conservation Laboratory.

- Readings were taken to the bottom of several ribs (see table A at the end of this section). Figure 5 shows the plan of where the readings were taken.

- Figure 6 shows a 3D plot of these readings. The readings taken along the walls and the edge beams generally plot as a straight line. To provide the installed alignment of the ribs, straight lines were drawn connecting the rib ends (except near

the chimney and the north wall).

2. Variance to theoretical.

• Using the ribs running from the east wall to the west edge beam, the estimated deflection from theoretical can be determined from the data in Appendix A. Straight lines were drawn connecting the rib ends except near the northwest buttress and along the plywood at the north wall.

• Measurements along Rib number 8 indicate the deflection at mid-span is approximately 4.9 inches and at the ¼ point and the ¾ point from east to west are 3.1 inches and 4.2 inches respectively.

3. Comparison to initial deflection reported.

• From an interview with Robert Lovett, there is only one reported deflection measurement that was taken following the removal of the shoring that was used during the roof construction. Reportedly, the deflection measurement (1.25 inches) was taken near the corner of the mezzanine. As best we know, it represents the deflection due to the roof dead lead only.

• Using the current field measurements (from Appendix A), the approximate deflection is 4.2 inches at the corner of the mezzanine. This indicates that the sag that has occurred since construction is approximately 4.2" – 1.25" = 2.95". The sag is likely due to creep deflection from the dead weight and snow. Based upon modern timber design, creep deflection could be over 2.5 times the dead load.

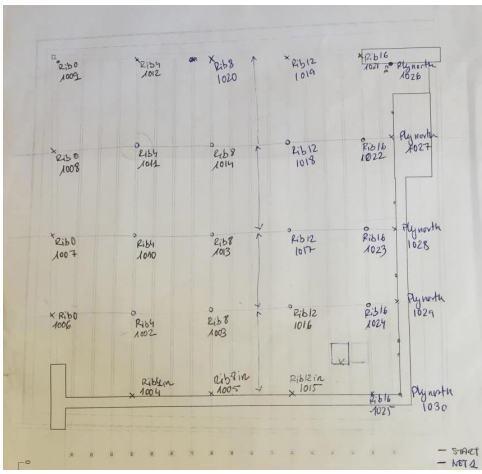


Figure 5. Plan of measurement locations.

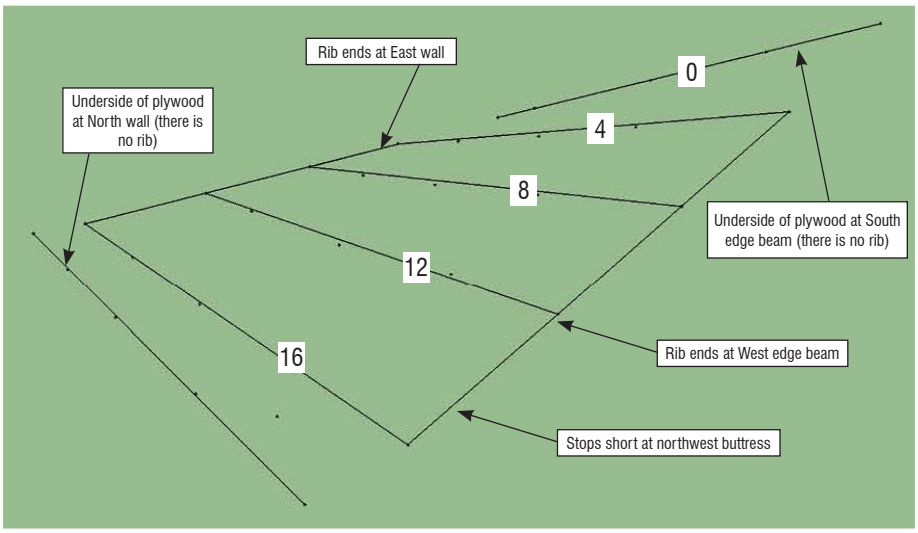


Figure 6. Plot of roof measurements. Numbers indicate rib number according to Reflecte Ceiling Plan (see Naka A-09. The Arts Building: Reflected Ceiling Plan).

The actual creep is estimated at (2.95/1.25) = 2.36 times dead load.

Analyses

1. Original Theory (Noted as Simplified Design Method in the thesis)

a. The theory relative to timber roofs was published in 1955[43] and later in 1957[44]. The original theory was stress-based; it did not address deflections.

b. The theory was based upon a level, symmetrical roof structure with two points

42. Anthony, *Wood Assessment, Nakashima Arts Building, New Hope, Pennsylvania*, Antonhy and Associates for University of Pennsylvania, School of Design, May 2016.
43. E. Reissner, "On some aspects of the theory of thin elastic shells" in *Journal of the Boston Society of Civil Engineers*, Vol. 42, No. 2, April 1955.
44. Newsum, *Standard Hyperbolic Paraboloid Roofs*, Newsum Timber Engineers, 1961

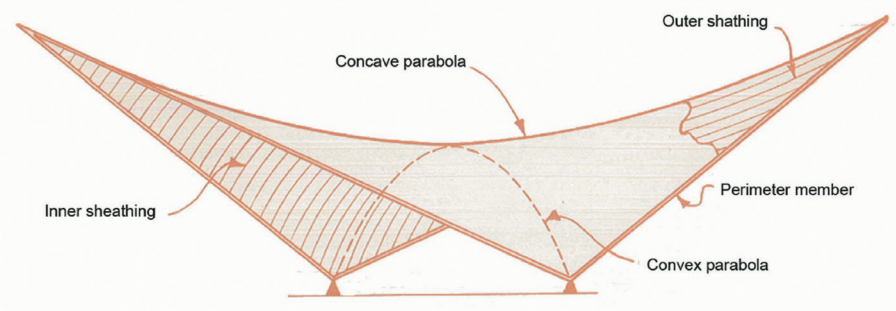
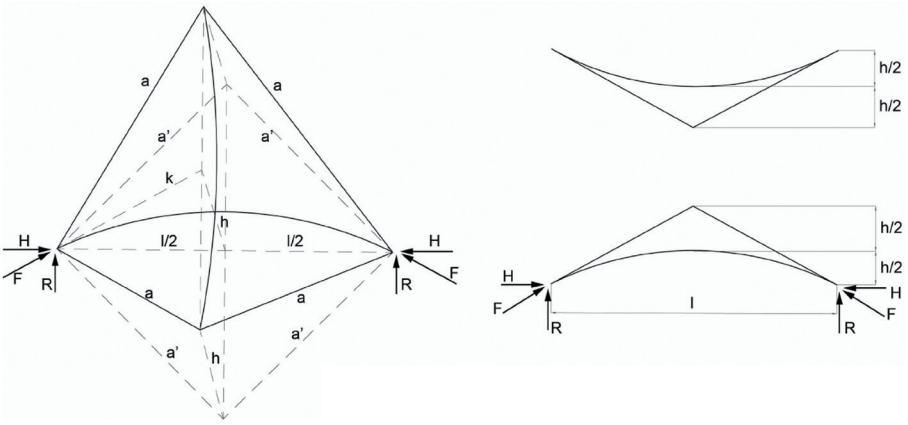
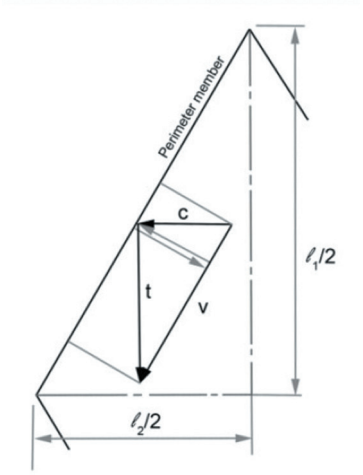


Figure 7. Level, symmetrical hyperbolic paraboloid





thrust is determined as follows:

(1) $\frac{R}{h} = \frac{H}{L/2}$ solving for H; $H = \frac{R\,L}{2\,h}$

The force, F, which is in the direction of the line, k, in Fig. 3a, is the resultant of the horizontal thrust, H, and the vertical reaction, R.

(2) $\frac{F}{k} = \frac{R}{h}$ solving for F; $F = \frac{R\,K}{h}$

Dividing the force, F, into components parallel to the perimeter members, the compression force, C, in the perimeter members is:

$\frac{F/2}{k} = \frac{C}{a}$ solving for C; $C = \frac{a\,F/2}{k}$

substituting the value for F in equation (2),

(3) $C = a\frac{\frac{R\,k}{h}}{2\,k} = \frac{R\,a}{2\,h}$

Figure 8. Original theory.
a. lenght onf one side
a'. horiz. projection of lenght a.
C. total compression force in perimeter member.
c. principal compressive force in sheathing per foot.
F. resultant of the vertical reaction R and the horizontal thrust H.
H. horizontal thrust.
h. vertical distance from point of support to highest point of the shell.
k. inclined distance from support to widpoint of length 1.
l_1. length along longitudinal axis.
l_2. length along transverse axis.
R. vertical reaction
t. principal tension force in sheathing per foot.
v. boundary shear force per foot.

of support as seen in Figure 7. Figure 8 is taken from that work. The roof acts as a membrane. There is tension on the catenary curve between the sloping sides, and compression arches between low to high. The Troci thesis1 explains the structural action in detail.

c. The analysis equations in the literature are for a level roof. The Arts Building is not a level roof, but there is some criteria given for a roof with its shape. Figure 9 is taken from "Standard Hyperbolic Paraboloid Roofs"[6] by Newsum Timber Engineers. It notes that the rise should be 1:2.5. For the Arts Building, this translates

to a rise of approximately 14 feet for a 36 foot edge. This compares well to the actual building.

d. In the same Newsum document, tabulated data was given for various shells. Figure 10 shows the table that is based upon boards for the membrane rather than plywood. For a 36 foot shell, the table would require 3 layers of ¾" boards. In the documents for the Arts Building, the roof structure was specified to have 3 - ½" layers of plywood; 3 layers of 5/8" plywood were actually used.

e. Comparing the construction of the Arts Building to the published information of the time, it appears that George Nakashima and his engineer, Paul Weidlinger, had access to the British information during the design of the Arts Building.

f. The original theory only accommodated balance loads from dead load (self-weight) and snow loads. The original theory did not account for unbalanced loads

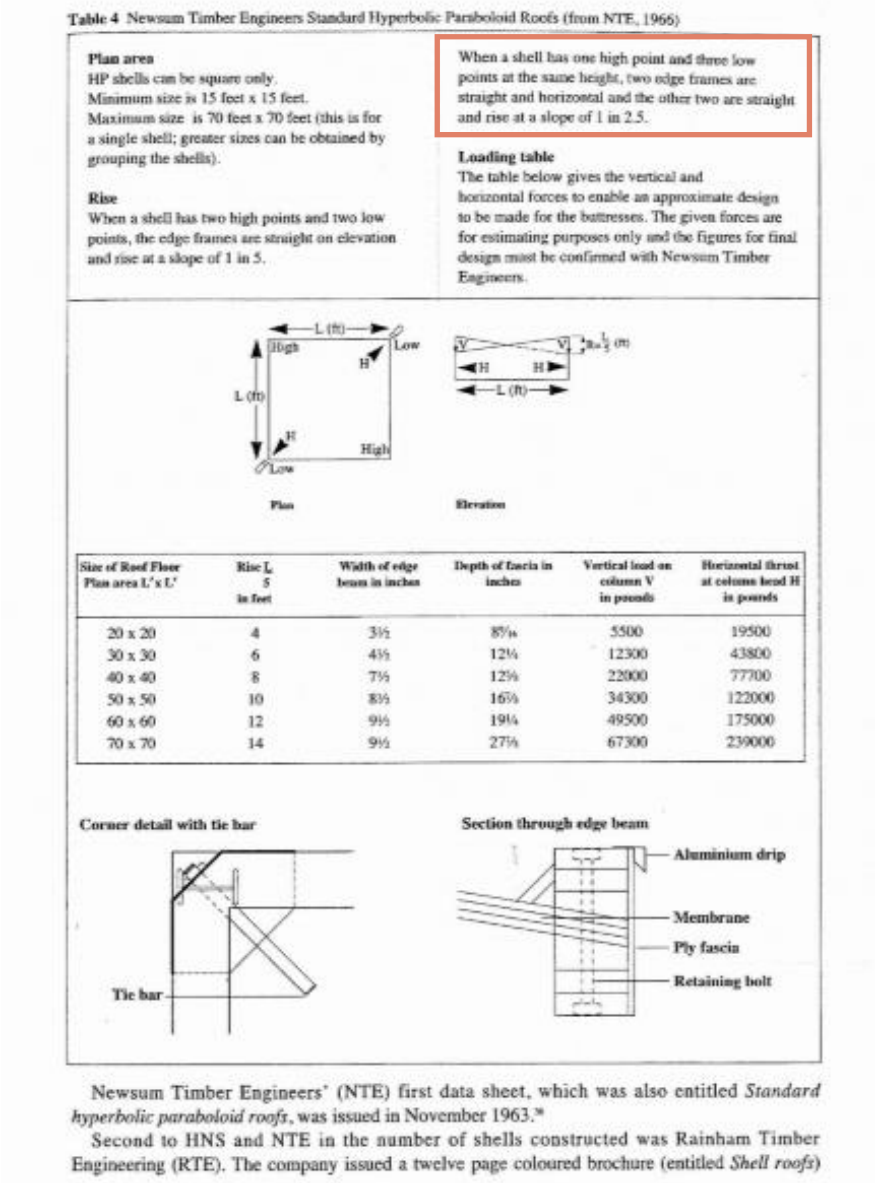


Table 4 Newsum Timber Engineers Standard Hyperbolic Paraboloid Roofs (from NTE, 1966)

Plan area
HP shells can be square only.
Minimum size is 15 feet x 15 feet.
Maximum size is 70 feet x 70 feet (this is for a single shell; greater sizes can be obtained by grouping the shells).

Rise
When a shell has two high points and two low points, the edge frames are straight on elevation and rise at a slope of 1 in 5.

When a shell has one high point and three low points at the same height, two edge frames are straight and horizontal and the other two are straight and rise at a slope of 1 in 2.5.

Loading table
The table below gives the vertical and horizontal forces to enable an approximate design to be made for the buttresses. The given forces are for estimating purposes only and the figures for final design must be confirmed with Newsum Timber Engineers.

Plan Elevation

Size of Roof Floor Plan area L' x L'	Rise L/5 in feet	Width of edge beam in inches	Depth of fascia in inches	Vertical load on column V in pounds	Horizontal thrust at column head H in pounds
20 x 20	4	3½	8⅝	5500	19500
30 x 30	6	4½	12¼	12300	43800
40 x 40	8	7½	12⅝	22000	77700
50 x 50	10	8½	16⅝	34300	122000
60 x 60	12	9½	19¼	49500	175000
70 x 70	14	9½	27⅛	67300	239000

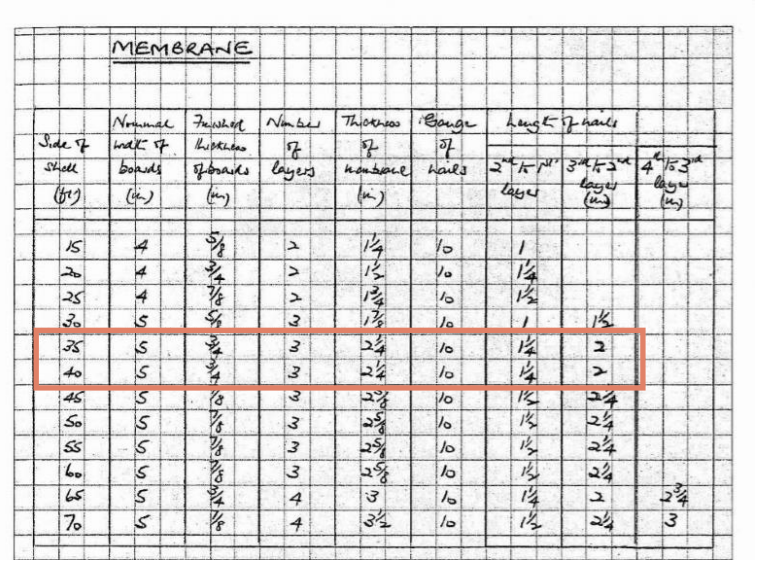
Corner detail with tie bar

Section through edge beam

Newsum Timber Engineers' (NTE) first data sheet, which was also entitled *Standard hyperbolic paraboloid roofs*, was issued in November 1963.[38]

Second to HNS and NTE in the number of shells constructed was Rainham Timber Engineering (RTE). The company issued a twelve page coloured brochure (entitled *Shell roofs*)

Fig. 9. Newsum Timber Engineers Standard Hyperbolic Paraboloid Roofs.



MEMBRANE

Side of shell (ft)	Nominal width of boards (in.)	Finished thickness of boards (in.)	Number of layers	Thickness of membrane (in.)	Gauge of nails	Length of nails: 2nd through 1st layer	Length of nails: 3rd through 2nd layer (in.)	Length of nails: 4th to 3rd layer (in.)
15	4	5/8	2	1 1/4	10	1		
20	4	3/4	2	1 1/2	10	1 1/4		
25	4	7/8	2	1 3/4	10	1 1/2		
30	5	5/8	3	1 7/8	10	1	1 1/2	
35	5	3/4	3	2 1/4	10	1 1/4	2	
40	5	3/4	3	2 1/4	10	1 1/4	2	
45	5	7/8	3	2 3/8	10	1 1/2	2 1/4	
50	5	7/8	3	2 3/8	10	1 1/2	2 1/4	
55	5	7/8	3	2 3/8	10	1 1/2	2 1/4	
60	5	7/8	3	2 3/8	10	1 1/2	2 1/4	
65	5	3/4	4	3	10	1 1/4	2	2 3/4
70	5	7/8	4	3 1/2	10	1 1/2	2 1/4	3

Figure 10. Table for Newsum shells.

due to snow and ice, wind loads or support conditions other than those shown in Figure 8.

2. Computer Modeling (Troci's thesis[1])

The thesis is provided for complete details of the analyses. Finite element analysis was used for the modeling. A summary of important information and results is provided in the following sections.

a. Computer modeling of the Arts Building is desirable for several reasons:

- There is a limited amount of analytical information derived from the hand calculations based upon the original theory.
- The original theory does not account for loading conditions other than balanced loading.
- The roof configuration with the inclined corner is not considered in the original theory.
- The original theory does not account for the vertical support of the edge beams and low walls.
- Deflections are not considered in the original theory.

b. Support conditions

- The modeling allows us to simulate different support conditions for the roof structure. Modeling the support provided by the walls, edge beams and posts is possible with the computer as well. Four configurations were evaluated (two without posts and two with posts). Only configurations 3 and 4 (with posts) represent the actual construction..
- In addition, the modeling allows us to include edge conditions in the analysis. The thesis compares the intersection of the roof plywood and the edges as either hinged or clamped.

c. Unbalanced loads

- Once the model is validated so that it adequately represents the existing conditions. The computer modeling can be manipulated to examine any number

of loading conditions, not just the balanced conditions.

- For the modeling, five loading conditions were selected. The loads are listed in the thesis in metric units.

The snow and wind loads match the building code requirements for Pennsylvania.
DL= Dead load = 24psf (pounds per square foot)
SL = Snow load = 30 psf
WL = Wind load = 25 psf

LC1: Full DL and SL uniformly distributed. This
LC2: Full DL + one quarter SL wind swept onto smaller area. See Figure 11 for load contours for the SL only. The winter of 2015-2016 did not produce significant snow fall to get a sense of the possible drifting conditions. The author (Biggs) selected this loading condition as a reasonable expectation for drifting.
LC3: Full DL + half SL wind swept on to smaller area. See Figure 11 for load contours for the SL only. This loading condition is considered the extreme that might be expected.
LC4: Full DL - wind uplift (0.6 x 25 psf = 15 psf) uniformly applied. Since this is a uniformly applied load, the results can be obtained from proportioning LC1.

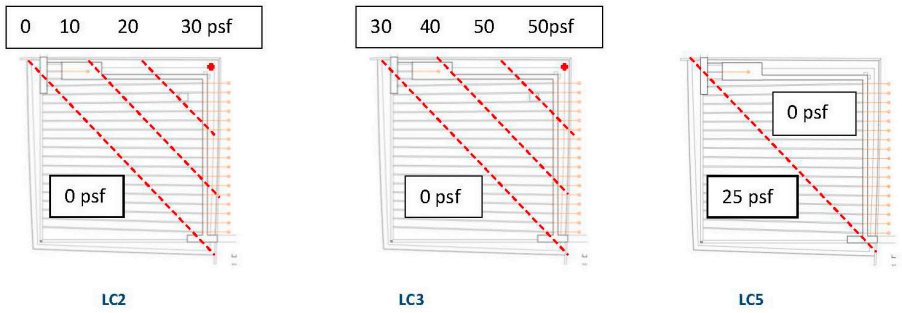


Figure 11. Snow and wind loadings acting downward on roof.

LC5: Full DL + downward wind on upper half of roof (25psf uniformly applied over loaded area). See Figure 11 for loaded area for the WL only. The author selected this as the loading for an extreme wind event.
d. Materials assumptions

Structural Element	Species	Code
South Edge beam	Douglas-fir	Western Lumber Grading Rules (2011)
West Edge beam	Douglas-fir	Western Lumber Grading Rules (2011)
Posts	Eastern white pine	Standard Grading Rules for Northeastern Lumber (2013
Plywood	Ponderosa pine	Plywood Design Specification (1997) - APA

Table 9.1 Species and referring codes of the structural elements.

With input from wood scientist, Ron Anthony4, the material properties for the wood elements of the roof were chosen as shown in Table 9.1 (reproduced from the thesis).

The plywood properties were selected from Table 3 of the American Plywood As-

ALLOWABLE STRESSES FOR PLYWOOD

TABLE 3

ALLOWABLE STRESSES FOR PLYWOOD (psi) conforming to Voluntary Product Standard PS 1-95 for Construction and Industrial Plywood. Stresses are based on normal duration of load, and on common structural applications where panels are 24" or greater in width. For other use conditions, see Section 3.3 for modifications.

Type of Stress		Species Group of Face Ply	Grade Stress Level(1) S-1 Wet	S-1 Dry	S-2 Wet	S-2 Dry	S-3 Dry Only
EXTREME FIBER STRESS IN BENDING (F_b)	F_b	1	1430	2000	1190	1650	1650
TENSION IN PLANE OF PLIES (F_t)	F_b & F_t	2, 3	980	1400	820	1200	1200
Face Grain Parallel or Perpendicular to Span (At 45° to Face Grain Use 1/6 F_t)	F_t	4	940	1330	780	1110	1110
COMPRESSION IN PLANE OF PLIES		1	970	1640	900	1540	1540
		2	730	1200	680	1100	1100
Parallel or Perpendicular to Face Grain (At 45° to Face Grain Use 1/3 F_c)	F_c	3	610	1060	580	990	990
		4	610	1000	580	950	950
SHEAR THROUGH THE THICKNESS(3)		1	155	190	155	190	160
Parallel or Perpendicular to Face Grain (At 45° to Face Grain Use 2 F_v)	F_v	2, 3	120	140	120	140	120
		4	110	130	110	130	115
ROLLING SHEAR (IN THE PLANE OF PLIES)		Marine & Structural I	63	75	63	75	—
Parallel or Perpendicular to Face Grain (At 45° to Face Grain Use 1-1/3 F_s)	F_s	All Other(2)	44	53	44	53	48
MODULUS OF RIGIDITY (OR SHEAR MODULUS)		1	70,000	90,000	70,000	90,000	82,000
		2	60,000	75,000	60,000	75,000	68,000
Shear in Plane Perpendicular to Plies (through the thickness) (At 45° to Face Grain Use 4G)	G	3	50,000	60,000	50,000	60,000	55,000
		4	45,000	50,000	45,000	50,000	45,000
BEARING (ON FACE)		1	210	340	210	340	340
Perpendicular to Plane of Plies	$F_{c\perp}$	2, 3	135	210	135	210	210
		4	105	160	105	160	160
MODULUS OF ELASTICITY IN BENDING IN PLANE OF PLIES		1	1,500,000	1,800,000	1,500,000	1,800,000	1,800,000
	E	2	1,300,000	1,500,000	1,300,000	1,500,000	1,500,000
		3	1,100,000	1,200,000	1,100,000	1,200,000	1,200,000
Face Grain Parallel or Perpendicular to Span		4	900,000	1,000,000	900,000	1,000,000	1,000,000

(1) See pages 12 and 13 for Guide.
To qualify for stress level S-1, gluelines must be exterior and only veneer grades N, A, and C (natural, not repaired) are allowed in either face or back.
For stress level S-2, gluelines must be exterior and veneer grade B, C-Plugged and D are allowed on the face or back.
Stress level S-3 includes all panels with interior or intermediate (IMG) gluelines.

(2) Reduce stresses 25% for 3-layer (4- or 5-ply) panels over 5/8" thick. Such layups are possible under PS 1-95 for APA RATED SHEATHING, APA RATED STURD-I-FLOOR, UNDERLAYMENT, C-C Plugged and C-D Plugged grades over 5/8" through 3/4" thick.

(3) Shear-through-the-thickness stresses for MARINE and SPECIAL EXTERIOR grades may be increased 33%. See Section 3.8.1 for conditions under which stresses for other grades may be increased.

Figure 12. Plywood properties.

Structural element	Grade	F_b	F_t	F_v	F_s	$F_{c\perp}$	F_c	G	E
		[kPa]	[kPa]	[kPa]	[kPa]	[kPa]	[kPa]	[Gpa]	[Gpa]
Plywood	EXP 1, 2 or INT	8,274	8,274	827	331	1,448	6,825	0.379	8,274

Table 9.3. Mechanical properties of the plywood (from thesis).

sociation Standard PS 1-95[7] as shown in Figure 12. The highlighted values were converted to SI units and used in the thesis Table 9.3 (reproduced below). These values are subject to change with further evaluation.

F_b: Extreme Fiber stress in Bending
F_t: Tension in Plane of Plies (at 45° to face grain use 1/6 F_t)
F_v: Shear Through the Thickness (at 45° to face grain use $2F_v$)
F_s: Rolling Shear in the Plane of Plies (at 45° to face grain use 1-1/3 Fs)
$F_{c\perp}$: Bearing on Face (perpendicular to Plane Plies)
F_c: Compression in Plane of Plies (at 45° to face grain use 1/3 Fc)

G: Shear Modulus Through the Thickness (at 45° to face grain use 4G)
E: Modulus of Elasticity in Bending in Plane of Plies

3.Comparison of original theory to modeling
a. Since the original theory was based upon a level, symmetrical roof with balanced loading, the computer modeling first examined that case.
b. The thesis highlights the differences in results between the original theory (shown in Figure 8) and the computer analyses. Figure 13 shows the results as listed in Table 7.1 from the thesis.
c. The results are within acceptable limits so the model is deemed reasonable. This helps validate the model.

		Simplified solution	**Numerical solution**		**% of difference**
Reaction **F**	[kN]	670,41	669		0,2%
Edge compression **C**	[kN]	466,86	459		2%
Shear stress **rs**	[kN/m2]	813	Max	-512	[-]
			Min	-823	[-]
			Average	-811	0,2%
Normal stress **rr-ss**	[kN/m2]	0	Max	182	[-]
			Min	-25	[-]
			Average	10	1.2%*
* indicates that is not a percentage of difference but the percentage of the shear stress.					

Figure 13. Comparison of original theory to computer analysis for level, symmetrical roof with balanced loading.

4. Modeling of actual roof configuration with balanced and unbalanced loading conditions
a. The actual inclined roof configuration was modeled. Figure 14 shows the results as listed in Table 7.3 from the thesis which compares the computer model to the level structure given in Figure 7.
b. The results indicate that the computer results are up to 15% different than the hand calculations (simplified method).

		Simplified solution	**Numerical solution**		**% of difference**
Reaction **F**	[kN]	670,41	568		15%
Edge compression **C**	[kN]	466,86	417		11%
Shear stress **rs**	[kN/m2]	813	Max	867	[-]
			Min	-688	[-]
			Average	726	11%
Normal stress **rr-ss**	[kN/m2]	0	Max	962	[-]
			Min	-1304	[-]
			Average	146	18%*
* indicates that is not a percentage of difference but the percentage of the shear stress.					

Figure 14. Comparison for level, symmetrical hyperbolic paraboloid.

c. Using the computer results for hinged supports (Configuration 4 in the thesis) for the actual inclined roof:

- The balanced load reaches 93% of capacity as shown in Figure 15

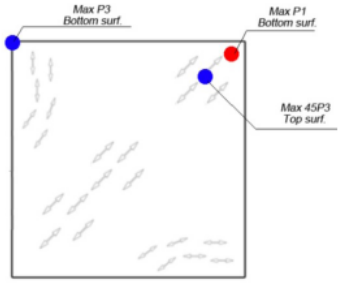


Figure 15. Maximum streess location for balanced snow load.

Figure 11.65 - Principal directions and location of maximum stresses LC1

Table 11.28 – Comparison stresses and strengths LC1

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,64	-6,83	**0,39**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,83	-2,28	**0,80**
Max P1	**Ft/6**	**6P1/Ft**
1,28	1,38	0,93

- For unbalanced loads, the load combination due to wind produced the maximum stress which is 99% of capacity (Figure 16).=

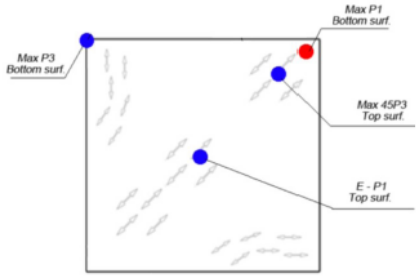


Figure 16. Unbalanced load combination 5

Figure 11.74 - Principal directions and location of maximum stresses LC5

Table 11.34 – Comparison stresses and strengths LC5

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,50	-6,83	**0,37**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,80	-2,28	**0,79**
Max P1	**Ft/6**	**6P1/Ft**
1,37	1,38	0,99
E-P1	**Ft/6**	**6D/Ft**
1,05	1,38	**0,76**

d. Deflections

- The calculated deflection at mid-span (LC1) for configuration 3 is 0.09 inches (2.4 mm). For configuration 4, the deflection is 0.07 inch (1.8 mm). The values for just dead load would be 24/54 (the dead load to total load ratio) times these values or 0.04 inches and 0.03 inches respectively. These are unrealistically low values given the reported deflection during construction was approximately 1.25 inches.
- The computer results that have greater deflection with clamped edges compared to hinged edges are also unrealistic. This requires further evaluation.
- There are several possibly causes for the deflection issue. First, the assumed stiffness represented by the plywood modulus of elasticity is likely too high. Second, the plywood layers are not acting fully composite. Third, both effects may be acting. Further evaluation is required.

Conclusions

1. General
a. Based upon observations of the existing building, the roof has structurally performed extremely well despite the original design theory being very basic and not accounting for the high end and the post supports.
b. Thanks to the SAHC program, we were able to accomplish significant computer modeling that was not possible within the grant budget.
c. The modeling has some limitations due to assumptions that were made with the material properties.
d. Refinements to the modeling would be possible with improved materials properties and dynamic testing of the roof.

2. Roof
a. Materials
- The roof assessment is based upon material assumptions. No physical testing was possible.
- Additional material assessment should be developed to refine the computer modeling and the assessment.
- Testing is required to evaluate the connection between the layers of plywood.

b. Loadings
- The original design was based upon only a balanced dead load and snow load. The theory assumed a level structure and did not make any adjustment for inclined structures.
- The computer modeling included the balanced load (LC1) and two unbalanced conditions (LC2 and LC3). We were also able to include two wind loadings (LC4 and LC5).
- LC1 and LC3 may represent the code required loadings, but LC2 is considered more reasonable. This could be evaluated by future readings during snow events.

c. Stresses
- The original design theory does not specifically account for the inclined roof configuration built. The original theory did not account for the vertical support of the walls and the posts. The computer analyses indicate these have a significant beneficial effect.
- Computer modeling indicates that the magnitudes of the actual stresses are similar to those determined by the original theory.
- There is insufficient snow data to determine if the building has ever been fully loaded.
- No additional dead load should be added to the roof without reviewing the modeling results.
- The computer results indicate that it would be advisable to provide temporary shoring during heavy snows that accumulate in the flattened area of the roof (along north wall).

d. Deflections
- The original theory did not address deflections.
- Based upon possibly unreliable information, the actual measured deflections

may be approximately one part dead load deflection and 2.4 parts creep deflection.

- The calculated deflections from the computer modeling are highly dependent upon many assumptions including materials characteristics, edge conditions and loadings. The calculated values are inaccurate and require further study.
- Due to lack of time, the computer model was not tuned to the measured deflected values. This requires more time and effort. Tuning requires adjusting the stiffness to the static deflections and the dynamic vibrations and running further iterations of the model.

e.Overload during unbalanced loadings need shoring

- The modeling results provided information about unbalanced loads that was not available from the original design.
- Unbalanced loading LC3 creates slight overload conditions. Temporary shoring should be considered until further studies are performed.

f. Importance of shoring during repairs

- The modeling highlights the need for providing temporary shoring during roofing repairs.
- Reportedly, previous plywood replacement in the northeast corner did not have shoring. It is fortunate that there were no repercussions because the plywood area replaced is one of the highest stressed parts of the roof.

3. Walls

a. The exterior cracking in the north wall appears to be due to horizontal forces from the roof structure. The computer modeling should be expanded to include the walls to validate this assumption.

b. The horizontal cracks in the north wall should be strenghtened.

Right: Table A. Survey measurements by César Bargues Ballester.

Summary

_DESC	Position X	Position Y	Position Z
Network 1_Start	5000.0000	5000.0000	1000.0000
Network2	5000.0010	5202.7184	1000.5618
1R1	5043.7119	4895.9146	1108.3752
1R2	4858.9755	5000.7829	1179.0243
1R3	4935.5916	4955.3229	1151.6713
1R4	4802.1198	5030.7504	1202.4110
1R5	4681.9194	5093.3633	1253.3158
3R1	5066.0933	4938.8588	1107.8680
3R2	4948.8767	5001.6242	1146.8703
3R3	4873.8265	5041.5278	1172.6415
3R4	4804.2228	5078.8651	1197.6986
3R5	4704.5227	5132.7618	1234.6708
5R1	5088.2349	4981.6699	1107.0576
5R2	4972.7220	5041.8368	1138.9505
5R3	4907.0186	5076.0081	1158.3642
5R4	4824.7970	5118.9474	1184.4486
5R5	4731.5919	5168.9584	1215.3110
7R1	5109.5414	5024.3271	1106.5392
7R2	5010.0373	5074.9378	1128.7348
7R3	4914.2118	5123.8401	1152.6568
7R4	4846.4101	5160.1006	1171.2390
7R5	4743.0366	5215.0637	1201.8665
8R1	5114.0617	5043.3900	1103.6368
8R2	5018.3350	5090.6344	1122.1163
8R3	4919.8924	5142.8750	1146.1394
8R4	4859.3159	5178.3679	1164.1333
8R5	4760.0234	5234.3203	1189.6330
9R1	5131.4420	5067.2406	1106.0094
9R2	5033.6368	5116.3850	1123.4755
9R3	4939.2907	5157.9904	1139.5486
9R4	4853.9538	5206.3490	1161.5534
9R5	4770.2884	5253.9436	1181.1748
11R1	5147.2610	5105.2860	1103.3532
11R2	5052.4392	5159.3360	1118.5929
11R3	4970.2441	5199.1409	1131.2931
11R4	4881.5879	5244.1250	1146.7031
11R5	4784.4890	5295.6973	1167.6870
13R1	5175.3608	5152.1079	1104.9475
13R2	5073.7235	5202.2240	1114.0865
13R3	4989.2920	5243.2526	1123.3271
13R4	4913.4393	5280.7653	1133.0178
13R5	4805.4777	5335.1535	1151.1202
15R1	5197.3611	5194.6152	1104.4434
15R2	5091.0618	5239.6424	1106.1720
15R3	4998.0886	5290.7912	1116.4261
15R4	4929.8088	5324.4828	1121.8221
15R5	4826.0313	5375.5079	1134.2240
17R1	5218.9375	5237.9267	1104.2552
17R2	5102.1117	5292.7604	1107.0102
17R3	5023.9737	5323.1487	1105.9160
17R4	4947.4579	5367.1510	1111.9608

Note:
Yellow means network points (f

Note:
Grey means rib in central positi

Summary

17R5	4861.1402	5404.7620	1115.3633
C1	4868.2044	5431.2858	1110.4742
C2	4913.3455	5407.5724	1110.0805
C3	4998.6509	5363.3989	1108.7799
C4	5081.0406	5315.4854	1104.6491
C5	5226.2402	5247.5092	1105.7102
C6	5170.2950	5276.7819	1106.2763

Note:
Blue means ceiling level (plywo

4.6. Envelope and Interior Assessment
Watson & Henry Associates

Background

The purpose of this consultation is to:
- Observe the building envelope and environmental management of the building;
- Observe the collections stored and exhibited in the building; and;
- Provide preliminary recommendations for:
    1. Monitoring of the environment and envelope performance;
    2. Mitigating the environmental vulnerabilities of the collections; and,
    3. Improving environmental management and the hygrothermal performance of the envelope.

The observations were made on Michael C. Henry's site visits of 24 July 2015, 23 October 2015, 12 November 2015, 02 March 2016 and 23 April 2016. Students enrolled in PennDesign's graduate course HSPV 516 Building Diagnostics and Monitoring accompanied him on the 23 October 2015 site visit. Leah Bright, a graduate student in the Winterthur/University of Delaware Graduate Program in Art Conservation (WUDPAC) accompanied him on the 23
October 2015 and the 02 March 2016 site visits with Professor Joelle Wickens from WUDPAC on the latter.

This section is organized as follows:
- Applicable Guidance
- Overview of the Arts Building and Cloister;
- The Collection and Environmental Vulnerabilities;
- Climatic and Situational Contexts;
- Building Envelope and Non-Mechanical (Passive) Environmental Management;
- Mechanical System for Environmental Management;
- Natural Light Management; and,
- Conservation Issues and Recommendations.

Attached to this letter are:
- Appendix B: Investigating the Preservation Needs of Objects within the George Nakashima Arts Building, by Leah Bright;
- Appendix C: Nakashima Art Studio Daylighting Study, by Shin-Yi Kwan and Janki A Vyas;
- Appendix D: Engineering Weather Data for Trenton/Mercer County Airport; and,
- Appendix E: Large Format Versions of Trend Graphs in this Report.

Applicable Guidance

The following guidance applies to environmental management at George Nakashima's Arts Building and Cloister:
- Secretary of Interior's Standards for the Treatment of Historic Properties 1995;
- New Orleans Charter for the Joint Preservation of Historic Structures and Artifacts;

• The American Institute for Conservation for Historic and Artistic Works Code of Ethics;
• American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE)
2015 Applications Handbook, Chapter 23: Museums, Galleries, Archives and Libraries and
ASHRAE 2010 Standard 55: Thermal Environmental Conditions for Human Occupancy;
• APT/AIC Guidelines for Light and Lighting in Historic Buildings that contain Collections; and,
• IESNA Museum and Art Gallery Lighting: A Recommended Practice, 1996.

Overview of the Arts Building and Cloister[45]

The Arts Building and Cloister (40.34N, 74.95W) is located at 1847 Aquetong Road, approximately 1.5 miles south of New Hope, Pennsylvania. The buildings are set at the toe of a wooded slope that rises to the north.

The Arts Building is a one-story cubic volume, roughly 36 feet by 40 feet in plan, obliquely truncated by a hyperbolic paraboloid roof which varies from about 22 feet above the finish floor at the southwest corner to about 9 feet above the finish floor along the east wall. At the southwest corner of the Arts Building, a reinforced concrete box, approximately 9 feet high, projects outward from the south and west elevations. The box, with an inclined west wall, forms an entry space to the building; above the entry space is an interior mezzanine and an exterior porch or gallery on the south and west elevations. The high point of the roof bears on the reinforced concrete waffle slab of the concrete box. Above, and to the sides of the concrete box, the south and west elevations of the Arts Building are glazed walls, framed in wood, terminating in rubble stone wing walls or buttresses that extend beyond the intersecting walls. The north and east walls of the Arts Building are slightly set into the toe of the adjoining slope, with the finished floor below the exterior grade; the north and west walls are concrete unit masonry, and anchor the low edges of the hyperbolic paraboloid roof.

The Arts Building contains the following spaces:
• The entry space, including a wet bar alcove concealed in the north interior wall of the concrete box;
• The main or exhibit space, surrounding the entry space, under the hyperbolic paraboloid roof; and,
• The mezzanine or loft, set on top of the entry space, and accessed from the main space by stair treads cantilevered from the north wall of the entry space.

The Cloister is a simple one story volume roughly 18 feet by 39 feet in plan, set under single slope shed roof and containing four spaces. The west wall of the Cloister is offset eastward from the east wall of the Arts Building; the Cloister extends southward on its long axis. The Cloister walls are concrete unit masonry, perforated by two windows and an exterior door on the east wall and three exterior doors on the west wall.

45. This is an abbreviated description of the building for purposes of orientation in this report; a full description of the building is found in section 5.1.





Left: Arts Building & Cloister from south-west. Right: Arts Building from west. Photos by Michael C. Henry.





Left: Arts Building from Cloister. Right: Arts Building from northeast. Photos by Michael C. Henry.





Left: Cloister from Arts Building. Right: Arts Building along east wall. Photos by Michael C. Henry.





Left: Arts Building toward southwest. Right: Arts Building along north wall. Photos by Michael C. Henry.

The two structures are connected by a canopied walkway, in the plan of an L. The main axis of the pair is rotated about 15° clockwise from the north-south axis.[46] The canopied walk runs along the south wall of the Arts Building and the west wall of the Cloister. The Cloister walls are concrete unit masonry, perforated by two windows and an exterior door in the east wall and three glazed exterior doors in the west wall. The Cloister contains a small sleeping room at the south end, a storage room at the north end, and a bathroom/kitchenette and mechanical room in the center.

46. Although the building is slightly skewed from the north-south axis, the building orientations in this report will reference north, south, east and west as if there was no skew.

47. The records stored in the Cloister were not surveyed for this report.

The Arts Building is interpreted to the public and is used for meetings throughout the year.

The Collection and Environmental Vulnerabilites[47]

The Arts Building contains a variety of works on paper, sculpture, furniture, textiles and objects related to George Nakashima (Attachment A contains a more detailed description) as well as large slabs of wood. The collection of furnishings and objects in the Arts Building are directly associated with George Nakashima and his vision for the building; therefore, they are integral to the experience and interpretation of the building. The material integrity and longevity of this collection is as important as conservation of the building. A fundamental element in minimizing the rate of deterioration of the collection is to address the environmental vulnerabilities of the collection through preventive conservation and management of the interior environment.

Appendix B contains the report Investigating the Preservation Needs of Objects within the George Nakashima Arts Building by Leah Bright.

Table 1 of Bright's report categorizes the material types in the collection and the primary environmental risks and sensitivities associated with each material category, as summarized below:

Material	Examples	Risks/Sensitivities						
		Relative Humidity			Light	UV	Pests	Physical forces
		Fluctuations	Min-Max Range	High Max				
Wood	Furniture, slabs	✓			✓	✓		
Textiles	Rug				✓		✓	
Metals	Sculptures		✓					
Small assemblies paper	Dolls	✓	✓				✓	
Large works on paper	Drawings, prints		✓		✓	✓		
Complex composites	Musical instruments	✓					✓	
Organic	Baskets	✓	✓		✓		✓	
Inorganic	Ceramics							✓

Bright also identified specific concerns with selected objects, including: an Asian lacquer box (light damage); the 1959 Ed Fields rug (light damage); and, the Harry Bertoia Bush and Sonambient sculptures (corrosion and particulate accumulation).

Management of the interior environment and natural light in the Arts Building for

preventive conservation of the collection is discussed in this report in the sections Environmental Management Performance and Management of Natural Light.

48. 7000 grains of water weigh 1 pound.

Climatic and Situational Contexts

Climate

The Arts Building and Cloister is located in the upper Delaware River valley. Published data from the National Climate Data Center (NCDC) for the period 1973 to 1996 characterizes the climate at the Trenton/Mercer County Airport (40.28N, 74.82W), approximately 7.5 miles southeast, by the following statistics (Appendix D):

- Summer median extreme high temperature:
  97°F (dry bulb), 117 grains water[48]/pound of dry air;
  Summer 1.0% occurrence, high temperature:
  90 °F (dry bulb), 105 grains water/pound of dry air;
- Summer median high humidity ratio:
  83 °F (dry bulb), 142 grains water/pound of dry air;
  Summer 1.0% occurrence, high humidity ratio:
  82 °F (dry bulb), 128 grains water/pound of dry air;
- Winter median extreme low temperature:
  2 °F (dry bulb), 3 grains water/pound of dry air;
  Winter 99.0% occurrence:
  13 °F (dry bulb), 5 grains water/pound of dry air;
- Median daily dry bulb temperature range:
  18 °F.

The Trenton/Mercer County Airport dataset does not include precipitation, but the dataset for the Allentown Airport (40.65N, 75.43W) indicates the following precipitation for the same period:

- Mean precipitation:
  ≥4.0 and <5.0 inches per month: May, July, August, September;
  ≥3.0 and <4.0 inches per month: January, March, April, June, October, November, December; and,
  >2.5 inches per month:

The Arts Building and Cloister is located in ASHRAE/ANSI International Climate Zone 4A (Mixed Humid) and may be seasonally characterized as cold-damp to hot-humid.

Heating loads dominate from October through April, and cooling loads from May through September; Mean Annual Heating Degree Days (65°F base) are 4848 and Mean Annual Cooling Degree Days (65°F base) are 1102.

About 10% of the total annual infiltration heating load (160,513 BTU/cfm) is attributable to latent heating (humidifying to 30% RH). Infiltration cooling loads dominate June through August, with about 64% of the total annual infiltration cooling load (21,299 BTU/cfm) being attributable to latent cooling (dehumidifying to 60% RH). There is a small, but important, dehumidification load during the heating

month of September.

Winds occur throughout the year, with prevailing winds from the:

• Northwest and West	December, January and February;
• North, Northwest and West	March, April and May;
• North, Northwest, West and South	June, July and August; and,
• North, Northwest, West and South	September, October and November.

Atmospheric moisture may be very difficult to control if infiltration and exfiltration rates are large. Outside air infiltration at window and door openings may also be a significant source of particulates. Although air exchange can be effectively reduced when the building is closed, opening and closing of doors can result in a high exchange rate of air and moisture vapor.

Situational Context

The soils in the vicinity of the Arts Building and Cloister are identified by the Natural Resources Conservation Service (NCRS) as Mount Lucas Silt Loam, extremely stoney, with 8 to 25% slopes (MmD) north of the buildings and 0 to 8% slopes (MmB) south of the buildings.

The NRCS characterizes the profile of Mount Lucas Silt Loam as:

• Silt loam:	0 to 9 inches deep;
• Clay loam:	9 to 38 inches deep;
• Gravelly sandy loam:	38 to 60 inches deep; and,
• Lithic bedrock:	48 to 99 inches deep.

As a class of soils, the Mount Lucas Silt Loam is considered moderately well drained, with a water transmission capacity (Ksat) ranging from moderately low to moderately high (0.06 to 0.60 inches per hour). The depth to water table ranges from 6 to 36 inches.

The NRCS notes that the Mount Lucas Silt Loam has the following limitations for buildings:

- Very limited for buildings with basements;
- Somewhat limited for buildings without basements;
- High risk with respect to steel corrosion; and,
- Moderate risk with respect to electrochemical deterioration of concrete.

Source Moisture Control

The hyperbolic paraboloid roof of the Arts Building drains to a single gutter hung on the north and east eaves; at the west end, the gutter discharges to a small pond at the north end of the west wall and at the south end, the gutter discharges to a pond opposite the walkway canopy.

The slope on the north side of the Arts Building terminates at a stone surfaced area along the north and east walls. Water runoff from the slope and overflow from the gutter will penetrate the gravel and saturate the soil unless intercepted by subsurface drainage along the wall. The Cloister roof and the walkway canopy drain to an at-grade stone splash along the south and west sides of the walk.

Moisture saturation of the soil near the two buildings can contribute to rising damp in porous masonry walls and evaporation of soil moisture into the building interiors.

Water stains and water damage to the wood framing at window glazing are evident throughout the south and west walls of the Arts Building. These are the result of:

- Condensation on the interior face of the glazing;
- Rain water leaks at the joint between the glass and the frame; or,
- Both of the above causes.

Building Envelope And Non-Mechanical (Passive) Environmental Management

George Nakashima's Arts Building and Cloister is understandably recognized for its distinctive hyperbolic paraboloid roof and its expression of traditional Japanese architectural design, but the Arts Building is also significant for Nakashima's incorporation of the principles of bioclimatic design.

The applications of bioclimatic design, contemporarily espoused by Victor Olgyay[49] and Baruch Givoni[50] that are evident in the Arts Building include:

- Orientation for passive solar heating in winter.
  Slightly skewed east of south, the south and west glazed elevations provide the opportunity for passive solar gain in winter with thermal storage being effectively accomplished by the slab-on-grade concrete floor, the concrete mezzanine, and the west and south masonry walls. Thermal losses through the glazing are reduced by insulated glazing units in most of the window openings;
- Orientation and geometry to minimize winter heating loads.
  The low exposed heights of the north and east walls minimize thermal envelope loads in winter, and the hyperbolic paraboloid roof effectively deflects winds from the north;
- Shading devices on the south and west walls.
  Roof eaves on the south and west elevations and the walkway canopy reduce solar gain in summer when the sun angle (altitude) is high. Interestingly, the deep shelving units set along the south and west elevations also act as shading devices. Exterior wood grilles and relocatable interior shoji panels on the south and west elevations can reduce unwanted solar gain and natural light;
- Radiant cooling through the roof.
  The white gravel ballast on the minimally insulated roof assembly reduces radiant heat gain in summer, acting as a "cool roof"; and,
- Enhanced natural ventilation.
  Operable casement windows near the high point of the south and west elevations, large sliding door openings at or near floor level on the south and west elevations and at the south elevation of the mezzanine and the slope of the ceiling, combine to promote effective natural ventilation in summer. Furthermore, the two small water features near the south and west walls could provide evaporative cooling of incoming outside air when relative humidity is low enough for effective evaporation.

The following observations of the Arts Building suggest that the optimum hygro-

49. Olgyay, Victor. Design with Climate: Bioclimatic Approach to Architectural Regionalism. Princeton University Press, Princeton, NJ. 1963.
50. Givoni, Baruch. Man, Climate and Architecture. Elsevier Science, Ltd, Amsterdam and New York. 1969.

From top to bottom:
Arts Building, drainage at north wall.
Arts Building, glazing/frame joint.
Photos by Michael C. Henry.





thermal performance of the building envelope may be limited by:
• Excessive air infiltration at the sliding doors, due to large gaps between the frames of the sliding units and the adjoining fixed framing at the jambs, head and sill;
• Use of single glazing, rather than insulated glazing units in the sliding doors, a compromise that presumably was made to reduce the weight of the sliding doors; and,
• Discontinued seasonal use of the relocatable shoji panels.

Mechanical System for Environmental Management

In addition to the non-mechanical features for environmental management of the Arts Building, George Nakashima's Arts Building and Cloister have the following mechanical system:
• Hot water boiler and circulating pumps in the Cloister, serving both buildings, and fueled by heating oil supplied from an external fuel oil storage tank located on the north end of the Cloister;
• Hot water baseboard heating in the Arts Building, consisting of single piping along the east and north walls, dual pipes along the west wall the main space and dual pipes on the west wall of the mezzanine, all controlled by a simple thermostat located under the mezzanine stair;
• Hot water radiant floor heating in the entry of the Arts Building, controlled by a simple thermostat on the south wall; and,
• Hot water baseboard heating in the Cloister, controlled by a simple thermostat.

The following observations of the mechanical system are notable:
• The mechanical room in the Cloister that contains the oil-fire boiler contains exposed combustible wood construction without fire-resistant separation from the rest of the building. A small piece of asbestos cement board fastened to the wood framing directly above the boiler is ineffective protection in this respect;
• The boiler may be nearing the end of its service life;
• The condition of the heating piping, including pipe wall thickness, corrosion and water quality, is unknown;
• The boiler sits on a small concrete slab, lower than exterior grade, but higher than an adjoining crawl space under the Cloister. A water or fuel oil leak at the boiler could flood the crawl space; a fuel oil leak would require a substantial environmental clean-up; and,
• The fuel oil tank is a single wall tank exposed to the weather as well as internal condensation from temperature cycling. The condition of the fuel oil tank, including wall thickness or internal/external corrosion, is unknown. There are no provisions for spill/leak containment of fuel oil at the tank. Spillage during delivery, or a leak from the tank, would require environmental clean-up.

Environmental Management Performance

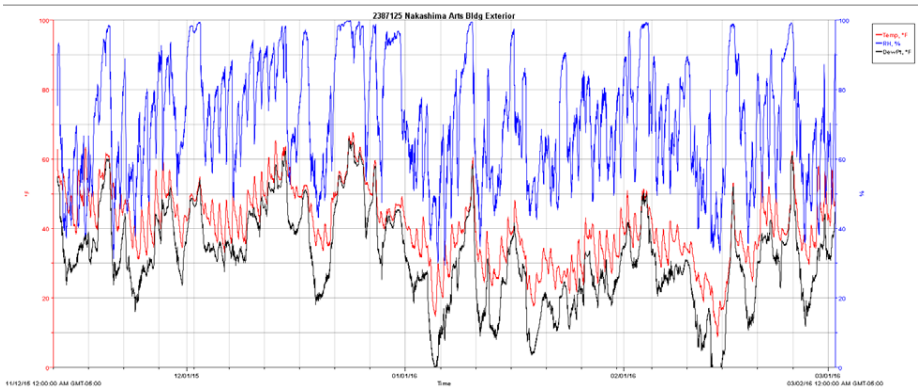
Background
César Bargues Ballester and Michael C. Henry deployed two HOBO® dataloggers at the Arts Building on 12 November 2015 as follows:
• A U23-001 temperature and relative humidity datalogger (SN 2387125) installed

on the underside of the north roof eave, near the chimney;[51] and,
•A U12-012 temperature, relative humidity and light intensity datalogger (SN 928636) placed in the opening in the north interior wall of the entry, near the Harry Bertoia “Bush” sculpture; this datalogger appears to have been inadvertently relocated to the closed alcove containing the small sink and domestic water heater in the alcove in the north wall of the entry space. Based on the data, the relocation occurred at 3:15 PM EST on 17 December 2015.[52]

On 02 March, Michael Henry redeployed dataloggers for the interior:
•The U12-012 temperature, relative humidity and light intensity datalogger (SN 928636) was returned the opening in the north interior wall of the entry, near the Harry Bertoia “Bush” sculpture;
•A U12-012 temperature, relative humidity and light intensity datalogger (SN 828445) was placed in the closed alcove containing the small sink and domestic water heater in the north wall of the entry space.

Overview of Environmental Conditions during Winter
Environmental performance during winter months is illustrated by the following two trend graphs of temperature, relative humidity and dew point temperature data for the exterior datalogger and the interior datalogger for the interval from 12 November 2015 through 02 March 2016.
The following trend graph compares the exterior and interior dew point tempera-

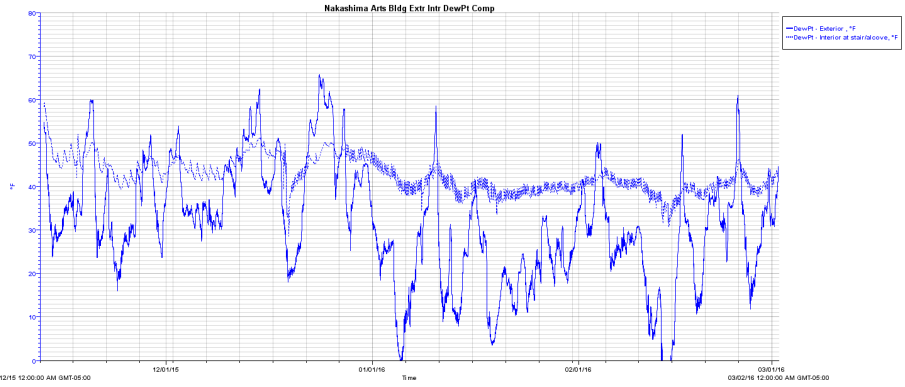
51. Datalogger SN 2387125 belongs to the PennDesign Architectural Conservation Laboratory.
52. Dataloggers SN 928636 and 828445 belong to Watson & Henry Associates.





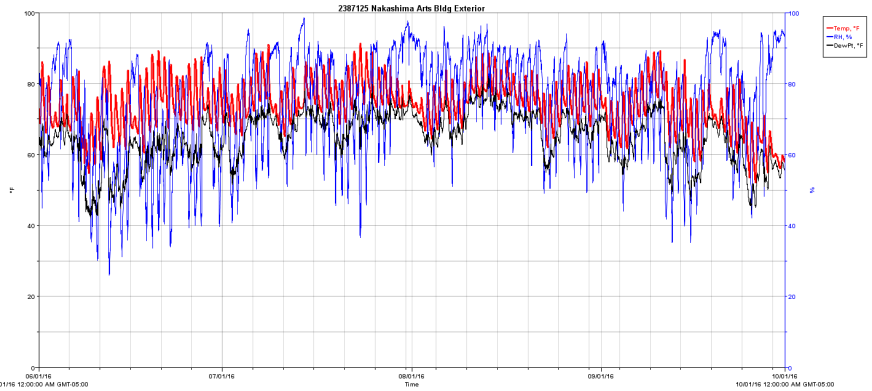
tures for the 12 November 2015 to 02 March 2016 interval. Although the Arts Building does not have a humidification system, the interior dew point temperature in the Arts Building is remarkably consistent, despite the wide fluctuation in exteror moisture vapor and the potential for air and moisture vapor infiltration at the sliding doors. The consistency of the interior dew point temperature may be attributable to one or more of the following:

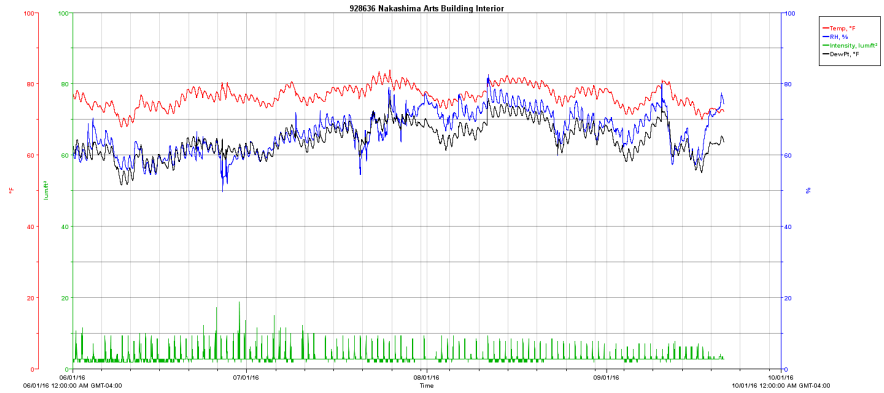
- A moisture or vapor leak from the heating system piping;
- A moisture or vapor leak from the hot water heater or hot water piping serving the small sink in the alcove;
- Evaporation of soil moisture through the concrete floor or through the north and east masonry walls;
- Moisture buffering by the hygroscopic building materials; and,
- Moisture buffering by the large wood slabs in the Arts Building.

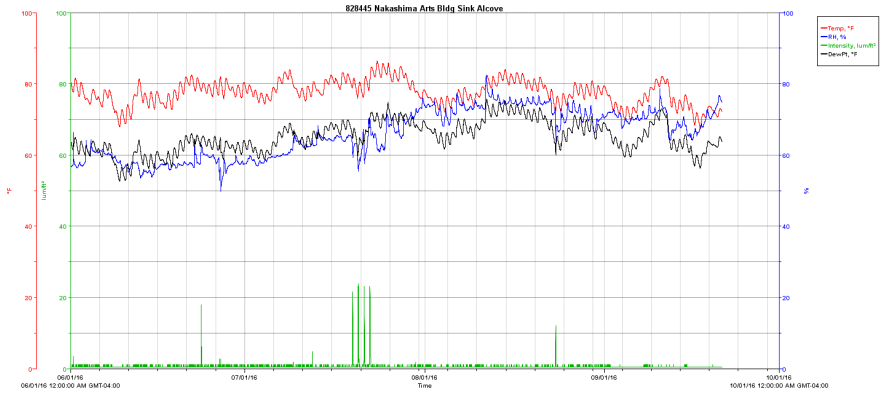


Overview of Environmental Conditions during Summer

Environmental performance during summer months is illustrated by the following three trend graphs of temperature, relative humidity and dew point temperature data for the exterior datalogger and the interior dataloggers for the interval from 12 November 2015 through 02 March 2016.

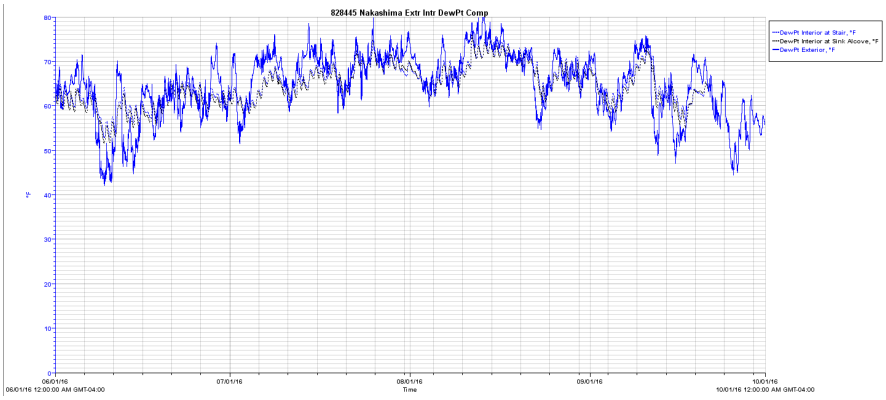






The following trend graph compares the exterior and two interior dew point temperatures for the 01 June 2016 through 01 October 2016 interval. In contrast to the winter interval, the interior dew point temperature in the Arts Building during summer tracks closely with the exterior dew point temperature, with a smaller difference between interior and exterior moisture levels. Close tracking of the interior and exterior dew point temperatures during summer may be attributable to one or more of the following:

- Infiltration of moist exterior air in summer has a greater effect on interior conditions that other potential moisture sources;
- Evaporation of soil moisture through the floor slab and the north and east walls is diminished due to higher interior mositure vapor levels in summer;
- Moisture buffering by the hygroscopic building materials is limited by the higher interior relative humidity in summer; and,
- Moisture buffering by the large wood slabs in the Arts Building is limited by the higher interior relative humidity in summer.

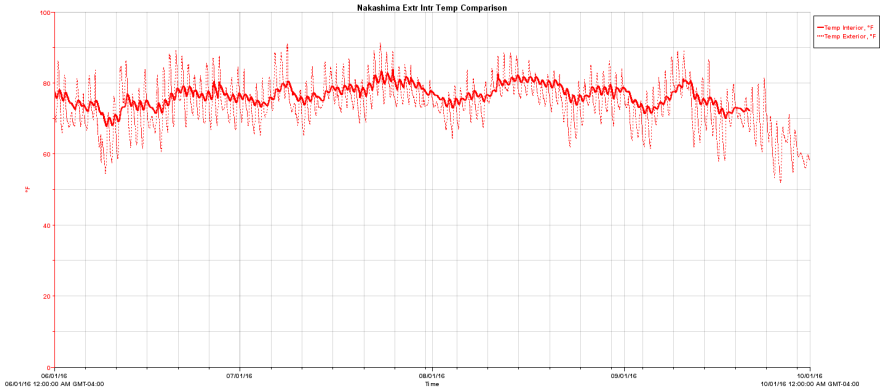


Since the Arts Building is not air conditioned, temperature conditions during the summer are of interest. The following trend graph compares interior and exterior temperatures in the Arts Building for the summer interval from 01 June through 01 October 2016.

Statistics for the data for the period from 01 June to 01 September 2016 are:

Nakashima Arts Building Interior/Exterior Temperature Comparison 01 June to 01 September 2016		
	Interior	Exterior
Maximum	83.8 °F	91.4 °F
Average	76.9 °F	75.2 °F
Minimum	67.7 °F	54.6 °F
Standard Deviation	2.77 °F	5.95 °F

On a daily basis during summer, the interior temperature tracks closely with the average daily exterior temperature, but the thermal mass of the building, which is concentrated in the slab-on-grade construction, the concrete box of the entry space and the north and east walls, effectively buffers the wider temperature fluctuations of the exterior.



Environmental Management Performance and Collections Risks

For buildings containing culturally significant objects, such as museums, the guiding technical guidance for environmental management is found in the 2015 ASHRAE Applications Handbook, Chapter 23, Museums, Galleries, Archives and Libraries.

Preliminary analysis of the environmental monitoring data collected for the Arts Building during the two intervals spanning from 12 November 2015 through 23 April 2016 strongly suggests that the interior relative humidity in winter and early spring seasons approaches ASHRAE Class B/A criteria for collections environments.[53] This is remarkable for a building without humidification in the mid-Atlantic and Zone 4A Mixed-Humid climate.

53. ASHRAE Class of Control B presents "Moderate risk of mechanical damage to high vulnerability artifacts; tiny risk to most paintings, most photographs, some artifacts, some books; no risk to many artifacts and most books." ASHRAE Class of Control C presents "Small risk of mechanical damage to high vulnerability artifacts; no mechanical risk to most artifacts, paintings, photographs, and books."

However, the trend graph for the summer interval from 01 June through 01 October indicate that interior relative humidity in the Arts Building occasionally approaches and exceeds the ASHRAE A23 relative humidity limit of 75%RH; this occurred during the interval from 11 August through 20 August. Sustained excursions above 70%RH can result in mold germination.
Full assessment of the environmental risks to the collection in the Arts Building will require a complete and uninterrupted set monitoring data for twelve months and analysis of the data set using eClimateNotebook® (https://www.eclimatenotebook.com/).

Environmental Management Performance and Human Thermal Comfort
ASHRAE Standard *55 Thermal Environmental Conditions for Human Occupancy* provides an adaptive comfort standard (ACS) that addresses warm indoor temperatures in naturally ventilated buildings without air conditioning, such as the Arts Building. The adaptive comfort standard takes into account occupant clothing and activity level, interior temperature and relative humidity, air movement and exterior conditions.

Application of the ASHRAE Standard *55 Comfort Model* to a limited number of interior conditions at the Arts Building indicates that the interior conditions in summer are acceptable to 90% of a typical population of visitors in summer clothing and relaxed, standing activity; however, 10% of the same population will probably report being somewhat warm and dissatisfied.

Full assessment of the occupant thermal comfort in the Arts Building during summer will require analysis of the summer data set using the ASHRAE Standard *55 Comfort Model* software.

Management of Natural Light

Natural light enters the Arts Building through the south and west glazed walls and is an important aspect of the non-mechanical environmental management of the building, especially in winter when the building is partially heated by the infrared component of sunlight entering the building; however, as noted in Leah Bright's report (Attachment A), exposure to high levels of natural light and ultraviolet radiation from sunlight can damage materials and fade colors.

Light can cause spot heating and localized surface desiccation of hygroscopic materials, resulting in strain gradients that lead to cracking. Thermal energy from light can elevate material temperatures, accelerating chemical deterioration. Lastly, natural light and ultraviolet radiation can reduce the elasticity of materials and applied finishes.

The Illuminating Engineering Society of North America (IESNA) has published guidance for light exposure of artifacts in museums and art galleries, IESNA Museum and Art Gallery Lighting: A Recommended Practice, 1996. Table 3.1 provides the following guidance:

TABLE 3.1
Recommended Total Exposure Limits in Terms of Illuminance Hours Per Year to Limit Light Damage to Susceptible Museum and Art Gallery Artifacts

Note: All ultraviolet radiation (400 nm and below) should be eliminated.

Types of Materials	Maximum Illuminance (Neither value should be exceeded)	Lux-Hours/Yr
Highly susceptible displayed materials: textiles, cotton, natural fibers, furs, silk, writing inks, paper documents, lace, fugitive dyes, watercolors, wool, some minerals.	50 lux	50,000
	Note: Approximately (50 lux) × (8 hours per day) × (125 days per year). Different levels (higher or lower) and/or different periods of display (4 hours for 250 days) may be appropriate, depending upon material. If in doubt, consult a conservator.	
Moderately susceptible displayed materials: textiles with stable dyes, oil paintings, wood finishes, leather, some plastics.	200 lux	480,000
	Note: Approximately (200 lux) × (8 hours per day) × (300 days per year). Lower levels may be appropriate, depending upon material. If in doubt, consult a conservator.	
Least susceptible displayed materials: metal, stone, glass, ceramic, most minerals.	Dependent upon exhibition situation.	

It is possible to monitor the light exposure and intensity and exposure at a specific location in a space, but this type of monitoring is best suited for artificial lighting where light distribution, intensity and exposure duration are uniform and consistent. However, monitoring natural light intensity and exposure is much more challenging than artificial light due to diurnal and seasonal variations in sun altitude and azimuth. For natural light (daylight), computer modelling and simulations can provide a better understanding of the light intensity and exposure of specific collections in a space, including the identification of the specific locations of seasonal “hot spots” of high intensity.

To evaluate the interior light levels from daylight through the south and west elevations of the Arts Building, PennDesign students Janki A.Vyas and Shin-Yi Kwan performed a daylighting simulation using DIVA software (Attachment B).

The daylighting simulation included daylight through windows without, and with, the shoji screens in place.

The table in the follwoing page summarizes the seasonal daylight intensities (illuminance) graphically identified by the Vyas-Kwan daylighting simulation.

Note that Leah Bright’s spot readings of light transmission through windows, without and with a shoji screen, showed that the shoji screens provided a greater reduction in light transmission that predicted by the computer simulation (Attachment A, page 10-11).

Although the daylighting simulation was not calibrated with spot readings, the model and the spot readings show that significant reductions in illuminance could

Comparison of Illuminance Values in the George Nakashima Arts Building without and with *shoji* screens using DIVA daylighting simulation software				
Location/plane	Seasonal Peak Illuminance (lux)		Occurrence	
	Without *shoji* screens	With *shoji* screens	Date	Time
Main space south wall	1919	762	21 March	12:00 PM
	2992	1568		3:00 PM
	3105	1476	21 December	12:00 PM
	1509	625		3:00 PM
Main space west wall	446	260	21 March	12:00 PM
	1566	905		3:00 PM
	754	444	21 December	12:00 PM
	1318	573		3:00 PM
Main space east wall	1102	659	21 March	12:00 PM
	3406	2182		3:00 PM
	1382	802	21 December	12:00 PM
	3343	2075		3:00 PM
Main space north wall	1641	1258	21 March	12:00 PM
	3819	2113		3:00 PM
	1747	1262	21 December	12:00 PM
	11424	4038		3:00 PM
Mezzanine (Loft) south wall	2610	1368	21 March	12:00 PM
	3182	1968		3:00 PM
	2244	1225	21 December	12:00 PM
	1556	1093		3:00 PM
Mezzanine (Loft) west wall	3436	1418	21 March	12:00 PM
	3040	1431		3:00 PM
	8890	3232	21 December	12:00 PM
	1742	1102		3:00 PM

be achieved by reinstating seasonal placement and relocation of the shoji screens.

Summary

The Nakashima Arts Building and Cloister present a number of challenges in preventive conservation of the building fabric and the collection. Interior environmental management in winter appears to rely heavily on the passive solar heating through the south and west glazing; however, penetration of daylight into the building is greatest during the heating seasons and the illuminance levels during the heating seasons present the greatest risk to the collection. Active seasonal deployment of shoji screens would mitigate light damage to the collection.

Assessment of the efficacy of the recommendations is essential, and can only be accomplished through rigorous monitoring of environmental conditions and the rate of deterioration of the architectural fabric and the collection.

GEORGE NAKASHIMA
ARTS BUILDING AND CLOISTER
CONSERVATION & MANAGEMENT PLAN

PART II



1. What Is a National Historic Landmark?

Left: Study to determine the effect of lighting in the loft. William Whitaker, 2017.

The George Nakashima House, Studio and Workshop site was designated a National Historic Landmark (NHL) in 2014. Additional recognition includes its inclusion on the National Register of Historic Places in 2008, Historic American Building Survey (HABS No. PA-6783) in 2011, and placement on the 2014 World Monuments Fund Watch List. Completed in 1967, the Arts Building and Cloister and surrounding lanscape is an integral part of this complex.

In the United States, the National Historic Landmark Program was designed to officially recognize heritage resources, including districts, sites, buildings, structures, or objects, in public or private ownership, that possess exceptional value in commemorating or illustrating the nation's history. Typically, a heritage resource receives designation if it:

- is a location with a strong association with a turning point or significant event in American history,
- is the best location to tell the story of an individual who played a significant role in the history of the United States,
- is an exceptional representation of a particular building or engineering method, technique, or building type in the country,
- provides the potential to yield new and innovative information about the past through archeology.[1]

Heritage resources, including associated activities must be preserved for the benefit of present and future generations. Therefore, places of cultural significance listed as National Historic Landmarks often warrant a cautious attitude to change. This includes Preservation, as the most appropriate primary treatment approach, and Restoration, as additional action when needed. To clarify these terms, and others used throughout this document, the following definitions have been adopted from the Secretary of Interior's Standards for the Treatment of Historic Properties as well as accepted international criteria such as Venice ICOMOS charter and the Madrid Document:

Cultural Significance is defined by aesthetic, historic, scientific, social or spiritual value for past, present or future generations. Cultural significance is embodied in the place itself, its fabric, setting, use, associations, meanings, records, related placed and related objects.

Heritage Value is the aesthetic, historic, scientific, cultural, social or spiritual importance or significance for past, present and future generations. The heritage value of an historic place is embodied in its character-defining materials, forms, location, spatial configurations, uses and cultural associations or meanings.

Authenticity is the quality of a heritage site to express its cultural significance through its material attributes and intangible values in a truthful and credible manner.

Integrity is a measure of the wholeness and intactness of the built

1. https://www.nps.gov/nhl/learn/intro.htm

heritage, its attributes and values.

Character-defining Elements are the materials, forms, location, spatial configurations, uses and cultural associations or meanings that contribute to the heritage value of an historic place, which must be retained to preserve its heritage value.

Conservation is all the processes of looking after a heritage site so as to retain its cultural significance.

Maintenance is the continuous protective care of the fabric and setting of a place, and is to be distinguished from repair.

Reversibility implies that an intervention can essentially be undone without causing changes or alterations to the basic historical fabric. In most cases reversibility is not absolute.

Retreatibility implies that the application of a specific treatment does not preclude continued maintenance, the implementation of other options and future treatment.

Preservation is the act or process of applying measures to sustain the existing form, integrity, and materials of an historic property. It includes the maintenance and repair of existing historic materials.

Restoration is the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period.

Reconstruction includes the recreation of vanished or non-surviving portions of a property for interpretative purposes.

Rehabilitation is the act of altering and adding to a historic resource to meet continuing or changing uses while retaining the property's historic character.

Intervention is change or adaptation including alteration and extension.

2. Assessment of Cultural Significance

As an integrated environment by George Nakashima

George Nakashima (1905-1990) began his professional career as an architect before committing to a life as a woodworker. Nakashima's earlier work connects with his time at Antonin Raymond's office in Tokyo. There, Nakashima absorbed Raymond's synthetic approach and practice through projects like the Raymond's Summer Studio (1933) and the St. Paul's Catholic Church (1934-1935), both in Karuizawa. In 1936, on behalf of Raymond's office, Nakashima traveled to India to supervise the construction of a dormitory of disciples of Sri Aurobindo. His work at the ashram became a pivotal moment in Nakashima's life both outwardly and inwardly that shaped his spiritual and philosophical approach to woodworking and architecture.

All the above experiences proved influential to the creation of a style unique to him. Economic struggle in the US and racial upheaval caused by the war affected Nakashima, as well as his contemporaries. Nakashima was in his 40s when he made a seminal contribution to woodworking in the United States, the free-edge furniture, which brought him both national and international recognition.

His shift to furniture making did not preclude Nakashima from architecture.[2] Perhaps, it enhanced his conviction on the integration of architecture, furnishing and landscape. His career resulted in a handful of designs, which were mostly concentrated in New Hope. The Arts Building and Cloister was his most personal work and his last interpretation of modernist structural theory through the combination of Japanese and Pennsylvanian traditional building techniques. The special treatment of the facades and the thoughtful incorporation of bioclimatic principles adds another layer of significance to the building.

On a smaller scale, Nakashima's unrelenting aspiration to enhance the wood's natural beauty by means of intense skill is recognizable through built-in furniture as well as architectural elements at the site, and particularly in the Arts Building. Examples are manifold: the Conoid Bench installed on the loft and the monumental lighting fixture. Interrelationships with the furniture are abundant, from the cantilevered stairs leading to the loft which resonates with Nakashima's earlier Milk House table to the joinery on the exterior walkway pots.

As an ideal space for an ideal community

In George Nakashima's complex on Aquetong Road, each building displays a specific idea. Unlike the pragmatic nature of the other buildings –the residences, workshops, showroom, and others- the Arts Building and Cloister embodies Nakashima's search for enlightenment and understanding of beauty, art, and spiritual transcendence.

At the time the Arts Building was built, Nakashima was involved in the design and construction of sacred spaces, including Christ the King Church in Katsura,

2. As he published in the 1961 catalog, activities included "architecture and construction on a private basis, church and monastic furnishings, and consultation."

Japan, and Christ in the Desert in Abiquiu, New Mexico. Nakashima's ties with Catholic monastic communities are fundamental to understanding the impulse behind the Cloister, and even behind the Arts Building, which has been compared to a church in recent conversations with the Nakashima family.

Dedicated on May 7, 1967, the building was inaugurated as the Minguren Museum, influenced by Nakashima's friendship with Masayuki Nagare, who introduced him to the Minguren Group in Japan. The Minguren vision resonated with him and the spirit of community he was nurturing in New Hope.

The Arts Building and its setting was used to foster cross-cultural interchange as well as spiritual enrichment through a process of socialization not possible previously. This is exemplified by the annual Marion's Dogwood O-Hana Mi (blossom viewing), concerts and talks by disciples from the Sri Aurobindo Ashram, Catholic gatherings, as well as by the events organized by the Foundation.

At the same time, highlighting its flexible use, the Arts Building was intended as a retreat for the woodworker indulged in quiet contemplation. In many instances, he engaged other craftsmen as an education process.

Landscape features include ponds, stone arrangements, self-seeded trees and species planted by Nakashima. Although partially modified, the landscape contributes to a secluded ambience that reinforces the idea of retreat and place of peace, opposite to the constant activity in the shops.

As a building housing a specific collection

The program for the building was simple, but its significance increased through its association with a collection of art, folk art, furniture prototypes, and wooden specimens collected by Nakashima.[3] The idea of creating a gallery space for Ben Shahn's prints shaped the interior treatments of the north and east walls. The posthumous installation of the large scale mosaic mural, "Poet's Beard", on the west inclined concrete wall reinforced the initial significance as a space of display.

The window niches in the loft area, still house a lively display of folk art and objects acquired by Nakashima during his trips to Japan and India during the late 1960s, including objects with specific connections to the Minguren group, as well as gifts from close friends, including Ben and Bernarda Shahn, Stanley and Nita Brogren, and Father Peter Sidler among others. This assemblage tells us about the long lasting professional and personal relationships Nakashima nurtured throughout his life.

Finally, besides the Conoid Studio, the Arts Building is one of the only locations where Nakashima's furniture can be seen together with the raw wood that inspired it.

Degree of wholeness and intactness

3. George Nakashima. *The Soul of a Tree: a Woodworker's Reflections*, 32

It is important to note that the Arts Building and Cloister possesses high integrity in its design, setting, materials, craftsmanship, and feeling. As seen in Volume I, alterations have been very few and, except for a handful of less significant interventions, include repairs and replacement in kind. Changes have been primarily the result of a more intuitive and practical approach, such as the substitution of the dome skylights, the addition of a wooden log to support the deflected waffle slab, or replacement with other wood species.

The cultural significance of the place (understood as the integration of landscape, buildings and collections) has been negatively affected by:

- Visual impacts and additions that divert the role of the landscape from its original intent,
- Reactive responses to failure and accretive change through replacement of architectural elements, and
- Significant elements of the collection are not tied to the building.



3. Statement of Significance

• A significant work of architecture associated with one of the most outstanding woodworkers in the United States.

The Arts Building and Cloister is of national significance through its association with George Nakashima (1905-1990) "one of America's most eminent designer-craftsmen and a significant force within the American Craft movement of the mid-twentieth century."[4] Nakashima himself, designed and participated in the construction of the building and furnishings.

• A rare interpretation of modernist ideas with vernacular traditions in the eastern United States

The compound is demonstrative of Nakashima's unique interpretation and combination of modernist structural and environmental design theory with traditional Japanese and local vernacular building and landscape techniques, which stem from his apprenticeship and earlier experiences.

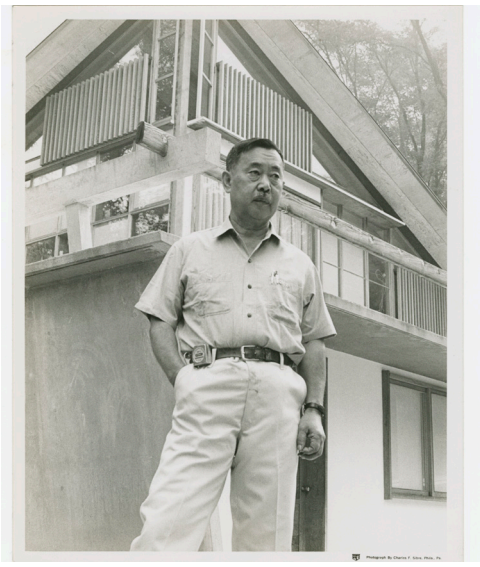
This is an architecture that blends traditional materials such as wood and stone, with new manufactured materials such as plywood, structural concrete block, and poured concrete. George Nakashima's integration of interior space, architecture, and landscape, shaped the distinctive character of the Arts Building and Cloister, orientation, setting and views. There is a clear connection between furniture and architecture through aesthetic and functional principles as well as fine craft.

• An outstanding example of a hyperbolic paraboloid roof expressed in plywood

The use of the hyperbolic paraboloid roof closely relates to the rise of warped roofs in post war America and represents a rare example of the use of structural plywood representing an evolution of experimental architecture practiced at Nakashima's property.

• Continued use as an ideal space for an ideal community.

The Arts Building and Cloister provides a distinct experience from the rest of the woodworking and residences complex, as it embodies the interrelationship between the art and craft as well as Nakashima's sense of beauty, transcendence, and community. This connection is evident by the original name of the building Minguren ("People's Tools Guild") and the collections, which comprise: specimens of wood, furniture prototypes, art, artifacts and objects that offer an insight in Nakashima's interest, source of inspiration, and ties, including the exterior mural mosaic, a humble tribute to his friend artist Ben Shahn. Spiritual values are especially evident in the cloister-garden design, which links the building with the monastic Benedictine life, and the isolated location on a slope at the edge of the property.



George Nakashima standing in front of the Arts Building. Author: Charles F. Sibre, Phila, Pa. ca. 1968. Source: George Nakashima Woodworker Archives

4. David Kimmerly and Catherine C. Lavoie. *George Nakashima Woodworker Complex. National Historic Landmark Nomination* (November 2007 (NR documentation); October 2012; Designation April 2014), 14
5. Mira Nakashima, *Nature, Form & Spirit: The Life and Legacy of George Nakashima*, (New York: Abrams, 2003), 190

4. Character Defining Elements

There are a number of elements and qualities of the building and setting which are essential to George Nakashima's concept of place and must be retained and conserved in accordance with this CMP:

a. The isolation of the building in its setting as a counterpoint to the wood-working and residence activities.

b. The hyperbolic paraboloid plywood shell roof, shed roofs, interplay of glass and wooden structural elements, massive masonry, openings, grills, and finishes.

c. The orientation and exterior relationship between the Arts Building and the Cloister, including the canopied walkaway and arrangement of plantings, large stone, stones, pavements, and the Pond.

d. The visual relationship between spaces, and between interior and exterior, particulary to the large area and pond on the south elevation, as well as the tree tops through the window walls.

e. The palette of materials chosen by George Nakashima for the exterior and interior spaces.

f. Coffered ceiling, skylights, and stone floor in the Cave.

g. The exhibition walls, the fireplace, and the vinyl flooring pattern and grid.

f. Cantilevered steps, built-in furniture and balcony rail in the loft.

i. Elements in the collection of exceptional significance such as the Minguren IV table, the Tatami Platform, and the English Oak Light Sculpture.

Notes for the management of future adaptation

In the Arts Building and Cloister, the architectural fabric has an exceptional degree of integrity.This compels a cautious attitude toward any change. However, drawing on the assessments presented in Part I of this CMP, it is possible to draft a hierarchy that would accomodate original and new uses of the space.

Setting	
Visitor Pathway	Less significant
Driveway and Car Park	Less significant
Arts Building Interior	
Cave	
Closet	Less significant
Wooden post / column	Intrusive
Plaster treatment in display niches	Intrusive
Storage furniture and bookshelves	Intrusive
Cloister Interior	
Storage room	Less significant
Boiler room	Less significant

5. Guidance and Recommendations

This section provides guidance prepared in response to the many conservation and management issues identified through sections of the CMP. It takes into account the full range of character-defining features from landscape to collections conservation needs, the building and its environment, use and management. Conservation is not limited solely to physical intervention, but includes consideration of all recommended measures that will affect the associated spiritual values of the place.

5.1. General Policies

Acceptance, Review and Diffusion

Policy 1 Adoption of the CMP

Accept the statement of cultural significance and endorse the principles and recommendations contained within this CMP as a starting point for any further intervention and planning in the Arts Building and Cloister.

This CMP is the principal working document guiding conservation, use, and management for the Arts Building and Cloister, including its setting. After a donation by Marion Nakashima in 2003, the Foundation exclusively owns the Arts Building and Cloister. The Foundation is part of the Minguren Condominium, who owns the Pool House, the Swimming Pool, the Reception House, as well as the land comprising the woodworking complex and residences. It is recommended that a Management Plan for the entire site be prepared in the near future.

Policy 2 Review of the CMP

Review the CMP on a regular basis, usually every five years or at any time a major intervention is proposed.

The CMP needs regular review to ensure that the policies and recommendations remain relevant and that the information contained within it is up to date. Monitoring of the CMP implementation can be done internally or by a preservation specialist whenever necessary. Review and amendment of the CMP require appropriate professional advice.

Policy 3 Diffusion of the CMP

Make the CMP available to any parties with a well-founded interest in the place, including relevant and legal stakeholders as well as professionals able to share specialist knowledge and experience.

Overarching Principles

Policy 4 Significance Guides Conservation and Planning

Establish whether there is sufficient information to understand the impact of potential modifications and consider the effects of any intervention/change on each aspect of the cultual significance of the place.

Policy 5 Manage in Accordance with National and International Heritage Standards

The proposed conservation plan is based on an appropriate routine of management and maintenance. Any alteration or repair on the building should have an awareness of all necessary legislation requirements as well as national and international standards, such as the Secretary of Interior's *Standards for the Treatment of Historic Properties*.

Policy 6 Retreatability & Reversibility

The application of a specific treatment does not preclude future interventions and continued maintenance, such as cleaning, consolidating or renewal of sacrificial materials. When choosing between different treatments or interventions, consider the potential reversibility or retreatability of changes without damaging or altering the original fabric.

Policy 7 Material Compatibility

Intervene as little as possible and retain as much of the original fabric as possible. The introduction of new materials should be compatible with original materials and should not compromise their continued performance. Replacement of original fabric should be made using in-kind materials and good craftsmanship.

Policy 8 Outcome Monitoring and Evaluation

Monitor and assess regularly the impact of any maintenance, repair, conservation, and restoration work to determine its effectiveness. This allows managers to collect information to implement remedial measures as well as amend the CMP objectively.

In the event that the unexpected is revealed during the implementation of recommendations, involvement of experts and evaluation of alternatives is advisable in order to minimize harm. If a permanent solution or recomendation to identify problems cannot be implemented, propose temporary remedial measures to prevent the problems from escalating. Temporary solutions should be effective, timely and reversible.

Policy 9 Consultation

Implement the necessary statutory and stakeholder consultation process whenever work is planned. Engage consultants with demonstrated expertise in the preservation field to implement the recommendations contained in this CMP or other future actions on the place, including training programs.

Policy 10 Legislation and Statutory Control

Determine conformance with codes and ordinance requirements, foundation bylaws as well as condominium bylaws.

Policy 11 Building Management

Ensure setting, building and collections management roles and responsibilities are clarified, clearly defined and assigned.

Research and Recording

Policy 12 Updates

All new significant information disclosed or uncovered between CMP updates will be recorded and retained in an accessible database.

"Records inevitably reflect the state of knowledge prevailing at the time they are made, and the completion of even a detailed record does not preclude re-examination of the building, or its record, at a later date. New evidence may come to light and may need recording. Recording of any features uncovered should be consistent with any recording undertaken prior to work commencing and used to update, and if necessary reinterpret, earlier findings."[6]

Policy 13 Work record and material archives

Work to the building will be properly documented so that the evolution of the building, as well as intervention success or failure is understood in the future. This includes recording and archiving parts of significant elements and materials that will be removed or altered prior to and during the work.

Inescapable negative impact or loss of fabric demands mitigation to reduce any detriment to the cultural authenticity and integrity of the place and setting. This is key to creating cumulative knowledge to inform future stewardship, as well as to understanding how and why cultural significance can be altered. An individual record for any work project should include project worksheet, sketches, photo documentation prior, during and after completion, written description, who carried out the work and when, cost, as well as supplementary technical information and samples of materials used whether maintenance, repair, or conservation work.

6. Historic England, *Understanding Historic Buildings: A Guide to Good Recording Practice*,9

Policy 14 Record production and maintenance

The maintenance of these records should be assigned to a single individual. Contractors and interns will transfer relevant information to this individual. This record will be incorporated to an accessible database and will inform CMP updates.

Policy 15 Further Research

The research projects identified in the recommendation contained in this CMP will be carried out. In addition, relevant research and collaborative agreements as well as links to other organizations will continue to be developed.

Cyclical Maintenance

Policy 16 Maintenance as a Strategy for Preservation

The conservation of the Arts Building and Cloister must be founded on appropriate routine management and maintenance.

Policy 17 Maintenance Plan

Prepare a financially sustainable Cyclical Maintenance Plan and Manual tailored to the needs of the Arts Building and Cloister as well as related landscape. Maintenance is defined as routine, cyclical, non-destructive actions necessary to slow the deterioration of a historic place. The Maintenance Plan will entail periodic visual inspection, routine cleaning, minor repair and refinishing operations, replacement of sacrificial materials, as well as predictable actions like shoveling in the winter, or unclogging gutters during the fall. Review the plan on a regular basis.

Policy 18 Visual Inspection

Program visual inspection of the building on an annual basis. Supplement this routine with actions following a major or unusual weather event. Periodic survey should include checking the condition of mortar joints, exterior renders, wooden elements, plywood soffits, as well as the water disposal system. In the interior, plasters, masonry, window and door frames, as well as the plywood ceiling.

Policy 19 Cleaning

Test any cleaning method prior to application to determine whether or not single or repeated application may cause harm to the historic fabric, and ultimately to the cultural significance of the place.

Policy 20 Renewal

Periodical renewal of sacrificial materials such as sealants, wooden stops, waterproofing membranes, is advisable unless any damage is caused and could not be recovered over time.

Policy 21 Maintenance Record

Record in a logbook visual inspections, maintenance and minor repair work including who carried out the work, as well as the cost.

Conducting Works & Maintenance

Policy 22 Roles and Responsibilities

Determine if works and maintenance will be undertaken internally or externally, or both. Identify and maintain an up to date list of approved contractors, preferably those with experience on the place. Provide one individual with responsibility for coordinating efforts and with capability to make decisions as a project manager.

Policy 23 Training and Intern Program

As an educational opportunity in conservation and preservation of George Nakashima's legacy, special care needs to be taken in sharing know-how and providing specialist training on conservation and repair, both internally in good craftsmanship, as well as through the engagement of external consultants with proven expertise in practical conservation techniques. To this end, identify specific training needs and ensure external consultants are adequately briefed about the values and significance of the place.

5.2. Landscape Management Plan
Nicholas Pevzner

This section presents a treatment strategy for the long-term preservation and management of the Arts Building and Cloister landscape. The treatment strategy is composed of four main parts:

1. Manage vegetation for historic character and vegetation health
2. Curate and restoring views
3. Restore non-living elements to historic condition and arrangement
4. De-emphasize non-historic features

Landscapes are dynamic and constantly evolving, and cannot be frozen in time. That said, vegetation was planned to convey a particular design intent with regards to the other static elements of the gardens and paving. While it is natural for vegetation to grow and eventually die, the decision of whether, and when, to replant is important to choreograph Nakashima's design intent.

Policy 24 Manage Vegetation for Historic Character and Vegetation Health

Managed planting areas:

• In places where vegetation is clearly missing, throwing off the geometry of the design intent (as in the West Gravel bed near the West Pond, where a tree is clearly missing based on the shape of the gravel beds), it should be replaced, in consultation with historic photographs for species selection and growth form.

• Where vegetation matches the historic conditions, but has merely grown larger, and taller but is otherwise recognizable and in good health, it should be preserved and supported. Support might include assistance for root health and vigor, for example through applications of compost tea or other soil amendments to the root zone. The health of trees in this category should be monitored to track the progress of decay in otherwise healthy-looking trees, so that limbs don't unexpectedly drop onto the Arts Building or other contributing features of the Arts Building landscape, potentially causing damage. Assessment of health should be done by a trained arborist, and can include decay detection techniques such as minimally invasive increment boring or tomography.

• If a tree is deemed to be in poor health, decayed, and in danger of collapse or death, consideration should be given to how the replacement of that tree will affect the larger character area. When choosing a replacement tree, evaluation should be made of light and shade conditions, and how it will interact with neighboring vegetation to reshape the overall character area.

• For areas of more finely wrought landscape design, such as the garden around the main Pond (Pond Planting), the spatial relationship of all the vegetation in the character area, taken together, should inform planting choices. If the older Eastern red cedar tree were to go into decline, show signs of disease, or die, the entire main Pond garden should be reconsidered in light of historic design intent. This could mean the planting of a new Eastern red cedar sapling, a new evergreen shrub near the Arts Building sliding doors, and a new medium-sized deciduous

tree next to the saddle-shaped “large rock,” to reflect the vegetational spatial arrangement visible in historic photographs of the Pond.

• Where self-seeded vegetation has taken root and achieved a significant dimension — especially when it would have already been present in George Nakashima’s lifetime, as in the flowering dogwood at the western edge of the South Patio — the vegetation should be left to grow as long as it doesn’t threaten the material integrity of the permanent landscape elements or the Arts Building itself. Even though this vegetation does not conform to original design intent, cutting it now in its advanced state would leave an unsightly stump, which would require subsequent removal, and which could upset existing stones and gravel.

• Any new saplings that subsequently take root spontaneously amid the stones, groundcover vegetation patches, gravels, or planting areas in the Arts Building landscape should be evaluated against historic photographs, and removed at an early stage if found to be out of compliance with historic design intent.

Wooded Verges:

• Even-aged stands of woodland are problematic from a forest management perspective, since disease, weather events, or old age can decimate an entire even-aged stand. Therefore, it is recommended that attempts be made to diversify the age of the existing forest, by planting seedlings and nursing them past the period of vulnerability to deer browsing. For wooded areas such as the South-side Wooded Verge, East-side Wooded Verge, or North-side Wooded Verge, it is recommended that any naturally self-establishing saplings be protected against deer browsing with deer-proof fencing, and new saplings added to diversify the age of the currently existing woodland.

• Hearne Hardwoods Inc., based at 200 Whiteside Dr., Oxford, PA maintains the forest and trees surrounding the Arts Building and Cloister today. John Curlew, the Assistant Logger at Hearne Hardwoods, worked for George Nakashima and has been working on the property in an on-call capacity ever since. It is recommended that John Curlew be consulted regarding forest and woodland health, as part of a groundcover restoration or forest age diversification effort.

Policy 25 Curate and restore views

Part of the management plan for the wooded verges includes not only the health of the woodland, but the woodland’s role in directing or screening views. In the case of the South-side Wooded Verge, the clearing of forest that accompanied the construction of the neighboring house resulted in high porosity and visibility of the neighboring house and property from the Arts Building and South Patio.

The design intent of the South View was intended to include the pond in the foreground, and was intended to terminate in the wooded backdrop. The construction of the neighboring house (with associated clearing of a majority of the woods on that side) is a visual imposition on the intended view from the Arts Building, and is certainly non-contributing.

The Foundation has been planting pine trees and bamboo for a number of years in an attempt to screen out the house. The bamboo is a highly aggressive species and can “escape,” becoming very difficult to control if left unchecked. Pine trees

are not typically associated with the surrounding oak-mixed hardwood forest, although a related forest type — the "Hemlock (white pine) – red oak – mixed hardwood forest" does include pines in its composition.

• A more holistic visual screening strategy should be considered, which extends the character of the native Pennsylvania woodland and enhances the ecological health of the forest verge while minimizing use of invasive vegetation.

• Of particular note are native deciduous woodland species that hold onto leaves throughout most of the winter (trees that exhibit marcescence), since these species increase the visual screening effect in winter. Some American beech (Fagus grandifolia) trees are already present in the South-side Wooded Verge, and the beech population should be expanded to provide additional visual screening that is in keeping with the native woodland species mix. Additionally, shrubs with marcescent qualities, such as American hophornbeam (Ostrya virginiana), American hornbeam (Carpinus caroliniana) and Spicebush (Lindera benzoin) can be added to the understory to aid in visual screening year-round.

• The South-side Wooded Verge and the East-side Wooded Verge, if given new saplings and understory shrub planting, should simultaneously be protected by a deer exclosure fence to ensure the survival of the new planting and the visual screening effect that it is intended to provide—based on the state of the Wooded Verges today, it is clear that deer browsing is decimating understory vegetation and young saplings. If painted black, the exclosure fence will be visually unobtrusive, while enabling the survival of the newly planted vegetation despite the high population of deer around the property.

• Looking in the another direction, the West view from the South Patio is another important view of the Arts Building landscape. Included as part of the West view is the Seasonal Pond. Currently the Seasonal Pond appears as an isolated element within the larger mowed lawn at the south of the property. The pond is very close to the South Patio and is a visual point of interest, but it may feel visually more integrated into the larger landscape if taller grass vegetation is allowed to extend further around the seasonal pond, interacting more with the taller vegetation of the hay meadow beyond. The line of mowed lawn vs. hay meadow should be reconsidered as part of a re-evaluation of the view from the South Patio to the west.

Policy 26. Restore non-living elements to historic condition and arrangement

Non-living elements in the Arts Building landscape are not continually growing, although some may still be in flux from forces of deterioration and weathering.

• For stones that have migrated or are missing, attempts should be made to restore these primary structuring elements, in consultation with historic photographs. Of primary note is the area between the South Patio and the Pond Planting: attempts should be made to locate the missing stone(s) of the retaining wall border between the two zones, and to reset them.

• For wooden posts lining the edges of the main Pond, which are currently in an advanced state of decay, a conservation management plan should include a methodology for evaluating posts on an ongoing basis. Firstly, the wood species of the current, original posts needs to be determined. Next, source material for

the posts needs to be located, and the depth of existing posts determined through an evaluation of existing posts. Finally, posts should be as necessary to maintain their historic appearance as part of the pond perimeter.

• For gravels, because the mixing of gravels between zones results in a blurring of the design intent, a regime of raking and separating gravels on a periodic basis is needed. As part of a conservation management plan for the landscape, gravels that appear to have migrated from their designated zones need to be periodically raked up, sieved to separate them from soil and other extraneous material, and replaced in their appropriate zones. The gravels are underlain by landscape fabric, which prevents weed growth in the gravel areas. Whenever landscape fabric becomes exposed and visible above the gravel, it needs to be re-pinned every 12" with landscape fabric pins or staples.

Policy 27 De-emphasize non-historic features

• Lastly, as part of the conservation management plan, attempts should be made to minimize and de-emphasize the visual presence of non-historic and non-contributing features, such as electrical outlets, pumps, termite control systems, and other extraneous features, so as to not detract attention from the historic Arts Building and Cloister landscape.

5.3. The Building Compound: Material Conservation
Cesar Bargues Ballester

Based on visual inspection and condition assessment, the project team identified a series of conservation issues and alterations to the building that have been summarized in the first volume of this CMP. The following is a list of policy and recommendations.

Exterior of the Arts Building

Policy 28 Form and Character of the Hyperbolic Paraboloid Roof

The original form, fabric, structure and finishes of the hyperbolic paraboloid roof, including the eaves, must be retained. Any repair, sensitive adaptation or replacement must respect and consider the original design intent and character of the roof.

After investigation with an IRT Camera, Roof probes revealed the presence of moisture entrapped on the northeast lower end of the roof. While not damaged, the exposed surface of the plywood deck was visibly wet, and the fiberboard insulation completely deteriorated. Although the asphalt lining is in overall good condition, exposed areas show alligatoring.

Reportedly, alterations to the roof focused on the north and east eaves. It included the redesign of the water disposal system, replacement of deteriorated plywood, flashing, and installation of a new built up roofing finished up with gravel.

Recommendations	Priority
• Remove moss as well as litterfall and cover exposed areas of asphalt lining with historically matching ballast stone.	Annual
• Visual inspection of the roof after major weather events.	Annual
• Repair the northeast area affected by the entrapped moisture.	1
• Replace in kind the rotted areas of plywood on the north and east eaves.	1
• Remove current white opaque finish in eave soffits and recoat with a historically appropriate translucent finish.	3
• In the event of a significant intervention, consider restoring the water disposal system as it appeared at the time of construction and was envisioned by George Nakashima.	3

Concerning the plywood deck, areas of rot are visible in the Arts Building eaves. A section in front of the chimney stack is highly deteriorated. The following recommendations are also applicable to the Cloister porch plywood soffit. Moisture damage to this element can be indicative of failures in the roofing system.

Recommendations	Priority
Keep in sound condition exterior finishes through routine maintenance and reapplication.	Annual
Minimize the potential for damage by periodically inspecting the condition of flashing, waterproofing systems, and keeping gutters clean of debris and tree litter.	Annual
Confirm and remediate causes of moisture infiltration affecting Arts Building eaves and Cloister roof.	1
Remove unsound areas on the north and east eave of the hyperbolic paraboloid roof as well as the Cloister porch and replace them with matching plywood: species , grain, and other visual characteristics. Complete replacement in kind is recommended when deterioration affect large areas and can compromise the performance of the assembly.	1
Edge of panel products are more susceptible to water uptake and release than are their faces, due to the end grain exposure of the veneers Edge-seal the plywood sheets with a compatible, non-visible, material.	2
Plywood that has minor external damage from impacts can be repaired using wood putty. Prior to repair, be sure to use compatible putty by testing to assure proper matching once cured and stained. Superficial scratches can be sanded, sealed and finished.	3

Concerning flashing and gutters, failing sealants and cracks are visible on the eaves, as well as impact damage on gutters.

Recommendations	Priority
Check flashing and sealants around the base of the chimney, hyperbolic paraboloid roof eaves, window seat canopy, walkway, and Cloister roofs. Look for areas where water can infiltrate. Check interiors and soffits to see evidence of water infiltration. Recaulk and repair flashing accordingly.	Annual
Current sealants on the flashing installed upon the eaves show cracks, deterioration and brittleness. Remove and apply new appropriate sealant. Reattach loose fasteners, be sure nails are chemically compatible.	1
Repair cracked flashing sheets and consider a system to allow thermal expansion aesthetically and functionally sensitive to the original installation. Avoid standing seams.	2
Assess the remaining service life of the roofing system and adequacy of current gutters.	2
In the event of a major intervention, consider restoring the water disposal system as it appeared at the time of construction and was envisioned by George Nakashima.	3

Carpenter bee holes are evident on the lower face of the fascia. Also, woodpeckers have caused severe damage.

Recommendations	Priority
Determine and apply an appropriate insecticide and plug up the carpenter bee holes in the fall months.	Annual
Replace sections of the fascia that are rotted with the same wood species. Check the condition of fasteners and reinstall missing plugs.	1
Limit the use of epoxy resings to minor reapir and hidden areas. Consider Dutchmen and face repair for large and exposed areas.	1

On the south and west elevations, the interplay of wood, glass and infill panels is a character-defining feature of exceptional significance. Nakashima's final scheme included the installation of cypress grills on the exterior and interior shoji screens in selected locations. The concept of the grills is visible in the ealier hand drawings. The west elevation is visible from the Conoid Studio and Chair Department, from the driveway leading to the Pool House, and from the approaching visitor pathway. Openness allows visitors to contemplate the rhythm of the ribs and the plywood ceiling from a distance. On the west elevation, the canopy over the window seat is a deviation of the design intent.

Policy 29 Character of the South and West Elevations

Retain the configuration of grills, glass panes, and infill panels as designed by George Nakashima. (See Policy 39 View to the Landscape)

The edge beams are in excelent condition. The lower ends of the tapered edge beams are notched into stones at the walls. Reportedly, these lower ends were bolted to the stone masonry. Rust stains on the south wall may be indicative of rusting fasteners.

Recommendations	Priority
Confirm the joint components and identify corroding metals that can compromise the assembly and the structural performance.	1
Evaluate the cause of the corrosion process and evaluate possible repair in collaboration with a structural engineer.	1

To a greater or lesser degree, the interface between infill panels and concrete surfaces shows a gap running vertically. This condition allows moisture infiltration and heat loss, particularly on the south elevation.

Recommendations	Priority
Inspect wall panels for moisture infiltration or damage and repair accordingly. Repair should be made using same materials and techniques. Consider the possibility of improving the insulation keeping the same thickness.	Annual
Monitor and investigate active movements of the assembly. Evaluate and determine the use of a joint sealer, such as 790 silicone building sealant, and rope for filling in the gap. Ensure color and texture matching.	1

In many instances, wood stops are deteriorated compromising the tightness of windows and sliding doors. Insulated glass and single panes are in good condition. At the Arts Building, two impacts have been detected in the south sliding door.

Policy 30 Replacement of Glass

Replacement of individual glass panels should match the color, reflectivity, and translucence of the existing glass. If it becomes necessary or feasible to replace or improve current panels to achieve better thermal properties or UV protection, consider historical character and perception.

Recommendations	Priority
Inspect condition of sealing in junctions between window and door frames and the walls. Missing, deteriorated or cracked filler must be removed and replaced. Material of current sealants is unknown. Ensure that the replacement is elastic enough to accommodate movements.	Annual
Inspect condition of any fixtures and fittings, such as hinges, knobs, locks, catches and operator handles, particularly on the window casements. Check materials and condition of the framework, including wood stops and lead flashing. Replace deteriorated wood stops with same species. Consider the addition of hidden caulk to improve performance.	Annual
Prepare and implement a plan for routine cleaning to remove dust, dirt and spider webs that can build up into a crust. Evaluate and determine a cleaning methodology. Use the mildest method moving to a more invasive one if required without question.	Annual
Develop and deploy a system for monitoring condensation and water infiltration as per Environmental Engineering recommendations.	1
Source glass as per Policy 30 and replace pane deteriorated by impact damage.	2
Locate potential risks related to use and visitation, as well as future causes of deterioration, and identify measures for mitigation.	2

UV induced damage is visible elsewhere on the wooden elements. Reportedly, Nakashima craftsmen have usually finished the architectural wood elements with boiled linseed oil thinned with turpentine. Over time, this finish has darkened considerably.

Recommendations	Priority
Determine and evalute a gentle method to remove mildew from wooden elements.	Cyclical
Subject to the respect of the original finish, evaluate improving the specification to combat known causes of deterioraton. Determine and evaluate a preservative method to prevent further UV induced damage to wooden elements.	Cylical

On the north and east wall, the current rendering is original except for localized repairs. Horizontal cracking, hairline cracks following the perimeter of the masonry units, carbonate calcium deposits, efflorescence, as well as surface loss through disaggregation are visible on the north wall to a greater extent. Thermal imaging survey showed a thermal bridge on the interface between the rendered CMU masonry wall and the chimney stone masonry stack, as well as areas of the CMU wall slighty colder than otehr forming vertical bands.

Recommendations	Priority
Conduct routine cleaning. Identify and evaluate an appropriate method of cleaning for attached soiling, crust and stains.	Annual
Provide reinforcement as per structural engineer recommendations, and expand the structural model to determine wall stability, as well as causes of induced stresses and cracking. If repair is necessary, preserve as much as possible of the existent stucco.	1
Determine if raising damp is occurring as per environmental engineer recommendations.	1
On both the east and north elevations, confirm the presence of a French drain and assess its performance. Below grade, install a new waterproof membrane covering the wall foundation and consider the creation of an impermeable barrier, such as flashing, that will stop water infiltration through capillary rise, or evaluate the implementation of an electro-osmotic pulse technology.	1
Ensure the wall assembly is enough dry before remedial work is applied. Remove mineral deposits and brush off superficial efflorescence. Evaluate and determine a tailored poultice technique for salt removal.	2

Hairline cracks (less than 1/32") and crazing does not require treatment. Inactive cracks larger than 1/32" and affecting all the coat thickness must be filled with a color-matched lime mortar, slightly weaker than the surrounding material. Cracks may need to be cut out by shaping an inverted crack able to receive and provide a key for the new mortar. Protect mortar while curing.	2
Consolidate areas with superficial damage through disaggregation.	2
Use compatible materials and technique similar to the installed to repair bigger areas and chipped corners. Analyze current material and evaluate replacement mortars. In all repair work, evaluate mock ups and ensure color matching and texture. Consider the use of mineral silicates to blend previous repairs.	2

Hairline cracks and failing joints on the buttresses were noted during visual inspection, along with biogrowth (mosses and lichens). Several stones showed flaking and superficial delamination.

Recommendations	Priority
Evaluate, determine and apply a biological growth removal treatment to retard deterioration. Water washing, PH neutral and biodegradable cleaners, such as D/2 Biological Solution, are preferable to highly hazardous acid cleaning methods that can etch permanently the masonry, particularly the stones of calcareous nature.	Annual
Rake deteriorated mortar joints and point with a historically appropriate replacement mortar.[7] Before approval and application, prepare different mortar samples to match in color and texture the original mortar.	1
Confirm the causes of efflorescence occurring on the south stone masonry. Check gutters and flashing to be sure there are no failures in the water disposal system. Repair accordingly. Determine and evaluate a tailored poultice for salt removal.	2

Overall, exposed concrete is in excellent condition. On the exterior, a significant alteration was the installation of a fiberglass membrane to prevent rainwater leaking into the interior space. On the interior, a waffle slab forms a low ceiling for an entrance hall or "Cave." Daylight, filtered by *shoji* screens, comes through five skylights on the west elevation and a window on the south elevation.

Policy 31 Concrete Volume

Maintain the legibility of the primary concrete and wooden elements of the volume accomodating the terrace and the main entrance to the Arts Building, including interior character-defining features such as the waffle slab. Intrusive elements and paints are not acceptable.

7. Gravimetric analysis is provided in the Arts Building and CMP Vol. 1, Appendix F

Policy 32 Exposed Concrete Surfaces

When repair of exposed concrete elements becomes necessary, care should be taken to maintain quality control of color and texture to match existing fabric.

Recommendations	Priority
Evaluate and determine a cleaning methodology for routine removal of bio growth and soiling, as well as calcium carbonate deposits on soffits. Consider if the subtrate will be damaged, safety and hazards to the environment and workers. While protected areas retain original surface, signs of superficial erosion and mechanical impact are visible on exposed surfaces.	Annual
Brush off carbonate deposits on the concrete soffits and joists in the cave. Monitor presence of new crystallization afterward.	1
Evaluate and determine a cleaning methodology for removing iron stains and carbonate leachng crusts from the concrete soffits and joists in the cave.	2
Remove hooks from concrete elements and evaluate an alternative hanging system if necessary.	2
Consider the removal of the fiberglass membrane as well as epoxy paints on the terrace. Engage an architectural conservator to evaluate condition of exposed surface and explore alternative treatments to restore original appearance and finish. In the event this was not possible, explore ways to deemphasize the current coating.	3

Canopied Walkway and Exterior of the Cloister

In Soul of a Tree, George Nakashima recognizes the importance of the post in the traditional Japanese architecture. He illustrated three types of work: menkawa, shi-ho-masa, and shibori. The *menkawa* is “a post with four planed sides; the four unplaned surface are left with the natural contours.” The *shi-ho-masa* is a “four sides straight grain” post. The *shibori* is the natural trunk of a tree, which could be cultivated, with a characteristic mottled underbark.

In the canopied walkway, the 4x4 inch black locust posts were prepared after the *menkawa* post. Nakashima’s design choice resonated with his free-edge furniture. This craft highlighted the beauty of the natural form of the selected species, while confering simplicity to the structure. The replacement with other species and appearance, while functional, deviated from the original intent.

Policy 33 Character of the Canopied Walkway

Recognize the significance of the *menkawa* posts as expression of George Nakashima’s ideas. Remaining original posts should be maintained and the overall unity recovered.

Recommendations	Priority
Inspect condition of flashing, sealants, and waterproofing membranes. Keep it clean of biogrowth and litterfall.	Annual
Repair or replacement of deteriorated members should use the same species. Follow table provided by wood scientist or identify species when unknown. The Center for Wood Anatomy Research, USDA Forest Service, Forest Products Laboratory, in Madison, WI can identify and confirm a maximum of five wood samples	1
Limit the use of epoxy resins to minor repair and hidden areas. Consider Dutchmen and face repair for larger and exposed areas.	1
In the event of major intervention or deterioration, consider replacing current machine made Ipe posts with Black locust as per wood scientist recommendation.	3
Check and confirm rot extension in rafters supported by IPE post number 2 and 3 (See drawing sheets NAKA A-.02 and NAKA C.05). If this is the case, determine and evaluate the area of repair, proper joint and reinforcement if necessary. Repair wood should match species, grain orientation, moisture content, growth characteristics and section orientation. Exposed elements do not accept partnering timber or supplemental elements, except as a temporary shoring.	1
Treat the plywood deck as per above recommendation (see page 24).	2
In the event of a major intervention, consider restoring the water disposal system as it appeared at the time of construction and was envisioned by George Nakashima. (See Arts Building and Cloister CMP Vol. 1 Section 6).	3

Exposed Waylite block masonry reinforces the idea of simplicity recognizable both in the exterior and in the interior of the Cloister. Hairline cracks in the masonry are likely the result of shrinkage of both the block and mortar, the block being the major contributor. Hairline cracking does not constitute damage and does not compromise the structural integrity of the masonry. Cracking also occur on the interface between block and concrete lintel above window openings.

Policy 34 Exposed Concrete Block Masonry

Respect the restrained character of the exposed concrete block, and retain the exterior and interior exposed surfaces.

Policy 35 Potential Improvement of Storage Room

Should it be an improvement of the storage space to meet comfort or environmental requirements; it would be advisable careful consideration of the treatment, its reversibility, and compatibility with architectural detailing by George Nakashima visible on the place.

Recommendations	Priority
Evaluate, determine and apply a cleaning method to remove stains caused by dirt and moderate biological staining.	Annual
Evaluate, determine and apply a biological growth removal treatment to retard deterioration.	Annual
Monitor step cracking on southern corner. If settlement occurs investigate footings, evaluate, and implement remedial measure.	2
If major work is undertaken, consider the removal of the cementitious sill built in summer 2016. Follow the general policies to propose an alternative solution.	3

The exterior lighting fixtures are original to the Cloister. The wall sconces are similar to Thomas Lighting SL875-3. Light corrosion products, spider webs, and dust accumulates on the surfaces of the exterior lighting fixtures.

Policy 36 Exterior Lighting Fixtures

Original functional design and simple form of the outdoor wall sconce should remain. Should it be replaced, select the most efficient light bulb that maintain the quality and color of light provided by the original lighting system.

Recommendations	Priority
Conduct routine cleaning to remove dust, spider webs, and dauber wasp next that can build up a crust that requires a more invasive cleaning. Evaluate and determine a conservation-based methodology to clean corrosion products.	Cyclical

The seven by twenty-three feet mosaic mural, “Poet’s Beard”, manufactured by Gabriel Loire after Ben Shahn’s gouache, has exceptional significance. This work memorializes Ben, close friend of the Nakashimas and was intended to be seet at a distance.

Policy 37 Ben Shahn’s Mosaic Mural

Because of its exceptional contribution to the cultural significance of the place, retain and respect “Poet’s Beard” as integral to George Nakashima intent and the Arts Building. Refer to the Collections Management Policies in 6.4.

Recommendations	Priority
Engage an art conservator or graduate student research to conduct a comprehensive condition assessment and evaluation of preferred treatments, including consolidation of deteriorated tesserae and selection of architectural adhesives.	1
Gabriel Loire Atelier is still active (loire@wanadoo.fr). Consider obtaining their advice and sourcing materials in kind for future repairs.	2

Interiors

At the time of the completion of this document, an external party executes routine cleaning of the interiors. Reportedly, cleaning products and methods are gentle.

In the Cave, the stone slab flooring shows missing and failing joints, as well as stains as a result of catering activities, are visible. In the Gallery, concerning the vinyl flooring, current tiles show some loss of adhesion to the concrete slab in the Arts Building and to the plywood substrate in the Cloister. Shrinkage as well as minor damage was noticed. Wooden surfaces show moisture stains and UV light damage. In the Loft, the concrete floor shows stains as a result of the 2016 campaign to clean and oil the walnut flooring. Allback Organic Linseed Soap slightly diluted with water was used to remove original finish. The new finish was achieved with Sutherland Welles Polymerized Tung Oil and Sutherland Welles Finishing Varnish. Reportedly, for any following refinishing project only the tung oil will be applied.

Recommendations	Priority
Rake loose joints and point with an historically appropiate lime-cement mortar. Ensure texture and color match.	1
Conduct a test to determine asbestos content in the vinyl flooring.	1
Consider the risks associated to the use of an open-hearth fireplace and the adjacent materials.	1
Test alkalinity and measure the vapor transmission rate through the concrete floor slab as per the Environmental Engineering recommendations (ASTM F-1869 and F1907-04).	1
Evaluate and determine the best method to reinstall the current tiles (without disturbing asbestos if present). Consider implications in the interior environment.	2
Determine the type of stains on the concrete floor, oil or varnish, and evaluate a conservation-based cleaning system for removal.	2
Determine and evaluate a cleaning methods for stains visible on the stone slabs.	2
Materials adjancent to surfaces to be cleaned must be protected before, during, as well as after job is undertaken.	Cyclical
Existent vinyl tiles show signs of tear and wear after almost 50 years of use. It is likely the material is near the end of its life expectancy. A strategy should be formulated to guide tile replacement, including their procurement or recreation. Replacement should be in kind, ensure color matching and texture, improved fire resistance and resilience would be acceptable.	3

Policy 38. Interior Lighting Fixtures

Improve lighting as per Collections Assessment and Policy Recommendations

Recommendations	Priority
Conduct routine cleaning to remove grass stains, dust, spider webs that can build up a crust that requires a more invasive cleaning.	Cyclical
A strategy should be formulated to guide fixtures replacement, including their procurement. This strategy should include consideration of reinstatement of original Isamu Noguchi designs in the Arts Building.	1

In detailing the west and south elevations, George Nakasima incorporated strategies for control of natural light. This includes roof overhangs and cypress grills on the exterior, as well as Shoji and curtains inside. It is a carefully considered composition of traditional Japnese elements and his own design aesthetic. In so doing, he is establishing precise relationships with the landscape both in daytime and night time.

However, in order to improve the environment for the collections and interior surfaces, consideration for additional strategies for natural light control are important, especially for effects from direct sunlight exposure.

Policy 39. Views to the Landscape

Maintain views out from the space. Consider the impact of modifications to the existing strategies for the control of direct sunlight.

Recommendations	Priority
The curtains in both the mezzanine and the lower level are arguably an integral part of the design in their respective locations, as elements to control light intake and privacy. Their condition is good, but lower areas need to be rewoven. Check condition of hangers and rehang.	1
Repair deteriorated paper on shoji screens.	2

5.4. Structural Wooden Elements
Ron Anthony

1.Repair or replacement of deteriorated members should use the same species.
2.The patches of moss on the roof should be removed periodically to prevent them from becoming established to the point where they gain roof penetration through the membrane and into the diaphragm below.
4.The biological growth on the south railing of the terrace should be removed periodically. Remedial preservatives, such as borate rods, could be inserted at the connections to retard the action of wood decay fungi or insect attack.
5.The base of the four original posts in place at the landing with the sliding doors on the south elevation do not require repair; however, the southeast post has more extensive deterioration at the base and is suitable for a hidden repair (if desirable) to prevent further deterioration of the wood. The post does not need to be replaced.
6.More information could be obtained on the Arts Building roof diaphragm material and construction through one or more roof probes. The information would be beneficial in understanding the structural performance of the roof as well as potential durability issues.
7.The supporting posts on the walkway between the Arts Building and the Cloister, as well as the posts supporting the Cloister porch/soffit, have been replaced.
It is recommended that the trim at the base of the replacement posts be removed to the original configuration, which will allow for the posts to dry when they get wet. Use of a spacer at the bottom of the post would prevent the end grain of the post from absorbing water under most circumstances. Consider replacing the posts with new posts made of black locust.
8.The Cloister roof should be repaired and maintained. The plywood soffit should be repaired.

5.5. Structure
David Biggs

1. Additional roof testing should be undertaken to provide additional data to tune the computer model.
a.Materials. Non-destructive testing should be considered if physical samples can't be obtained.
b.Dynamic monitoring should be undertaken. This requires installing sensors (accelerometers) on the roof structure and inducing vibrations by having someone jump on the roof. From this, the natural frequencies and mode shapes can be obtained and correlated to the computer modeling. The computer model could then be "tuned" to the actual vibration characteristics.

2. Additional modeling would improve the results.
a.Since exact material properties are uncertain, the computer model could be evaluated based upon variations in material properties.
b.The modeling should be refined to include the masonry walls and timber edge beams more exactly.

c.Determine the natural frequencies and mode shapes of the roof to harmonize the computer model with field testing.
d.Professor Kabele at the Czech Technical University in Prague has graciously offered another SAHC master's student during May to July 2017 to continue the computer modeling. The current model should be reviewed and modified for consistency with the measured deflections and to determine how the edge conditions are affecting the deflections.
If the dynamic monitoring is provided, the dynamic modeling can be added and further tuning completed.
If time allows, a spreadsheet might be provided that provides guidance on temporarily supporting the roof during large snow events or repairs.

3. Roof Shoring
a.Repairs
The modeling stress results could be consulted for determining possible shoring locations during future repairs.
b.Unbalanced snow loads
•If possible, evaluate the actual snow loads during future major snow events. This may be impractical if the site is not available in the winter.
•Compare the actual conditions to assumed loadings.

4. Wall strengthening
a.The large exterior cracks in the walls should be repointed.
b.The horizontal cracks in the north wall should be strengthened. This might include adding vertical strips of frp adhered to the wall, internal reinforcement or both. The rendering would need to be replaced.

5. Roof repairs - wet roof
a.The roof membrane must be kept dry.
b.Repair the roofing at the northeast corner where wet insulation and plywood were found.
c.Evaluate the effectiveness of the roof vents installed on May 10, 2016.

6. Miscellaneous
a.Repair any exposed wood deterioration in the posts and beams.
b.Repair the cracked rib.

5.6. Environmental Management and Hygrothermal Performance
Michael C. Henry, AIA, PE, PA#026615E

Based on observation of the buildings and the collection and based on the environmental data collected to date, several potential conservation issues related to environmental management and hygrothermal performance of the building have been identified, along with recommendations for their resolution.

Natural Light Damage to the Collection and Interior Architectural Materials/ Finishes
Damage from exposure to natural light was noted in the collection (Attachment A) and the architectural materials, notably the wood framing for the wall glazing . The illuminance levels for the collection and architectural surfaces that were estimated by the daylighting simulation (Attachment B) exceed the recommended levels necessary for protection of museum collections.

Natural light levels in the Arts Building interior should be reduced, and the combination of shoji screens and exterior wood grilles can provide an architectural solution to this problem, consistent with Nakashima's original design of the building.

Recommendations
1. Install and monitor prototype shoji screens for the south and west elevations to reduce natural light levels. Design the shoji screens to allow air circulation between the room and the glazing surface in order to prevent microclimate-induced condensation (see Moisture Damage at Windows, below).
2. Monitor light levels at selected locations in the interior, with and without the prototype shoji screens for 12 consecutive months and analyze the data to validate/confirm the results of the daylighting simulation (Attachment B); and,
3. Based on 1 and 2, develop and implement an operational strategy for seasonal deployment of shoji screens and exterior wood grilles for natural light reduction at the glazed south and west elevations.

Ultraviolet Radiation Damage to the Collection and Interior Architectural Materials/Finishes
Damage from exposure to high levels of ultraviolet radiation was noted in the collection (Attachment A) and the architectural materials .

Recommendations
4. Apply ultraviolet filtering adhesive film to existing glazing in the south and west elevations; and,
5. Require that replacement glazing (single glazing or thermal insulated glazing units) incorporate stable, long-term ultraviolet filtration.

Environmental Management Performance for Collections and for Comfort
Preliminary analysis of basic environmental monitoring data from November 2015 through October 2016 has informed understanding of the environmental response and comportment of the Arts Building and the range of interior conditions that the

collections in the building experience.

The preliminary analysis of the data suggests that interior conditions in winter may satisfy ASHRAE A23 Class A/B criteria, while conditions in summer are likely to satisfy ASHRAE A23 Class B/C criteria. Data for the transition seasons of spring and fall have not been analyzed, but these seasons are likely to be problematic with respect to the range of short term fluctuations. Sampling of summer data suggest that interior conditions in the naturally ventilated Arts Building meet the criteria for adaptive thermal comfort of occupants set out in ASHRAE Standard 55.

The basic monitoring and preliminary analyses conducted for this report have not been comprehensive in scope, but have been sufficient to identify needs for future monitoring and analysis, including diagnostic monitoring of conditions in significant architectural fabric such as the roof assembly.

Recommendations
6. Formalize the environmental monitoring program using web-based monitoring systems such as HOBOLink® and HOB RX3000 loggers by Onset Computer Company, Inc. (http://www.onsetcomp.com/). Include the records storage space in the Cloister in the spaces to be monitored;
7. Expand the monitoring program to acquire exterior data such as solar radiation, wind direction, rainfall and temperature and relative humidity;
8. Incorporate diagnostic monitoring of conditions in the roof assembly and soils into the program to assess potential for damage from moisture migration through the building fabric; and,
9. Analyze environmental monitoring data using eClimateNotebook® (https://www.eclimatenotebook.com/) to determine environmental risks to collections.

Relative Humidity in Winter and Implications for Source Moisture Control
As indicated by the trend graphs, the dew point temperature in the Arts Building during winter is consistently higher than the exterior dew point temperature, which is surprising, considering the infiltration of dry outside air that is possible through gaps in the sliding doors and windows. The moisture content of the interior air in winter strongly suggests that there is a moisture source sufficient to offset the dilution from infiltrating dry exterior air; however, the effect of this source of moisture is suppressed in summer, when interior and exterior moisture vapor track more closely due to infiltration of humid outside air.

If the source of moisture is the soil abutting the north and east walls of the building or below the floor slab, the soil moisture evaporating from the north and east masonry walls or through the floor slab will have implications for longevity of the wall assemblies or the floor finishes , apart from its beneficial effect in elevating interior relative humidity in winter. Excess soil moisture may result from runoff from the adjoining site slope or from overtopping of roof gutters along the north and east walls, or from both.

Recommendations
10. Continue monitoring interior and exterior environmental conditions for 12

consecutive months and analyze the data with respect to this issue;
11. Check the drainage capacity of the existing gutters on the north and east eaves for adequacy, taking into account projects for increased rainfall intensity and frequency due to climate change. If necessary, increase the size of the gutters. Establish a program to check the gutters monthly and remove accumulations of tree litter;
12. Conduct a moisture survey of the north and east walls using a capacitance-type building moisture meter and infrared thermography to determine if rising damp is occurring;
13. Measure the vapor transmission rate through the concrete floor slab (ASTM F-1869 and F1907-04) at an exposed area of the concrete floor slab near the northeast corner of the exhibit space to determine if soil moisture is evaporating through the slab;
14. Consider installing dataloggers and soil moisture sensors along the north and east sides of the building to determine if variations in soil moisture content correspond with rain events and variations in interior dew point temperature;
15. Check the existing foundation drain along the north and east wall for functionality and/or blockage; install a clean-out in the piping to facilitate regular flushing and root clearing. If necessary, design and implement an improved drainage system to intercept storm water runoff from the north site slope and divert the runoff away from the Arts Building and the Cloister; and,
16. Determine if soil moisture and evaporation toward the interior in winter has a detrimental effect on the floor finishes and the concrete masonry walls.

Relative Humidity in Winter and Implications for Hyperbolic Paraboloid Roof Assembly

The hyperbolic paraboloid roof assembly is described as (from interior to exterior):

- Three layers of 5/8 inch thick plywood panels, in alternating orientation, screwed and possibly glued;
- One or two layers of Celotex® insulation board;
- Asphalt impregnated roofing membrane; and,
- Marble stone ballast.

The plywood roof deck was supported by shoring during construction; when the shoring was removed, the deck reportedly deflected, which would likely result in the formation of air spaces between the plywood sheets.

The trend graph for the period from 12 November 2015 through 01 March 2016 indicates that for the interval from 01 January through 01 March, the interior dew point temperature averaged 40°F (31°F to 48°F range) and the exterior temperature averaged 35°F (9°F to 62°F range). This raises the possibility of migration of interior moisture vapor through the roof assembly with condensation or frost forming where the dew point gradient and the temperature gradient intersect, with the resultant moisture enabling concealed deterioration of the plywood. Locations of particular concern would be the northeast corner of the roof, where thermal bridging from the uninsulated projecting eave would lower the temperatures on the interior side of the north and east walls.

Recommendations
17. Confirm the dimensions and materials of the roof assembly and, using confirmed information perform a transient hygrothermal analysis using WUFI® (Wärme Und Feuchte Instationär) software to determine the potential for condensation or frost within the roofing assembly;
18. Continue monitoring interior and exterior environmental conditions for 12 consecutive months and analyze the data with respect to this issue; and,
19. Based on the above, determine a maximum allowable value for interior relative humidity and dew point temperature in winter above which there is risk of condensation or frost in the roofing assembly.

Moisture Damage at Window Glazing
Moisture damage at interior wood window framing in the south and west glazed walls and moisture damage to collections displayed in the shelving in the south and west glazed walls at the loft are caused by either condensation on the glazing or by leaks of wind-driven rain at the glazing/framing joint, or by both.

Glazing condensation in winter may be resolved by source moisture control, provided that the resultant winter relative humidity is not less than the ASHRAE Class B limit of 30%RH or the Class C limit of 25%RH. Glazing condensation in winter may be exacerbated if interior shoji screens are redeployed to illuminance levels at the collection, since installation of the shoji screens may create a cool microclimate at the interior surface of the glazing.

Determination of the actual cause(s) moisture damage is necessary to identify actions to resolve the issue and effectively reduce the rate of deterioration of the original wood framing as well as the collection.

Recommendations
20. Continue monitoring interior and exterior environmental conditions for 12 consecutive months and analyze the data with respect to this issue;
21. Develop a method for observing or monitoring the wood framing near glazing to differentiate moisture originating from condensation or from rain leaks; and,
22. Install and monitor prototype shoji screens for the south and west elevations that are specifically designed to allow air circulation between the room and the glazing surface in order to prevent microclimate-induced condensation (See also Natural Light Damage to the Collection and Interior Architectural Materials/Finishes).

Indeterminate Service Life of the Boiler and Risks of Fuel Oil leaks in the Mechanical System
The remaining service life of the boiler has not been determined; if the remaining service life is less than five years, consideration should be given to replacing the fuel-oil fired boiler with a high efficiency propane or natural gas boiler.

The condition of the exterior, single-wall fuel oil tank and associated piping is unknown. Internal corrosion from condensation may have compromised the wall thickness of the tank, increasing the risk of a future leak. Since there is no spill/leak containment at the tank, a leak would contaminate the soil requiring environ-

mental clean-up. There are no provisions for fuel oil containment at the boiler; a fuel oil leak in the tubing supplying the boiler would contaminate the adjoining crawl space. If fuel oil is to remain the primary energy source for the boiler, then the risks of fuel oil spills and leaks must be reduced.

Recommendations
23. Evaluate the remaining service life of the boiler; before replacing the boiler, evaluate the comparative efficiencies and costs of an alternate fuel source and boiler, such as propane or natural gas; and,
24. If fuel oil is to remain as the energy source for the heating system, replace the existing single wall fuel oil storage tank with a double-wall, UL-listed fuel oil storage tank with rain shield, similar to http://www.roth-usa.com/products_dwt.cfm. Construct a concrete pad for the new tank in accordance with the tank manufacturer's instructions, extending the pad at least 12 inches larger in each direction than the footprint of the tank.

Indeterminate Risks of Water Leaks in the Mechanical System
The condition of the hot water piping in the heating system is unknown; internal corrosion from water chemistry or from galvanic corrosion between ferrous and copper piping, valves and fittings, may have compromised the wall thickness of the piping system, increasing the risk of future leaks, including leaks where piping is concealed.

Recommendations
25. Perform a hydrostatic test on the piping system to determine if there is any pressure loss due to leaks;
26. Remove two samples of piping from the system piping to check for internal corrosion or loss of wall thickness; and,
27. Resolve any problems identified by the two actions above.

Need to Reduce Fire Risk
The space in the Cloister that contains the oil-fire boiler contains exposed combustible wood construction without fire-resistant separation from the rest of the building. A small piece of asbestos cement board directly over the boiler is ineffective in this respect;

The Arts Building and Cloister are not protected by fire detection and alarm system; a fire in the Cloister could spread rapidly to the Arts Building.

Recommendations
28. Install fire resistant finishes over all exposed combustible construction in the boiler room in the Cloister;
29. Install an aspirating smoke detection system, similar to a VESDA (https://xtralis.com/p.cfm?s=22&p=244) for earliest possible fire detection throughout the Arts Building and Cloister.

5.7. Use, Collections and Interpretation
William Whitaker

This report presents research and findings related to the collections housed in George Nakashima's Arts Building and Cloister, particularly an assessment of their significance and use.

The purpose of this survey is to:

- Review historical records, conduct oral histories, and to examine artifacts housed in or associated with the building.
- Provide documentation for assessing the significance of the collection and its integrity.
- Provide policy recommendations for conservation and management planning.

Collections housed in and around the Arts Building and Cloister include Nakashima designed furniture, art objects, folk art, and exceptional slabs of raw wood, as well as a mosaic mural designed by Ben Shahn. This report discusses the collections in the context of the building and their use over time, with particular emphasis on groupings of objects, their placement in particular locations, and how objects served Nakashima's vision for the use of the building.

The report is divided into sections that correspond to areas of the building and the adjacent site. These include the Western approach, the logia, the "Cave", Gallery, Loft, and Cloister. Additional sub-area are discussed, particularly elements in the main space of the Arts Building, the so-called Gallery. Thematic topics open up discussion of considerations relevant to the interiors, including: object labels and didactic texts; hanging artwork; and lighting.

General conservation policy recommendations are highlighted at the beginning of the report. Recommendations for specific locations in the Arts Building and adjacent landscape follow descriptions of individual areas. Lastly, the report provides a set of basic recommendations for administrative and collections management policies and for the physical care of the collections.

The following individuals contributed their insights: Mira Nakashima, Kevin Nakashima, Jonathan Yarnall, Jonathan and Jeb Shahn, Jerry Everett, Soomi Amagasu, Miriam Carpenter, Alexis Rosa Caldero, Heather Isbell Schumacher, and Cesar Bargues.

Introduction

Perhaps more than any other structure associated with George Nakashima's life and work, the Arts Building and Cloister embodies his highest aspirations as a woodworker, as an architect, and as an artist. It is his most personal building; a testament to his lifelong quest for enlightenment and understanding – of nature, of art and of the human spirit– and of his "stubborn efforts…to create beauty and truth in objects and environment."[7]

In its design, the Arts Building and Cloister stands apart. It is selectively positioned and selectively used and the objects associated with its conception and use over time are equally selective. At the same time, it is inextricably bound into an inter-related structure of landscape, architecture, and use. This is not a building conceived by Nakashima for daily life or routine work. It is a place of inspiration and retreat rooted in his personal experience of living and working at a Hindu monastery in south India in the late 1930s. "The monastic life is essential for understanding to be achieved," he said, and it was the discipline inherent in that experience that formed the basis for his own approach to design.[8]

For Nakashima, the Arts Building and Cloister provided a location to gather his most significant slabs of wood. In the beautiful light of this building, a growing understanding of the singularity of a piece was developed. Some of his selections remain to this day, others, as was intended, were transformed by his artistic vision. Examples of his furniture design are also to be found here; early prototypes and masterworks alike. This is one of the only locations where his furniture can be seen together with the raw wood that inspired it.

The building is a venue to celebrate the artistic achievement of his close friend Ben Shahn, among others, and the location he chose to concentrate a display of his collection of folk art and other works that "inspired" him.[9] He invited three Catholic priests, a Zen monk, and a Hindu holy man to discuss the state of the human spirit in this space and together with his wife Marion, celebrated the coming of the Cherry blossoms every spring in the landscape surrounding it. The tent-like space was great for parties and served as an ideal setting for peaceful gatherings too. In fact, the notion that the Arts Building and Cloister should "remain a place of peace" is foremost in the minds and hearts of his family.[10]

With his death in 1990, change came. A building that received and channeled his many energies quieted somewhat. But the community of woodworkers endured and now thrives again. This younger generation still convenes with wood, but rarely use the Arts Building to do so now (it is far easier to store and track slabs in the ample Pole Barn with lifting assistance provided by a forklift). Every once in a while, however, they come across a slab with George's chalk marks on it, revealing a glimpse into how he "read" a piece of wood and conceived of its transformation.[11] His spirit is there. Maybe, in the Arts Building, something of the man endures as well and can be rediscovered in the delicate and considered relationships between objects, building, landscape, and a life spent therein.[12]

7. Soul of a Tree, p.xiii.
8. Curran, Vince. "The Spiritual Pilgrimage of an Ealry 'Hippie'", in T*he Cahtolic Standard and Times*, 13 December 1968.
9. Soul of a Tree, 32
10. Interview with Mira Nakashima, 9 November 2016
11. Interview with Alexis Caldero, 7 January 2017
12. Paraphrasing remarks by John Yarnall, 9 November 2016

Conservation Policies – Summary

The Assessment of Cultural Significance found that the Arts Building is culturally significant as an outstanding work of architecture, and this significance is enhanced through its association with the collection of art, folk art, furniture, and wood slabs, selected and formed by George Nakashima, as well as through the building's integrity of use.

General Policies

Policy 40

Maintain the experience of seeing and interacting with Nakashima's collections within the Arts Building and Cloister. It is a significant collection within a highly significant building, and each contributes to the other.

Policy 41

The active and flexible use of the interior and related furniture for display, meeting, performance, and contemplation, were an inherent part of the original concept and should be recognized and maintained as significant to the Arts Building experience.

Policy 42

Recognize the distinct character of the collections assembled and displayed by Nakashima within the Arts Building.

Policy 43

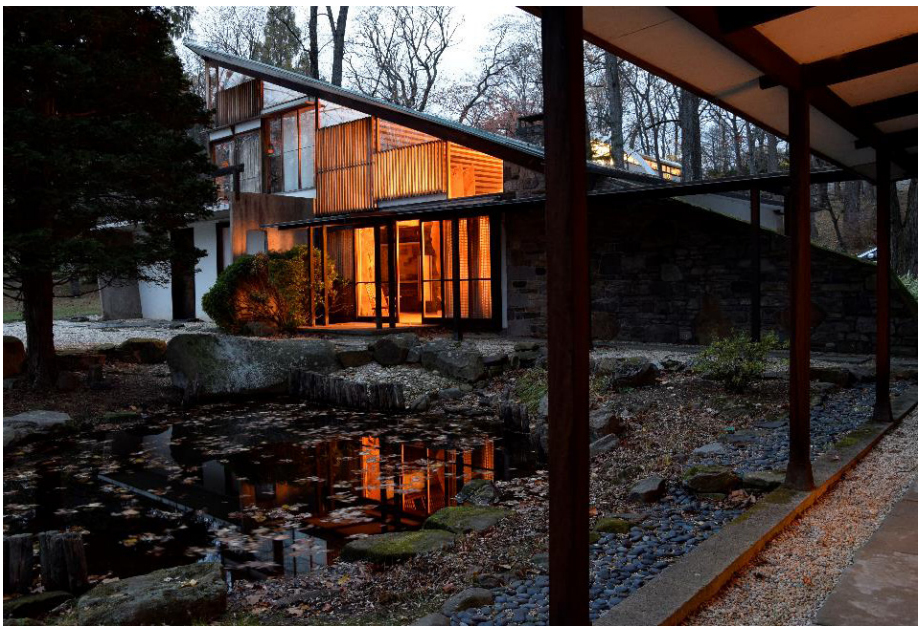
Maintain the active use of the building by the next generation of woodworkers.

Historic documentation reveals a constant state of change in the display of the furniture, wood slabs, and the folk art objects during Nakashima's lifetime. These objects, and the playful jostling of the relationships between them, are a direct channel to Nakashima's creative explorations and a means of generating new insights and deepening understanding of his art and work from the point of view of today. A connection between the use of the Arts Building and the next generation of woodworker could be encouraged though their involvement in curatorial selections and decisions about displays, providing a means of energizing objects and relationships with contemporary life and practice.

Vulnerabilities

The cultural significance of the building, with respect to use and the objects housed within, is vulnerable from:

1. The need to accommodate an increasingly valuable and fragile collection with the concomitant pressures of continued use, storage, handling, and security.
2. Disassociation or removal of significant objects from the building and the parallel loss of knowledge about the history, provenance, and description of individual objects.
3. The use of the gallery space for the storage and display of non-contributing collections or for other items that have no direct connection to the significance of the building and, thereby, diminish integrity.
4. A specific disassociation of use of the building and collections by the next generation of woodworkers.



Arts Building from Cloister, looking Northwest. November 2015.

General Description

George Nakashima's Arts Building and Cloister was dedicated on May 7, 1967. It was conceived at a time when the architect / woodworker was intensively involved in the creation of a number of sacred spaces for Catholic denominations, including Christ the King Church in Katsura, Japan and Christ in the Desert in New Mexico. In these commissions, Nakashima explored his deep commitment to create "an ideal space for an ideal community."[13] This experience is fundamental to understanding the Arts Building and Cloister.

The Arts Building is composed of three principle areas: the Cave, Gallery, and Loft. Entrance is through the so-called "Cave," a space for a special exhibit of the work of Nakashima's close friend Ben Shahn. This somber space opens into the luminous Gallery. The Gallery includes a number of sub-areas; the platform, fireplace and niche, as well as the staircase. The Gallery serves as a venue for meeting, performance, and contemplation, as well as a display area for extraordinarily slabs of wood and for Nakashima's own designs. The Loft is located above the cave and is accessed by a dramatic, cantilevered stair, and filled with his early works and prototypes, as well as a compelling collection of folk art and objects from early America, Japan, and India. A sliding door provides access to an outdoor balcony for landscape viewing.

Western Approach

The experience of the collections associated with the Arts Building begins on the exterior of the building. Approaching from the West, the large-scale mosaic mural, "Poet's Beard," was fabricated and installed in 1970 based on a sketch made by Ben Shahn prior to his death. This work is intended to be seen at a distance and was done, as Nakashima expressed in a letter to the mosaic's fabricator Gabriel Loire, "in the way of a memorial to Ben, whom we all loved."[14] Above the mosaic, a lively rhythm of five Shoji screens occupy select window niches, marking both the ties to, and the reinterpretation of, the architecture and craft traditions

13. Nature, Form and Spirit, 218
14. Letter, Nakasima to Gabriel Loire, dated 26 January 1970. George Nakashima Collection, James A. Michener Art Museum Archives.
Gift of Mira and Kevin Nakashima.





Above: “Poet’s Beard” and window niches (January 2017)
Below: Window niches without Shoji screens (March 20160

integrated into Nakashima’s design approach. Juxtaposing these translucent niches are nine transparent niches that invite engagement though the compelling display of objects in silhouette; a first glimpse of Nakashima’s collection of Japanese, Indian, and American folk art. The ambiance of the approach, especially in the afterglow of sunset, is subtle and meaningful. Interior lighting plays a key role in creating this effect.

At some point in the recent past, the Shoji screens were removed from the niches and positioned in the south elevation. A free-standing light fixture designed by Nakashima, called a Kent Hall lamp, key to providing illumination of the niches, was also relocated, likely due to the growth of the collections housed on the loft. These changes have a negative impact and should be reversed. Fortunately, the elements survive intact and are easily restored to their proper position.

Policy 44

The configuration of Shoji screens in the loft window niches and the contrast with the open displays of folk art is very significant and needs to be maintained as a character defining feature.

Policy 45

Reposition the Kent Hall lamp to its original location on the loft. Study and integrate its placement as a fixed element into any larger strategy for improving lighting in the building if this is pursued.

Loggia



Nakashima family portrait (July 1967). Kevin Nakashima stands on “Keyhole” next to his parents Marion and George.

Progression towards the Arts Building interior proceeds through a series of refined landscape features to the loggia (a detailed description and assessment of the landscape can be found in the Cultural Landscape Report). The loggia is austere in its character, contrasting smooth, fair-faced concrete and white painted surfaces with the beauty of the rare-wood entry door. Set in the ground to the right of the door is a sculpture entitled, “Keyhole,” contributed to the site by the artist, Masayuki Nagare in 1965; its rough textured, volcanic stone character resonant with that of the door. This piece was the first art object installed at the site (it appears in photos dating from February 1967) and was originally created for as an element in Nagare’s large installation “Stone Crazy” for the Japan Pavilion at the 1964 New York World’s Fair. Nagare became a close friend of Nakashima’s; introduced him to the Minguren Group in Japan (which he became a member of and christened the building in their honor); guided him in his first travels back to Japan after World War II; and assisted in organizing a series of exhibitions that successfully introduced Nakashima’s work to the Japanese market.

Policy 46

To maintain the display of “Keyhole” as Nakashima and Nagare intended.

15. See Appendix I. Arts Building: C. 1980. A Reconstructed Inventory.
16. Prescott, Kenneth. *The Complete Graphic Works of Ben Shahn*; NY, Quadrangle, 1973, 54
17. Ibid, 70,59, & 58

It should be noted that the piece is set directly on the ground and is subject to movement and disruption simply by touching it. Further, the piece is not secured against theft; improving stability and security are a high priority.

The "Cave"

Entry into the Arts Building is through a low-ceilinged space that Nakashima consistently referred to as the "Cave." A cave has monastic references (as a hermit's retreat for example) that certainly resonated with Nakashima's aspirations for the use of the building as a spiritual retreat. This vestibule-like area was carefully designed, furnished, and hung, to create an ambiance appropriate to the building's purpose; as a place of calm engagement and reflection; as an assembly of Nakashima's most significant specimens of wood; as a collection of folk art objects and artworks that inspired him; and as a reference collection of exceptional and early examples of his furniture design.

The character and integrity of the cave space, in terms of the objects displayed there, has been altered dramatically in ways that significantly deviate from Nakashima's preferences and intent. Changes have occurred through the disassociation of key objects from the building (through commercial sale or by movement to other buildings), the installation of works which that do not conform to his original intent (such as Nakashima's awards and examples of his early, Beaux-arts era student work), and by the adaptation of the space to include archival and collections storage and some open-access shelves (encompassing rare books, woodworking tools, and other personal possessions, such as suitcases). The latter, in particular, diminishes the quality of the visitor experience while raising special concerns for collection safety and security.

Historically, the dominant feature of this area was an installation of at least six framed serigraph prints by Ben Shahn – all housed in custom-made Nakashima frames. Shahn's prints surrounded visitors in this space and most, if not all, were installed in May 1967 and remained in situ (with possible minor shifts) until the late 1990s – almost a decade after Nakashima's death. It is assumed that Shahn and Nakashima collaborated on the placement of these works and that the hang was intended to convey a special meaning or resonance.15

For example, Shahn's *Maximus of Tyre* (1963) is the first work to be viewed upon entry. The piece portrays a figure with a mighty hand and an outstretched arm as "powerful symbols of Divine liberation."[16] Further, the placement of Shahn's *Poet* (1960) – installed in the dominant niche to the left upon entry – captures the intensity, focus and commitment of the artist (in this case one who expresses in words rather than wood). This work is presented-altar like-on a rough plaster background flanked by two, cast-iron candlesticks from Japan; top-lighting adds to the altar-like effect. Of additional significance is the relationship between Shahn's print, *Poet* and his design for the mural, *Poet's Beard* installed on the exterior wall of the Arts Building. Did the placement of one inspire the design of the other? Or vice versa?

Poet is flanked by Shahn's *Ecclesiastes* (1966) and *Gandhi* (1965) in niches to the left and *Branches of Water or Desire* (1965) in a niche the right.[17] The niches were originally papered panels of a Japanese bark paper and two other different

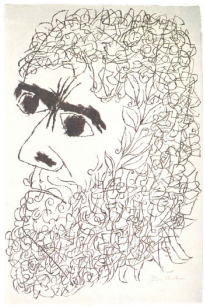








From top to bottom:
"Cave" interior with awards and student work (January 2017)
"Cave." Shahn's "Poet" (left) & "Maximus" (right; ca. 1980)
"R" bench with wood plank lean-to display, 2001
"Cave" interior, w/ non-contributing collections storage (January 2017)



From left to right: Ben Shahn. “Maximus of Tyre,” “Poet,” “I Think Continually…” (shown in situ, May 1967), and “Gandhi.”

patterns (Nakashima’s use of this traditional, folk art, is a display in and of itself). Note should also be made of the horizontal planks that support the framed works which, in their configuration, make reference to elements found in sacred spaces, particularly retables or reredos.

Associations with social justice and civil rights can be seen in Shahn’s *Gandhi* and *I Think Continually of Those Who Were Truly Great* (both 1965). The latter, positioned alone in the soft light of the south facing shoji-screened window, had a poignancy resonant with the work itself – dedicated to 10 martyrs of the civil rights movement killed in Alabama during 1963-65. The Nakashima family’s own experience of injustice and persecution at the hands of the U.S. government in WWII may underlie the special placement of this piece.

The Cave housed three pieces of Nakashima furniture specifically created for the space, including an American Walnut “R” bench and a Chest made from French Walnut (both eight feet in length), with the latter surmounted by a table lamp. The “R” bench is currently housed in the Conoid Studio. The chest was sold to Etsy Stowell in the late 1980s (by Nakashima himself), and while there is a table lamp housed in the Arts Building (on display in the loft area), it does not match—but is close in character to—the one shown in historic photographs.




From left to right:
Internal opening (January 2017)
West to east axis, with large niche at center (January 2017)

The internal opening in the rubble stone wall, elegantly proportioned and detailed (incorporating a pair of volcanic stones given by Nagare in the spring of 1964 as construction began), is a significant element related to Nakashima’s original organization. This element serves to provide visual relief and natural light to the cave space. It also energizes the visitor’s arrival, reinforcing the south to north direction of entry while setting up an important shift in axis, traveling west to east. The placement of collections within this opening, as well as in the space beyond, must be strictly controlled to maintain a high standard of appearance that does not become cluttered or distracting.

Nakashima contrasted strong, geometrical elements—as seen in the coffered ceiling of the cave and the related, vertical piers defining the wall niches—with irregular elements, like the random flagstone floor and rubble wall. The placement of furniture and objects in this space must be carefully controlled, for both visual continuity and artistic integrity. Subtleties of materials and scale must be appreciated and understood, contrasts of light and dark (as well as color) embraced, and the logic of the part (in this case the "cave") to the whole maintained.

Turning eastward, toward the "gallery," visitors were energized by a display of an extraordinary twelve foot tall plank of English walnut silhouetted against a luminous space. Perpendicular to this piece is an improvised, "light sculpture," assembled from one English Oak Burl slab and the "mate" of the English walnut slab. These elements have a powerful presence, spiritual perhaps, that would be intensified in in the late 1970s as Nakashima gathered his most prized slabs together in the Arts Building. Since the mid-1970s, slabs have come and gone from the Arts Building, some selected by Nakashima remain as unique testaments to his artistic spirit and vision.





Above: Silhouetted English walnut plank and "light sculpture), 1967

Below: Existing conditions (January 2017)

Policy 46

Restore the "cave" to its former use as a focused display of Ben Shahn's works with an integrated selection of furniture by Nakashima. Solicit return by donation or purchase of the original 8'-0" French Walnut Cabinet. If this is not possible, consider reconstruction or purchase of a similar cabinet.

Policy 47

To respect the internal opening as a significant element related to Nakashima's original organization and the need to provide visual relief and natural light to the cave room. Care should be taken in the placement of collections in this opening and the space beyond so the view does not become cluttered.

Policy 48

To recognize the coffered ceiling as a character defining feature that must be maintained. Mounting lighting or other interventions that diminish integrity must be avoided.

Policy 49

The closet in the cave is not a significant space, and alteration would be acceptable.

Policy 50

To restore the display of extraordinarily wood slabs within the cave and as part of the transition to the gallery as a highly significant, character defining element.



Gallery with Minguren IV table, Conoid Chairs, “light sculpture”, loft with cantilevered stair and platform (May 2016)

Gallery

The principle space of the Arts Building is the Gallery. It is an “L” shaped room measuring approximately 30 feet by 30 feet. The north and east walls of the space are defined by solid masonry—a structural necessity related to the dynamic, hyperbolic paraboloid roof. The up-swoop of the roof opens dramatically on the south and west facades. Intricately detailed windows combining shoji screens, vertical louvers, and deep niches for object display, animate the space. The cave, surmounted by the loft, is inset in the south west corner of the plan.

The gallery is a flexible space that has been used for the display of works of art on paper (Ben Shahn Print Collection exhibition, May 1967 to ca. fall 1973), for the display of a selection of Nakashima’s most valued slabs of wood (ca. 1974 to c. 2003), and in recent years for a combined display of the remaining wood slabs and a group of monumental, watercolor renderings that Nakashima made in the late 1920s as a student of architecture at the University of Washington, M.I.T. and the American School at Fontainebleau.

Integral with these displays are groupings of furniture that Nakashima designed and made specifically for the Arts Building, as well as individual examples brought to the space on a semi-permanent basis or for short term periods. Nakashima intended the Arts Building to serve, in part, as a showroom for his furniture designs and this remains a significant use of the building. Furniture is moved and reconfigured in support of events held in the Arts Building. Some pieces were designed to uniquely support those events and uses and are of exceptional value. These include the: Tatami Platform, 8’ American walnut “R” bench, large English walnut bench (with extraordinary slab), and Minguren IV dining table.

In documenting the use of the building, it is clear that the works of art, furniture, and extraordinary wood slabs are enriched by the building and vice versa.

The most significant change to the use of the space involves the storage of four very large didactic text panels created for the “Full Circle” exhibition in 1989 and





Right: Tea Ceremony w/ Tatami platform and “R” bench Aug. 1969
Left: “Renata and Hans,” Arts Building reception, May 1973



Indian Classical Music concert with Tatami and bench, May 1977







Left: “Hanami” flower viewing, May 1968
Right, above: Catholic Art Conf., GKN seated at Minguren IV Table, 1969
Below: Nakashima Family, Minguren IV table & lamp, July 1967





Current conditions (January 2017)

stacked along with the wood slabs. While housed in Nakashima frames, these are quite intrusive and serve to confuse visitors who start to read the text. In addition, the East wall (as well as a wall in the Cave and an area above the stair), have been given over to a display of Nakashima's Beaux-arts era student work. Beautiful such as they are, consideration should be given to restoring the display of wood slabs. These have been concentrated in the corner without any space to view or appreciate their wonder.

Policy 51

Maintain the gallery foremost as a space that celebrates the display of important furniture by Nakashima alongside a selection of large, wood slabs that were especially valued by Nakashima. The space should also be available for meetings, performances, and contemplation.

Policy 52

Recognize that the use of Nakashima's furniture in the gallery as significant and that fixed, museum-like display should be avoided.

Policy 53

Recognize that the Tatami Platform, 8' American walnut "R" bench, large English walnut bench (with extraordinary slab), 12' tall English walnut "light sculpture," and Minguren IV dining table are of exceptional value to the use of the space and the appreciation of Nakashima's art and should be maintained as elements integral to the building.

Policy 54

The periodic rearrangement of the gallery is welcomed, as it provides fresh opportunities for the display of the collection and the understanding of the building. However, the constraints imposed by the building should still be respected.

Policy 55

Colonization of the Arts Building gallery as a long-term storage space is inappropriate. The exception is the use of the space for activities related to the fabrication of a Peace Altar.

Platform

Located in the southeast corner of the gallery, the platform measures approximately 40 inches square, raised about 10 inches off the floor to conceal a water pump. The location has long been reserved for the display of metal sculptures by Harry Bertoia. A sounding sculpture acquired by the Nakashima's in 1974 was installed in this location and replaced a more diminutive work by Bertoia, entitled "Dandelion" (acquired before 1964 and now displayed in the internal opening of the cave wall).

The platform is intended to be an austere display, a focal point visible from both the Gallery and from the Cave (as an element in the arrival sequence). The view should be carefully composed and considered. As it is currently installed, the platform presents a jumble of unconnected objects. On the platform, visitors see the Bertoia, but also a black lacquer box and telephone. Ben Shahn's "Gandhi" is hung on the stone wall, but awkwardly blocked from view by the Bertoia. Flanking this haphazard group, is a hanging wall shelf with free edge (marked on the bottom, "Krosnick"), repurposed as a display for a hanging scroll (It has been turned vertical and tucked in between the wall and sliding door frame). This significantly diminishes the quality of the view from the Cave (as does the location of a stack of walnut slabs opposite it).





Platform, existing conditions (January 2017)

Policy 56

Recognize as significant the austerity of the platform and to restore the composition to a more appropriate display.

Fireplace and Niche

Like the platform, the fireplace and related niche were conceived to be carefully composed ensembles. In the fireplace niche, preference was given to folk art and traditional Japanese flower displays or Ikebana. Early views show a grouping comprising one hand carved wooden candle holder (made by Santiago Riva, of Santiago, Spain for St. Martin's Church in New Hope) set on the window ledge, a flower arrangement in a decorated pot on the lower ledge, a cast iron pot hanger (called a jizai-kagi, or adjustable pothook used in many Japanese farmhouses) hung from the beam above, and a pane of antique European stained glass (depicting a beastie) that hung at the top of the operable window in the niche. These elements remained in place until repairs to the beam above required their removal. These were not reinstalled.





Above: Fireplace niche (May 1967
Right: Existing conditions. Minguren I coffee table in foreground (January 2017)

The rubble stone wall area over the mantle was initially used for the display of artwork by Ben Shahn. An original work by the artist, in the form of Japanese calligraphy, hung here from 1967 to about 1977 when it was relocated to the Reception House and installed in a carefully conceived composition near the dining table. The stone mantle initially shows use as a location for the display of a single cast iron pot (possibly used as an ashtray), but later, additional folk art collections began to be assembled there. Recently, Nakashima's grave marker, made by his grandson, Ru Amagasu, was put on display.

This fireplace and niche are visible from the entry through the interior opening. It is important that this space be maintained with an austerity of character.

Policy 57

Restore the display of folk art in the fireplace niche, recognizing it as a significant element. The display should be austere.

Fireplace Seating Group

The grouping of furniture by the fireplace was created in the mid-1970s during the transition from use of the gallery as a display space for works of art on paper (the Ben Shahn Print Collection) to a space dominated by the display of wood planks and Nakashima designed furniture. The key element in this ensemble is the magnificent, oak burl Minguren I coffee table (1968), a masterwork by Nakashima.

Photographs dating from the mid-1970s to mid-1980s confirm that the Minguren I coffee table was displayed with a pair of Lounge Chairs with Arms, one left and one right. These chairs were made specifically for the Arts Building and installed in 1968.[18] A Settee with no arms (made in 1956) completes this grouping (and was likely moved from the Showroom). In addition a lounge chair without arms, made in 1966, is often seen in the vicinity of this group and can be counted as a contributing element.

Currently, this grouping has been altered to include two Conoid Cushion Chairs as well as by the inclusion of a Nakashima designed rug produced by Edward Fields. The Lounge Chair with Arm (left) is now located in the Showroom building. This change has the effect of compromising the visual continuity of the original grouping, which allowed for better viewing of the Minguren I coffee table and, from a seated position on the Settee, the displays of wood slabs beyond. The connection between the raw slabs of wood and the finished coffee table is significant.

Policy 58

Recognize the display of furniture related to the fireplace as a significant element that should be restored. Recognition should be given to the possibility that the Minguren I coffee table may be requested for loans to exhibitions and that this should be allowed.

Sliding Doors to Verandah

The view out the sliding glass doors in the south façade, through the verandah, to the large stone (an inspiration in the siting of the building) is significant. A variety of chairs (including a pair of Conoid Cushon chairs) have been placed flanking the doors, but never blocking the view.

Policy 59

The view from the interior of the gallery to the large stone near the pond is significant and should be maintained.

Staircase

A major element of the interior of the Arts Building is the staircase comprising wood slab treads dramatically cantilevered out of the masonry rubble wall. The element is a tour-de-force of Nakashima's design sensibilities; the interrelationship









From top to bottom:
English oak burl Minguren table with Lounge Chairs with Arms
Conoid Cushion Chairs (left; Jan. 2017)
English oak burl Minguren table with Lounge Chairs with Arms
Conoid Cushion Chairs (left; Jan. 2017)

18. Both are marked on the underside of the seat, "Arts Bldg."









From top to bottom:
View to loft from gallery (ca. 1980)
Furniture and folk art display (1979) – note Kent Hall lamp
Current display of 18 pieces of Nakashima furniture (Dec. 2016)
Furniture and folk art display (December 2016)

of furniture examples on view in the showroom space, particularly Conoid Chairs in teak, Rosewood, and oak, should be maintained.

The display of framed artworks on the masonry wall directly above and below the staircase at different periods has been unsatisfactory. There space is inadequate for viewing from a curatorial as well as a life-safety point of view.

Policy 60

The staircase is of exceptional significance and should be maintained without alteration.

Policy 61

The staircase should not be used as a place for display.

Loft

Where the Cave space is darkened and somber, the Loft is light-filled and exuberant. Nestled under the uplifting roof, the Loft provides display space for furniture, folk art and objects. Direct access to the outdoor balcony is provided through a sliding door; an especially beautiful prospect from which to view the landscape and spring bloom. Views to and from the gallery level are significant as well—the back-lit folk objects are a compelling and carefully conceived focus.

Visitors reach the loft via the cantilevered staircase. The South and West wall of the Loft are exterior to the building (the North and East overlook the Gallery). The west wall comprises a series of 21 window niches, 5 of which house shoji screens placed in a dynamic composition. Tucked within the niches is a lively display of folk art and objects. The southern wall features an exceptional shoji screen, permanently installed. This panel, distinctive for the hexagonal pattern, was made in Takamatsu, Japan by Kiyoshi Konishi – a founding member of the Minguren Group. The floor surface is part concrete (about a third) and part wood (two thirds) and slightly raised. Early, first-of-a-kind, examples of Nakashima's furniture are exhibited here (over 20 pieces).

Nakashima created two significant pieces of furniture for the Loft area, including a built-in Conoid Bench with Double Back and adjacent to it a built-in Side Table. Research has revealed that the original Side Table was replaced, although when and why this occurred has not been documented. The initial furniture display included these pieces, a Desk Lamp, Long Chair (which remains on view), and a Kent Hall Lamp (currently used in the Cave). The Kent Hall Lamp (named after a design he created for Columbia University) provides illumination and scale to the loft area and plays a significant role in providing even uplight for the ceiling and in the backlighting of the folk art displays. The latter being an integral element in the approach to the building at night.

Nakashima actively engaged with the display of the Folk Art and Objects. He clearly enjoyed revising the installation and exploring new combinations and juxtapositions. The bulk of the objects on view were acquired during his trips to Japan and India during the late 1960s, through gifts from close friends (including Ben and Bernarda Shahn, Stanley and Nita Brogren, and Father Peter Sidler to name a few), and from family collections. There are a number of items with

specific connections to his Minguren group colleagues. Period photographs and descriptions reveal his preference for a playful jostling between individual objects over more formal thematic or geographical displays. His installations are dense, but never crowded.

The objects housed and displayed on the loft are particularly vulnerable when the building is opened for events and public uses. The furniture, often first-of-a-kind prototypes, are not as robust as those housed on the gallery level where use is encouraged. In addition, the folk art and objects are displayed on open shelves, raising concern for their safety and security if left unsupervised. Today, the display has become overburdened by objects, many of which were added in the years after Marion Nakashima's death.

Policy 62

Maintain the loft foremost as a space that celebrates the display of early prototypes and designs by Nakashima and as the primary location for the installation of his collection of folk art and objects.

Policy 63

The periodic rearrangement of the loft furniture and folk art displays is welcomed, particularly as a strategy to continue Nakashima's intent and preferences for their exhibition and to reduce the density of the currently display. Constraints imposed by the conservation and security needs of individual objects should be respected, but solutions should not compromise the original design intentions for the building.

Policy 64

Recognize that the built-in Conoid Bench with double back, adjacent built-in Site Table, and Kent Hall Lamp are of exceptional value to the use of the space and should be maintained as Nakashima situated them.





Mock-up of loft furniture and folk art display based on 1979 photography. Note position of Kent Hall lamp.

The Arts Building gallery interiors are also determined by a series of other considerations:

Didactic Texts and Object Labels

Nakashima's initial exhibition of the Ben Shahn Print Collection provided visitors with a printed checklist. Didactic labels appear in photographs during the late 1970s on selected furniture and with some of the folk art exhibits. Object labels are now associated only with the display of folk art. Given the domestic character of the space (and Nakashima's preference that furniture should be experienced), it may be surmised that the use of object labels—particularly for the furniture—proved to be unsatisfactory. Labels for selected examples of the folk art were made by Soomi Amagasu are quite handsome and are printed on fine paper using Nakashima's favorite font. These are supported by a small wooden block made by Nakashima's grandson, Ru Amagasu.





Gallery interior ca. 1982 with object labels on furniture and with selected objects Label made by Soomi Amagasu in 2002

Policy 65

The use of object labels should be carefully studied and strictly controlled to maintain the domestic character of the space and to avoid visual clutter.

Hanging Artworks

Several different solutions for hanging framed works of art were used in the Arts Building that are distinctive and worthy of maintaining. In the cave, Nakashima created custom designed frames for works by Ben Shahn that were self-supported at their bases on furniture or special shelve units (there is insufficient information to determine if these works were "tethered" to the wall for safety; but current examples suggest this as a possibility). This is an unusual system of display that recalls carved altar screens (reredos or retables).





Right: Shahn's "I Think Continuously…" at Mira's (Jan. 2017) and "Cats Cradle" as displayed in Conoid Studio

Nakashima took care to protect the material integrity of wall surfaces, especially in the Gallery. Here, a distinctive band of darkened plaster denoted a zone for hanging. Works hung in this area were center aligned at an approximate center height of 66 inches using a steel cable hanging system. This hardware consisted of a custom-made wooden hanger (made by Nakashima) that "hooked" to the top of the wall. This hook was carefully positioned to maintain the vertical alignment of the cable which was extended down to the desired hanging height and attached to the frame. Currently, an off-the shelf system of stainless steel hooks is used in the Cave area.

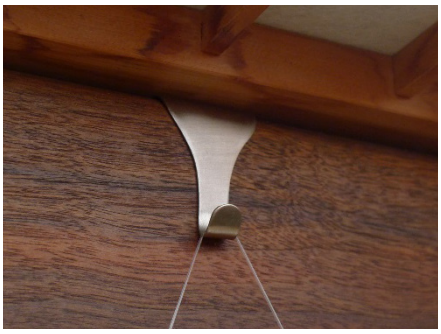
Nakashima also used conventional hanging hardware and even hung art on curtains and shoji screens for the Ben Shahn Print exhibition.

The recent installation of framed works made use of a wire hanging system, but this deviated from Nakashima's preference in the askew angling of the wires. In addition, large screw-type hooks were fastened to concrete and wooden ceiling beams at a number of locations.

Policy 66

Ensure that the installation of collection displays do not leave the fabric of the gallery with a progressively increasing collection of drilled holes and minor alterations that affect its visual appearance and integrity and that new installations conform to Nakashima's preferences, reuse of existing fittings and the overall approach to hanging should be maintained.





Right: Picture rail and cable hanging system, May 1967
Left: System used in Cave, hook of stainless steel (January 2017)



Detail of framed works hung on shoji screens, May 1967



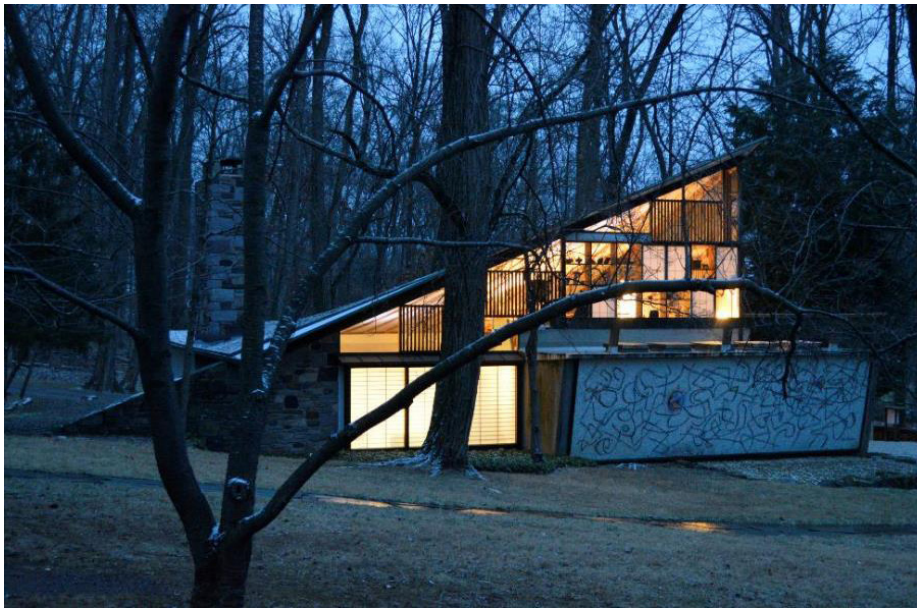




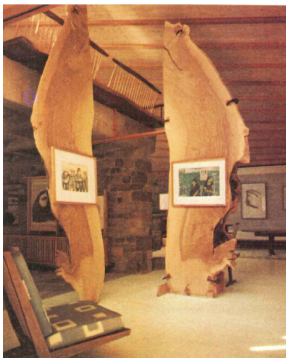
Hook hanging system showing holes drilled into concrete and wood. Screw anchor in masonry wall (January 2017)

Lighting

The lighting installation throughout the building was based on the use of hanging Akari Light Sculptures by Isamu Noguchi and floor and table lamps from Nakashima's existing catalogue of designs. Care was taken in positioning the lighting for both compositional and functional purposes and these relationship should be maintained. Nakashima improvised a "light sculpture" composed of 12 foot tall, book matched English walnut planks to illuminate the ceiling, an effect that conveys a special ambiance to the approach from the west. Path lighting is provided for special events thought the use of paper lanterns.



Dusk with Kent Hall lamp positioned on loft (January 2017)







Nakashima's "light sculpture" seen in 1972 with current side view and mechanics, January 2017

The paper Akari lamp associated with the platform has been replaced at least twice. The current fixture, while conforming in size (22 inch diameter) and character, does not bear the Noguchi stamp of authenticity. The lamp under the stair has also been replaced a number of times. The source and design of the unusual elongated original installation remains unknown. Originally, each was presented tightly to a wooden mount. Now, each shows a significant separation of mount and support; additionally the platform lamp has been lowered 18 inches and now hangs at 62 inches off the floor. The original height to bottom is estimated at 80 inches.

Nakashima outfitted the interior with a selection of his own designs, including a desk lamp in the Cave, a table and floor lamp in the Gallery, and a Kent Hall Lamp on the Loft. All but the Kent Hall lamp were repositioned according to need. At present, the floor lamp is housed at Mira's House—exchanged for a second Kent Hall Lamp. Judicious additions of Nakashima lighting could be explored.

Policy 67

The character and position of the light fixtures is an important design element which should be maintained. A color temperature range of 2700-2800K should reflect the incandescent light that was seen by Nakashima. Warm-white florescent bulbs were used in the Kent Hall lamp.

Policy 68

Any program to improve lighting conditions within the Arts Building must not compromise the original design intentions for the building.

Cloister

The cloister is a modest, utilitarian structure, connected to the Arts Building by a covered walkway and porch. A combined bath and kitchen connect to a living-sleeping room; a design reminiscent in character to Nakashima's Monastery of Christ in the Desert. The interior is simple, but thoughtfully furnished with Nakashima designs. Lighting is by Noguchi along with a desk lamp made in Takamatsu, Japan. Artwork by Nakashima's long-time friend, Dorothy Grotz (whose work can be found throughout the campus), and wall hangings collected in India in 1964, adorn the walls.

Policy 69

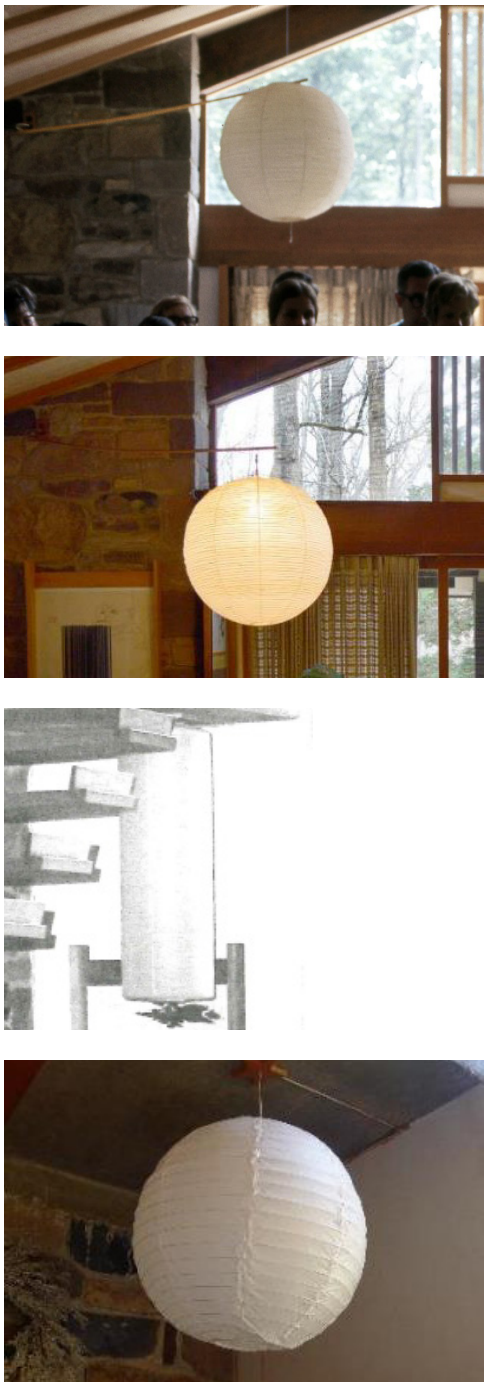
The cloister is an essential component of the Arts Building complex and its use and character should be maintained.

Policy 70

The archive room is not a significant space, and alteration would be acceptable

Policy 71

The combination bathroom and kitchenette is a space of significance and should be respected.



From top to bottom:
Platform lamp, August 1969
Current condition, January 2017. Note sagging in position of light, down over 18 inches.
Detail of lamp under stair, May 1973.
Existing condition, January 2017.

Administrative and Collections Management Policies

Collections are held in trust for the public and are made accessible for the public's benefit. It is crucial to maintain legal, ethical, and professional standards by establishing policies to support and guide the mission, operations, and decision-making of the collection. Institutional policies give the governing authority and staff the means to fulfill its responsibilities as stewards of collections. Following the mission statement, collections management is governed by establishing all of the policies and procedures connected with collection acquisition and management.

Recommendations

1. Expand the mission of the Nakashima Foundation to include the collecting, preserving, and interpreting of artifacts related to the life and work of George Nakashima in general and, specifically, works that contribute to the historical value of the Arts Building and Cloister as an integrated environment. Commitment at the board level is the highest priority and provides the legal framework around which the Foundation's collection can be established.

2. Draft key policies and procedures for the management and development of the Collection. Working with a curatorial or archival consultant, create a working collections development policy dedicated to reinforcing the significance of the Arts Building and Cloister. This is a high priority that needs to be carefully considered. Because of the significance of this policy, it should be a document formally adopted by the Foundation board. Policies related to the appraisal of objects for their historical significance and relevance to the collecting mission, accessioning and de-accessioning policies and procedures, as well as systems to maintain intellectual and physical control of the collection, should be prioritized. Disassociation of objects from the Arts Building is a serious concern that these policies will help address and control. A collections development policy provides the mechanism to consider additions to a collection, who has the authority to accept collections, and if the collection should be accepted or not. Create a template for a "deed of gift" based on best practices.[19]

3. Transfer legal ownership of objects determined to be of exceptional value and significance in maintaining the authenticity of the Arts Building and Cloister to the Foundation as quickly as possible. This is a high priority. It is important to recognize that the above referenced legal framework must be in place; a collections development policy agreed upon; and that decisions about gifting objects to the Collection rest with individuals and may be governed by long-term estate planning. Ensure that there is adequate space in the building to receive new collections.

19. Refer to the Society of American Archivists *A Guide to Deeds of Gift*, at http://www2.archivists.org/publications/brochures/deeds-of-gift

Physical Care of Collections

Preservation and safe access are the primary goals of collections management. Physical care of collections is controlled through a complex interrelationship of allocation and use of space, access, environmental control, furnishings, housing, and risk management. Mission and policies on professional standards guide all facets of collections management.[20]

Recommendations

1. Draft polices related to the handling, storage, housing, and exhibition of collections recognizing that a significant value associated with the Arts Building and Cloister is the continued use of the furniture and collections presented within. Engage an objects conservator to conduct a conservation needs assessment for the furniture, objects, and artworks as a means of guiding the development of policies. Identify individual items where use should be limited or restricted due to condition issues or on the basis of other criteria to be determined.

2. Create a dedicated collections storage and work area in the Cloister, north room. Remove business records, packing materials, and other "non-collection" items currently held in this location. Consult with an architect or engineer about improvements to this space to optimize environmental conditions for collections storage and security. Use this area to store items that contribute to the significance of the Arts Building and for related collections management records.

   This space may also serve as a holding area for objects that the Foundation is considering accessioning but may lie outside the collection development scope of the Arts Building. Nakashima's set of woodworking tools, for example, may be of value for interpretive purposes, but do not fit as elements for regular display in the Arts Building. Such items should be distinguished in their storage and cataloguing from collection materials specific to the Arts Building.

3. Take advantage of the loft, particularly the raised wood-floored zone, to delineate a restricted access, "hands-off" area that includes the adjacent window niches. This division can be reinforced, if necessary, by non-intrusive signage or other barriers. Active use of the furniture can be permitted elsewhere in the Arts Building. In fact, in keeping with Nakashima's preferences, this should even be encouraged. The loft, however, provides a natural division and an added layer of control and security that can be easily exploited to improve the physical safety of selected fragile or rare collection objects. In a very large public event, access to the loft can be closed off altogether. Visitors will appreciate the clarity of knowing that it is ok to touch downstairs, but not upstairs.

20. Refer to these resources for additional information. AAM: Direct Care of Collections Ethics, Guidelines and Recommendations, April 2016 http://aam-us.org/docs/default-source/default-document-library/direct-care-of-collections- ethics-guidelines-and-recommendations-pdf.pdf?sfvrsn=2



PENN PRAXIS/THE ARCHITECTURAL CONSERVATION LABORATORY

GEORGE NAKASHIMA ARTS BUILDING AND CLOISTER CONSERVATION & MANAGEMENT PLAN

APPENDICES

GEORGE NAKASHIMA
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B. Investigating the Preservation Needs of Objects within the George Nakashima Arts Building. Leah Bright, Winterthur/University of Delaware Program in Art Conservation, 2016.

C. Nakashima Art Studio Daylighting Study. Shin-Yi Kwan and Janki A. Vyas, Master of Environmental Building Design (MEBD), School of Design, University of Pennsylvania, 2016.

D. Weather Data for Trenton/Mercer County Airport.

E. Conditions Glossary

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H. Arts Building: C. 1980. A Reconstructed Inventory. William Whitaker. Architectural Archives, University of Pennsylvania.

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Appendix A

Modeling and Analysis of Plywood Plate Structure, Master's Thesis for Advanced Masters in Structural Analysis of Monuments and Historical Constructions (SAHC). Andi Troci, Czech Technical University in Prague, 2016.

ADVANCED MASTERS IN STRUCTURAL ANALYSIS
OF MONUMENTS AND HISTORICAL CONSTRUCTIONS

Master's Thesis

Andi Troci

Modeling and Analysis of Plywood Shell Structures.

This Masters Course has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Czech Republic | 2016

DECLARATION

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Supervisor(s): Petr Kabele and David Biggs

Year: 2016

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

I hereby declare that the MSc Consortium responsible for the Advanced Masters in Structural Analysis of Monuments and Historical Constructions is allowed to store and make available electronically the present MSc Dissertation.

University: Czech Technical University in Prague

Date: July 10, 2016

Signature: _____

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MASTER'S THESIS PROPOSAL

study programme: Civil Engineering
study branch: Advanced Masters in Structural Analysis of Monuments and Historical Constructions
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Student's name and surname: Andi Troci
Department: Department of Mechanics
Thesis supervisor: Petr Kabele and David Biggs
Thesis title: Modeling and analysis of plywood shell structures
Thesis title in English see above

Framework content: The aim of the thesis is the structural studying of the Nakashima's hypper roof shell in New Hope, Pennsylvania. The structure of the thesis is organized as following:

-Theory of shallows shells
- Simplified designing methods
- Analytical solutions and verification of the numerical model
- Sensitive analysis of the structure for different load cases and boundary conditions

Assignment date: 16/04/2016 Submission date: 10/07/2016

If the student fails to submit the Master's thesis on time, they are obliged to justify this fact in advance in writing, if this request (submitted through the Student Registrar) is granted by the Dean, the Dean will assign the student a substitute date for holding the final graduation examination (2 attempts for FGE remain). If this fact is not appropriately excused or if the request is not granted by the Dean, the Dean will assign the student a date for retaking the final graduation examination, FGE can be retaken only once. (Study and Examination Code, Art 22, Par 3, 4.)

The student takes notice of the obligation of working out the Master's thesis on their own, without any outside help, except for consultation. The list of references, other sources and names of consultants must be included in the Master's thesis.

.....
Master's thesis supervisor

.....
Head of department

Date of Master's thesis proposal take over: July 2016

.....
Student

This form must be completed in 3 copies – 1x department, 1x student, 1x Student Registrar (sent by department)

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Finally, to my parents and my sister for their never ending support.

Andi Troci

ABSTRACT

The main objective of the present thesis is to assess the static state and capacity of the roof at Nakashima Arts Building in Pennsylvania, U.S.A. The load carrying structure of the roof is a plywood hyperbolic paraboloid shell.This dissertation is a continuation of previous and ongoing studies of the Nakashima Arts Building, in which geometrical and damage survey was performed.

First, the theory of shallow shells is reviewed. Simplified statics and analytical solutions of hyperbolic paraboloid shells are developed for structural models with the same dimensions as the Nakashima Arts Building roof. The same structures are then analyzed by the finite element method (FEM) with program ADINA. Comparison of the results allows us to discuss the accuracy and limitations of the simplified and analytical solutions, as well as to verify the FE model.

Secondly, numerical analyses by FEM are carried out with the aim to understand the complex behavior of the Nakashima Arts Building roofstructure. Considering different configurations of boundary conditions and load cases allows us to determine and localize the vulnerabilities of the structure. Through these results it will be possible to focus inspection to the areas indicated as vulnerable and to adjust maintenance plans. Moreover, it is suggested to perform a measurements campaign of the roof deflection in winter time, when the snow load is acting, in order to compare deflections with the numerical results. This will allow further validation and refinement of the model.

ABSTRAKT

Hlavním cílem této diplomové práce je posoudit statický stav a únosnost střechy budovy NakashimaArtsBuildingv Pennsylvanii, U.S.A. Nosnou konstrukci střechy tvoří překližková skořepina ve tvaru hyperbolického paraboloidu (HP). Tato disertace navazuje na předchozí a probíhající průzkum budovy Nakashima ArtsBuilding, ze kterého byly získány informace o geometrii konstrukce i jejím stávajícím stavu poškození.

Nejprve je zpracována rešerše teorie mělkých skořepin. Zjednodušené statické řešení a analytické řešení jsou provedeny pro HP skořepiny stejných rozměrů, jako je střecha na NakashimaArtsBuilding. Tyto konstrukce jsou pak analyzovány metodou konečných prvků (MKP) v programu ADINA. Porovnání výsledků nám umožňuje nejen diskutovat přesnost a omezení zjednodušeného a analytického řešení, ale také verifikovat konečněprvkový model.

Následně jsou provedeny analýzy MKP, jejichž cílem je porozumět komplexnímu chování střešní konstrukce NakashimaArtsBuilding. Při uvážení různých okrajových podmínek a zatěžovacích stavů jsou identifikována a lokalizována slabá místa konstrukce. Tyto výsledky mohou posloužit k zacílení inspekčních prací na náchylné části konstrukce a k úpravě plánu údržby. Navíc je navrženo, aby bylo provedeno měření průhybů konstrukce v zimním období, kdy je zatížena sněhem. Porovnání změřených průhybů s výsledky numerických výpočtů umožní další validaci a zpřesnění modelu.

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1. INTRODUCTION

1.1 Shells, Special Structures

The shell structures have always been a clear proof of engineering abilities. Their first expression was through the dome shape. The Pantheon in Rome, built in 125 AD. still impresses for its dimensions and technology. It consists in a semispherical dome with a diameter of 43.3 m over a 6.4 m thick drum wall. It is still nowadays one of the largest dome structure in the world. This is what makes this structures so interesting and fascinating. Their dimensions seems to defy the physics laws and encourage engineers and architects to dare more in the development of their shape. Before the twentieth century, this structures were considered to be weighty and large perimeter walls were needed to support the high horizontal thrusts.



Figure 1.1 – Pantheon, Rome
(www.didatticarte.it)



Figure 1.2 - Zeiss Planetarium, Jena
(www.zendome.de)

The development of the new material reinforced concrete, became and inspiration for this type of structure, since it became possible to have thin shells with large spans. One of the first examples of this thin shells is Zeiss Planetarium in Jena (Germany). What makes this structure particularly relevant is the thickness of just 60 mm for a span of 25 m. Understanding the potential of this type of structure and of the new material the dome shape started to be considered as restrictive and new shell structures with double curvature were constructed. Pier Luigi Nervi, Eduardo Torroja and Felix Candela were pioneers of these new forms, crating structures extremely light and beauty. In the forties the theory of shells was well established and the development of the computers allowed to derive and verify solutions for very slender and shallow shells.

In a continuous process of innovation, in the fifties the timber shell structures started to became popular. Two representative structures are: the Forest Products Pavilion in Oregon and the four hyperbolic paraboloid timber shell roofs of the Former Silhouette Factory. This two examples show that timber was the pioneer of the hyper roofs.



Figure 1.3 – Nervi: Sport building, Rome (www.pinterest.com)



Figure 1.4 - Torroja: Zarzuela's Hippodrome, Madrid (www.archidose.blogspot.com)



Figure 1.5 - Candela: Los Manantiales, Mexico City (www.archdaily.com)



Figure 1.6 - Forest Products Pavillon, Portland (www.bonniehull.net)



Figure 1.7 - Factory for Silhouette Coursette, Market Drayton (www.architecture.com)

The advantages (efficiency on use of the material, elegance, large spans) introduced by this structure, have been hampered by the expansive and elaborate work required to build the formwork of the shell. Moreover, the deep understanding of their structural behavior was limited by the complex mathematical equations involved in the designing and analysis of these complex shapes.

From the first applications, timber showed to be a suitable material for this type of structures, since it is a flexible, workable and a sustainable material. Nowadays, many research projects have been carried out with the aim of understanding and improving the structural behavior of this material. Moreover, in the last 30 years the concept of sustainable buildings has increased its importance becoming nowadays an essential feature of every new building.

The fully understanding of shell structures behavior is not yet reached and history of civil engineering has repeatedly shown that new types of structures have been built before their behavior was fully understood (Bradshaw et al., 2002).

The development of the FEM concept, the free forms of the modern architecture and the concept of sustainable buildings encouraged nowadays the studying of the behavior of the timber shells structures. The increasing of their applications can be possible only through a process of knowledge of their behavior and the development of a clear design process to be followed. This is what motivates the work of this thesis, which is meant to be part of this development process.

1.2 Scope and Objective

The work is developed in such a way that two main objectives represent the thesis' goal. Those two objectives are different but strictly related one with the other. The first consist of an important path of literature survey with the aim of developing a deep knowledge of the theory that governs the shells behavior. Through the study of the theory, an analytical solution is to be performed and to be later compared with the numerical model in the ADINA software.

Furthermore, the design of the shell structures is a complex process since their performance depends on many factors, from the shape to the material and boundaries. Therefore, in the seventies, when shells reached the peak of popularity, simplified designing rules were developed. Subsequently, a process of comparison between this simplified design rules and the FE analysis is carried out with the aim of verifying their accuracy and applicability.

The second objective of the thesis is the structural assessment of the Nakashima Arts Building under different boundary conditions and load cases. The study is focused on the plywood shell roof and is done through the numerical model developed by the ADINA software. The intention of this second objective it to study of the effects of different boundary conditions and load cases. Note that this study is strictly related with the first objective explained above because is carried out only after the process of verification of the FE model.

As mentioned above the structural assessment concerns the Nakashima Arts Building which is characterized by a unique architectural style where the Japanese craft traditions are combined with the modern influences. The Arts Building was built between 1964 and 1967 by George Nakashima in New Hope, Pennsylvania. The architect's ability is reflected in the roof of this building, which is a hyperbolic paraboloid surface made by three layers of plywood. The projected shape of the roof is a 10,67 meters wide square. The hyperbolic paraboloid shape is obtained by lifting one corner of 4.27 meters. The Figure 1.9 shows the principal dimensions of the roof structure, while FIGURE shows the west elevation of the Nakashima Arts Building.



Figure 1.8 - West elevation of Nakashima Arts Building (www.nakashimawoodworker.com)

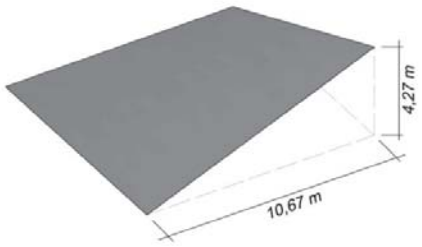

Figure 1.9 - Dimensions of the roof structure

This structure is a living documentation of shells popularity in the United States in the 1950's to 1970's. Its historical importance needs to be preserved and this thesis aims to help in the definition of the restoration and strengthening work to be done.

2. THEORY OF SHALLOW SHELLS – DONNELL THEORY

Shells are structure who's behave depending on the interaction between geometrical and mechanical properties. They are also often described as structure that resist through the shape. The shell geometry has the major influence on how the shell behave, if only in-plane behavior or also out-of plane behavior (Peerdeman, 2008).

As discussed in the Introduction, plywood hyppar roofs can be analyzed by means of the elastic theory of thin shells. In this study, we use the Donnell theory, which takes into account both membrane and bending effects. Basic components of the theory are reviewed hereafter. The review is based on a book by Johan Blaauwendraad and Joroen H. Hoefakker (Blaauwendraad and Hoefakker, 2014)

The well known theory of thin shells in this case needs to be extended in order to take into account both the membrane and bending behavior of shells type as the roof of Nakashima Arts Building. The theory which considers the both behaviors has been developed by Donnell (Donnell, 1933) and is applicable to shallow shells like roofs shells.

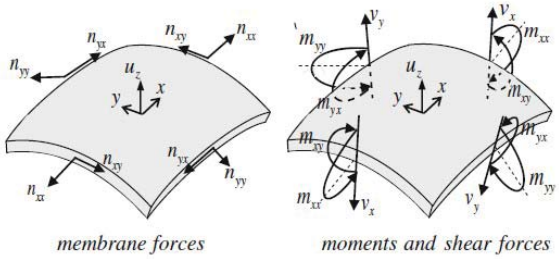

Figure 2.1 – Forces and moments on a shell element of arbitrary curvature **(Blaauwendraad and Hoefakker, 2014)**

In this theory a coupling occurs between the membrane action and the bending action and the aim is to obtain a differential equation which takes into account the coupled states. The difference between the global axis X,Y,Z to describe the geometry of shell and the local axis x,y,z in the shell surface with z normal to the surface is neglected, and this I permitted if the slope of the roof is sufficiently small. Moreover the deformation due to transversal shear is neglected. The Figure 2.1 shows the notation and sign convention for forces and moments.

In the following the relations between displacements, deformations, shell forces and external loads (Figure 2.2) are treated.

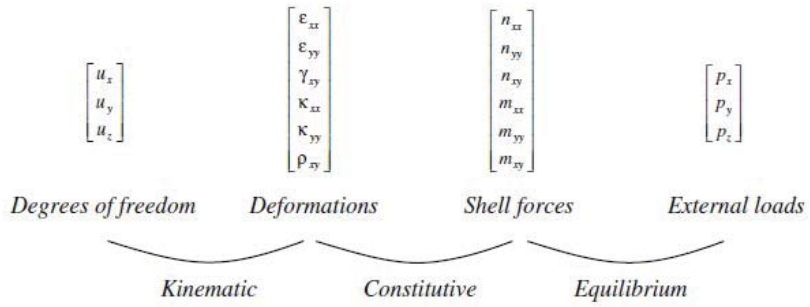

Figure 2.2 - Scheme of relationships for a shell (Blaauwendraad and Hoefakker, 2014)

2.1 Analytical Description of the Shell Surface

The shell's geometry is defined by the shape of the middle surface and the distribution of the thickness along the shell. Their shapes can be distinguished in two main groups: developed and undeveloped surfaces. A developed surface can be deformed into a plane shape without adopting any cut, instead for an undeveloped surface the transformation into a plane shape is possible only by cutting or stretching its middle surface. The geometry of the shell is obtained in three different ways and the way defines the type of the surface.

- Surfaces of Revolution: this surfaces are obtained by the revolution of a plane surface about an axis. An example of surface of revolution is the dome.
- Surfaces of translation: this surface is obtained by sliding a plane curve along another plane curve. The generator is the curve on which is applied the sliding process. The cylindrical surface or the hyperbolic paraboloid surface are obtained through this process.
- Ruled surfaces: this surfaces are obtained by the movement of a straight line through space. Examples of ruled surfaces are the conoid or the hyperbolic parabolid.



Figure 2.3 – Surface of Revolution: Dome (Blaauwendraad and Hoefakker, 2014)

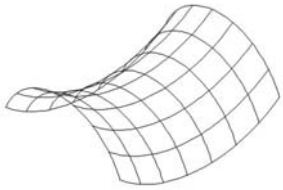

Figure 2.4 - Surface of translation: Hyperbolic paraboloid

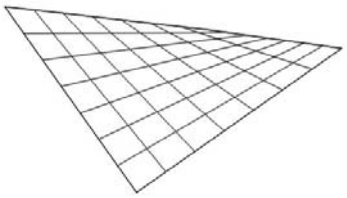

Figure 2.5 Ruled surface: Hyperbolic paraboloid

This thesis is focused more on the hyperbolic paraboloid shapes obtained as ruled surfaces. The equation that describes this surface is the following:

$$z = \frac{x\,y}{L1\,L2} h = \frac{x\,y}{a} \qquad (1)$$

The intersections of this surface with vertical planes x=const or y=const are straight lines, meaning that the curvature along x and curvature along y are zero. The quantity 1/a represent the twist of the surface $\frac{\partial^2 z}{\partial x \partial y}$ and for this type of surface the twist is constant .

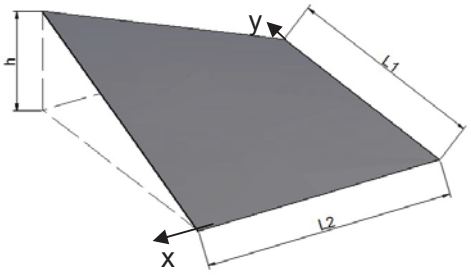

Figure 2.6 – Hyperbolic paraboloid

$$\frac{1}{a} = \frac{\partial^2 z}{\partial x \partial y} = \frac{h}{L1\,L2} \qquad (2)$$

2.2 Kinematic Relations

The kinematic relations between the membrane strains and the tangential displacements u_x and u_y (3) are the same as the description for a plate loaded in its plane.

$$\varepsilon_{xx} = \frac{\partial U_x}{\partial x}; \qquad \varepsilon_{yy} = \frac{\partial U_y}{\partial y}; \qquad \gamma_{xy} = \frac{\partial U_x}{\partial y} + \frac{\partial U_y}{\partial x} \tag{3}$$

In case of curved shell and twisted shells the effects of the normal displacements have to be taken into account.

Considering an infinitesimal shell element in the plane x-z as shown in the Figure 2.7 the inclination is defined as $\varphi_x = -\partial z/\partial x$ and the incremental change of the inclination over the distance dx will be:

$$d\varphi_x = -\frac{\partial^2 z}{\partial x^2} dx \tag{4}$$

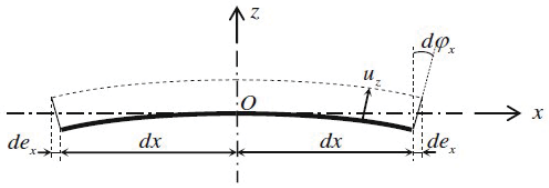

Figure 2.7 - Effect of displacement u_z in curved shell surface

(Blaauwendraad and Hoefakker, 2014)

The change of length due to normal displacement is $de_x = u_x d\varphi_x$ and the strain is defined as $\varepsilon_{xx} = \frac{de_x}{dx}$. From these two expressions and the eq. (4) the strain in the middle surface will be:

$$\varepsilon_{xx} = -k_x u_z \tag{5}$$

where k_x is the curvature and its expression is:

$$k_x = \frac{\partial^2 z}{\partial x^2} \tag{6}$$

The same considerations done in the plane Y-Z lead to the strain ε_{yy} in the middle surface (7).

$$\varepsilon_{yy} = -k_y u_z; \qquad k_y = \frac{\partial^2 z}{\partial y^2} \tag{7}$$

The effect of the normal displacement in terms of shear strain γ_{xy} has to be evaluated in the infinitesimal twisted shell part as shown in the Figure 2.8. The inclinations have the same expression

as previously defined $\varphi_x = -\partial z/\partial x$ *and* $\varphi_y = -\partial z/\partial y$. The incremental changes $d\varphi_x$ in y-direction and $d\varphi_y$ in x-direction are:

$$d\varphi_x = -\frac{\partial^2 z}{\partial y \partial x}\, dy; \qquad d\varphi_y = -\frac{\partial^2 z}{\partial x \partial y}\, dx \tag{8}$$

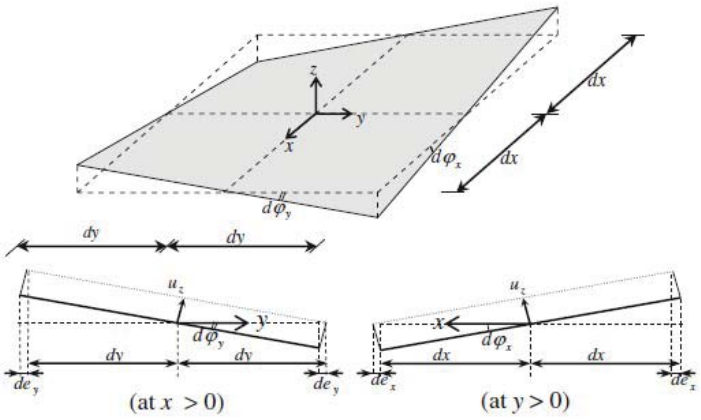

Figure 2.8 - Effect of normal displacement uz in twisted shell surface

(Blaauwendraad and Hoefakker, 2014)

For a continuous surface the two mixed derivatives (8) are equal to each other and the changes of length due to u_z are:

$$de_x = d\varphi_x u_z \qquad de_y = d\varphi_y u_z \tag{9}$$

the related strains $\mathcal{E}_{xy}$ and $\mathcal{E}_{yx}$ are:

$$\varepsilon_{xy} = \frac{de_x}{dy} \qquad \varepsilon_{xy} = \frac{de_y}{dx} \tag{10}$$

As the shear strain is defined $\gamma_{xy} = \mathcal{E}_{xy} + \mathcal{E}_{yx}$ and considering a continuous surface where the two mixed derivatives of the incremental changes of the rotations are equal we obtain:

$$\gamma_{xy} = -2k_{xy}u_z \tag{11}$$

where k_{xy} is defined as the mixed second curvature of the middle surface

$$k_{xy} = \frac{\partial^2 z}{\partial y \partial x} \tag{12}$$

The equations defined above are associated to the membrane behavior. Concerning the bending behavior the rotations of a flat plate applied to a thin shell of arbitrary curvature with infinitesimal length of arc *dx* and *dy* are:

$$\varphi_x = -\frac{\partial u_z}{\partial x}; \quad \varphi_x = -\frac{\partial u_z}{\partial x} \tag{13}$$

and the bending deformations are represented by the following relations:

$$K_{xx} = \frac{\partial \varphi_x}{\partial x} = \frac{\partial^2 u_z}{\partial x^2}$$

$$K_{yy} = \frac{\partial \varphi_y}{\partial y} = \frac{\partial^2 u_z}{\partial y^2} \tag{14}$$

$$\rho_{xy} = \frac{\partial \varphi_x}{\partial y} + \frac{\partial \varphi_y}{\partial x} = -2\frac{\partial^2 u_z}{\partial x \partial y}$$

Through these relations describing the effect of the normal displacement and rotations it is possible to write the kinematic relations:

$$\begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \gamma_{xy} \\ \kappa_{xx} \\ \kappa_{yy} \\ \rho_{xy} \end{bmatrix} = \begin{bmatrix} \frac{\partial}{\partial x} & 0 & -k_x \\ 0 & \frac{\partial}{\partial y} & -k_y \\ \frac{\partial}{\partial y} & \frac{\partial}{\partial x} & -2k_{xy} \\ 0 & 0 & -\frac{\partial^2}{\partial x^2} \\ 0 & 0 & -\frac{\partial^2}{\partial y^2} \\ 0 & 0 & -2\frac{\partial^2}{\partial x \partial y} \end{bmatrix} \begin{bmatrix} u_x \\ u_y \\ u_z \end{bmatrix}. \tag{15}$$

2.3 Constitutive Relations

The link between stresses and strains is described by the constitutive relations which depend on the material properties (e.g. elastic or plastic). Material properties can also vary in the stress-strain path in a linear or non linear way. Moreover, it can show different behavior in different directions (e.g. wood - anisotropic material, metal – isotropic material). All those properties depend on the type of material and its micro-structure. In structural analysis the real properties of the material are described by the constitutive model and it has to be carefully defined in order to describe in the best way possible the real behavior of the structure.

The following constitutive relations describe a linear elastic and isotropic behavior of the material. For this type of material the stress-strain relation is unique and independent of stress and strain history and it obeys the Hooke's law.

$$\begin{bmatrix} n_{xx} \\ n_{yy} \\ n_{xy} \\ m_{xx} \\ m_{yy} \\ m_{xy} \end{bmatrix} = \begin{bmatrix} D_m & vD_m & 0 & 0 & 0 & 0 \\ vD_m & D_m & 0 & 0 & 0 & 0 \\ 0 & 0 & D_m\left(\frac{1-v}{2}\right) & 0 & 0 & 0 \\ 0 & 0 & 0 & D_b & vD_b & 0 \\ 0 & 0 & 0 & vD_b & D_b & 0 \\ 0 & 0 & 0 & 0 & 0 & D_b\left(\frac{1-v}{2}\right) \end{bmatrix} \begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \gamma_{xy} \\ \kappa_{xx} \\ \kappa_{yy} \\ \rho_{xy} \end{bmatrix} \quad (16)$$

where:

- D_m: membrane rigidity ($D_m = \frac{Et}{(1-v^2)}$)
- D_b: flexural rigidity ($D_b = \frac{Et^3}{12(1-v^2)}$)
- E : Young's modulus
- v : Poisson's ratio
- t : shell thickness
- n: force per unit length ($n = \frac{\sigma}{t}$)

2.4 Equilibrium Equations

These equations are obtained by considering the equilibrium of the incremental forces along x, y and z direction (Figure 2.1). The two equilibrium equations along x and y direction are the same as for a flat plate loaded in-plane:

$$\frac{\partial n_{xx}}{\partial x} + \frac{\partial n_{yx}}{\partial y} + p_x = 0$$
$$\frac{\partial n_{xy}}{\partial x} + \frac{\partial n_{yy}}{\partial y} + p_y = 0 \quad (17)$$

Concerning the out-of-plane equilibrium there are three factors that influence in its definition regarding shells of arbitrary curvature. The first influence is the effect of curvature and due to this the normal stresses n_{xx} and n_{yy} will have vertical components depending on the ratio of curvature. Considering a shell strip of unit width and length dx (Figure 2.9) the vertical component of the n_{xx} is $n_{xx}d\varphi_x$. This lead to the following equilibrium equation:

$$p_z dx - n_{xx} d\varphi_x = 0 \quad (18)$$

Dividing the equation (17) by *dx* and considering the relations (4) and (6) the equilibrium equation become:

$$k_x n_{xx} + p_z = 0 \quad (19)$$

$$k_y n_{yy} + p_z = 0 \quad (20)$$

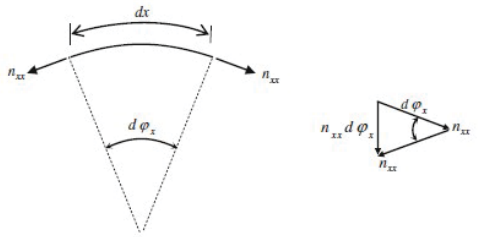

Figure 2.9 - Vertical component of the membrane force n_{xx}
(Blaauwendraad and Hoefakker, 2014)

The equation (20) is obtained in the same way considering a shell strip of unit width and length *dy.*

The effect of twist is related with the membrane shear forces. The shear membrane force n_{xy} acts over the *dy* edge in the y-direction and its vertical component is due to the inclination along the y direction $n_{xy}d\varphi_y$ (Figure 2.10). The same consideration leads to the vertical component of n_{yx} as $n_{yx}d\varphi_x$.

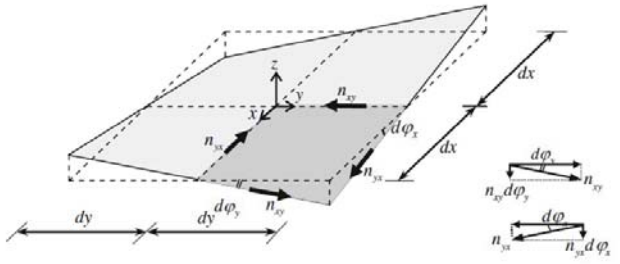

Figure 2.10 - Contribution of shear membrane forces in the equilibrium along z
(Blaauwendraad and Hoefakker, 2014)

The equilibrium equation along the z-direction is:

$$p_z dxdy - \left(n_{xy} d\varphi_y\right)dy - \left(n_{yx} d\varphi_x\right)dx = 0 \quad (21)$$

Substituting the equations (8) and (12) in the equation (21) and dividing by *dxdy* the equation becomes:

$$2k_{xy} n_{xy} + p_z = 0 \quad (22)$$

The last fact that influences the equilibrium along the z-direction is the bending behavior as it generates the transverse shear force. Considering the system of stresses and bending moments intensities per unit length in x and y, defined in the Figure 2.11, the equilibrium of moments in the x-direction is given by the integral (23).

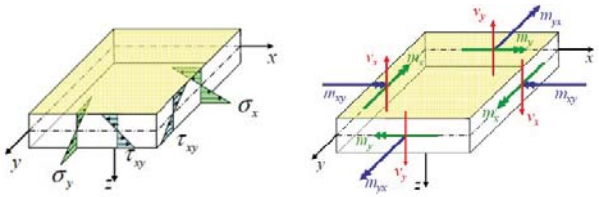

Figure 2.11 - Reference system of stresses and bending moments intensities per unit length (Petr Kabele, SAHC lectures, 2016)

$$\int_{-\frac{h}{2}}^{\frac{h}{2}} \left(\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z}\right) z dz = 0 \tag{23}$$

Considering that the integrals of $\sigma_x z$ and $\tau_{xy} z$ over the thickness dz represent respectively m_{xx} and m_{xy}, the equation (23) becomes the equation (24) and the equation (25) is obtained through the same considerations.

$$\frac{\partial m_{xx}}{\partial x} + \frac{\partial m_{xy}}{\partial y} = -\int_{-\frac{h}{2}}^{\frac{h}{2}} \frac{\partial \tau_{xz}}{\partial z} z dz = v_y \tag{24}$$

$$\frac{\partial m_{yy}}{\partial y} + \frac{\partial m_{xy}}{\partial x} = -\int_{-\frac{h}{2}}^{\frac{h}{2}} \frac{\partial \tau_{yz}}{\partial z} z dz = v_y \tag{25}$$

The vertical equilibrium of the system defined in the (figure XX) is between the incremental transversal shear forces and the vertical load p_z (26).

$$\frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + p_z = 0 \tag{26}$$

Substituting the equations (24) and (25) in the equation (26) the vertical equilibrium becomes:

$$\frac{\partial^2 m_{xx}}{\partial x^2} + \frac{\partial^2 m_{yy}}{\partial y^2} + 2\frac{\partial^2 m_{xy}}{\partial x \partial y} p_z = 0 \tag{27}$$

By considering the three effects of curvature, twist and bending defined by the equations (19), (20), (22) and (26) the final equilibrium relations are the follows:

$$\begin{bmatrix} -\frac{\partial}{\partial x} & 0 & -\frac{\partial}{\partial y} & 0 & 0 & 0 \\ 0 & -\frac{\partial}{\partial y} & -\frac{\partial}{\partial x} & 0 & 0 & 0 \\ -k_x & -k_y & -2k_{xy} & -\frac{\partial^2}{\partial x^2} & -\frac{\partial^2}{\partial y^2} & -2\frac{\partial^2}{\partial x \partial y} \end{bmatrix} \begin{bmatrix} n_{xx} \\ n_{yy} \\ n_{xy} \\ m_{xx} \\ m_{yy} \\ m_{xy} \end{bmatrix} = \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix} \tag{28}$$

2.5 Differential Equation

The differential equation is determined in the following only in regarding to the vertical displacement u_z. As mentioned previously the behavior of shallow shells is coupled between in-plane and out of plane, but the coupled solution is obtained by solving separately the membrane and bending state and coupling them through the differential and Laplacian operators.

2.5.1 In-Plane State

The force method is used to obtain the membrane solution. First, the equilibrium equations are solved by introducing the Airy function Φ. A direct solution of the equilibrium equations may be tried, but in most cases is advantageous to introduce an auxiliary variable, which reduces the system to one second-order equation. The method of the stress Airy function has proved to be a powerful tool for the treatment of this problem and is applied in this case as well (Flügge, 2013). Subsequently the solution of the equilibrium equations the kinematic equations are used. From this last step a compatibility equation between strains and curvatures is obtained and that means that those variables can not change in a free way but they have to satisfy that equation.

By the introduction of the Airy function the membrane forces are the following:

$$n_{xx} = \frac{\partial^2 \Phi}{\partial y^2} - \int p_x dx$$

$$n_{yy} = \frac{\partial^2 \Phi}{\partial x^2} - \int p_y dy \qquad (29)$$

$$n_{xy} = -\frac{\partial^2 \Phi}{\partial y \partial x}$$

Through the membrane forces defined in the equations (29), the third equilibrium equation yields a differential equation for Φ. Considering the geometry of hyperbolic paraboliod shell (Figure 2.12 as the Nakashima Arts Building) and the in-plane loads as zero (px=0 and py=0) the general solution of this differential equation is:

$$\Phi = \frac{1}{2} a p_z xy + f_1(x) + f_2(y) \qquad (30)$$

The solutions of the membrane forces are:

$$n_{xx} = \frac{\partial^2 \Phi}{\partial y^2} = \sqrt{\frac{a^2+y^2}{a^2+x^2}} \frac{d^2 f_2}{dy^2}; \quad n_{yy} = \frac{\partial^2 \Phi}{\partial x^2} = \sqrt{\frac{a^2+x^2}{a^2+y^2}} \frac{d^2 f_1}{dx^2}; \quad n_{xy} = -\frac{\partial^2 \Phi}{\partial y \partial x} = -\frac{a p_z}{2} \qquad (31)$$

In this case the equilibrium solution is very simple as the shear stress is constant along all the shell and the normal forces are constant the straight lines that generates the shell surface (x=const or y=const.).
From this follows that the values of the normal forces can be arbitrary prescribed by the way how the edge beams are designed. In case of edge beams with a axial stiffness (*EA*) much higher than the flexural (*EI*) and torsional stiffness the normal forces n_{xx} and n_{yy} in the shell will be approximately zero or much lower than the shear stress as the edge beams are not able to support flexural or torsional forces.

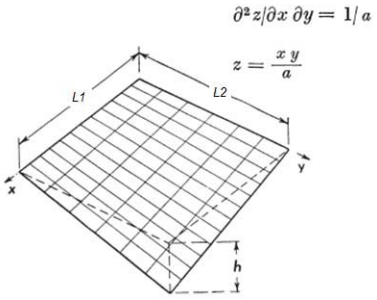

Figure 2.12 - Hyperbolic paraboloid surface
(Flügge, 2013)

By differentiating twice the kinematic equations, regarding the strains $\mathcal{E}_{xx}$, $\mathcal{E}_{yy}$ and γ_{xy} (15), and making the sum, the compatibility equation is reached (32).

$$\frac{\partial^2 \mathcal{E}_{xx}}{\partial y^2} - \frac{\partial^2 \gamma_{xy}}{\partial x \partial y} + \frac{\partial^2 \mathcal{E}_{yy}}{\partial x^2} = k_y K_{xx} - k_{xy} K_{xy} + k_x K_{yy} \tag{32}$$

The constitutive equations the equilibrium solution and the compatibility equations lead to the fourth-order in-plane differential equation (33).

$$\frac{\partial^4 \Phi}{\partial x^4} + 2\frac{\partial^4 \Phi}{\partial x^2 \partial y^2} + \frac{\partial^4 \Phi}{\partial y^4} + D_m(1-\nu^2)\left(k_x \frac{\partial^2 u_z}{\partial y^2} - 2k_{xy}\frac{\partial^2 u_z}{\partial x \partial y} + k_y \frac{\partial^2 u_z}{\partial x^2}\right) = p_z \tag{33}$$

2.5.2 Out-of-Plane State

The out-of-plane behavior is determined by applying the stiffness method. In this method the derivation starts through the kinematic equations and the last step is the introduction of these equations in the third equation of equilibrium, obtaining so the final differential equation. The bending solution represents the homogeneous solution while the inhomogeneous solution, or the response to the vertical load is represented from the membrane solution which is solved through the force method. For this reason the differential equation of the out-of-plane behavior is determined by excluding the contribution of the load p_z.

Substituting the last three kinematic (15) and constitutive (16) equations in the third equilibrium equation (28), which involves the bending stresses, the fourth-order differential equation is obtained.

$$-k_x \frac{\partial^2 \Phi}{\partial y^2} + 2k_{xy}\frac{\partial^2 \Phi}{\partial x \partial y} - k_y \frac{\partial^4 \Phi}{\partial y^4} + D_b\left(\frac{\partial^4 u_z}{\partial x^4} + 2\frac{\partial^4 u_z}{\partial x^2 \partial y^2} + \frac{\partial^4 u_z}{\partial y^4}\right) = 0 \tag{34}$$

2.5.3 Coupled States

The two differential equations (33) and (34) determined in the chapters above are coupled for the two unknowns Φ and u_z. Coupling the states means to replace those two differential equations by a single one for the unknown u_z. This is done by introducing two operators, Γ differential operator and the Laplacian operator Δ.

$$\Gamma = k_x \frac{\partial^2}{\partial y^2} - 2k_{xy} \frac{\partial^2}{\partial x \partial y} + k_y \frac{\partial^2}{\partial x^2}$$

$$\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \tag{35}$$

Through this two operators the equations (33) and (34) become:

$$\Delta\Delta\Phi + D_m(1-v^2)\Gamma u_z = p_z \tag{36}$$

$$-\Gamma\Phi + D_b\Delta\Delta u_z = 0 \tag{37}$$

Considering shells of constant curvatures k_x, k_y and k_{xy} is possible to write that $\Delta\Gamma=\Gamma\Delta$. The final eight order differential equation is obtained by applying once the operator Γ to the equation (36) , and twice the operator Δ to the equation (37) and subsequently by eliminating the Airy stress function.

$$D_b\Delta\Delta\Delta\Delta u_z + D_m(1-v^2)\Gamma^2 u_z = \Delta\Delta p_z \tag{38}$$

The solution of the eight-order differential equation has to be found through 16 boundary conditions, four at every edge. At every edge two boundary condition concern the membrane state and other two the bending behavior. The membrane boundary conditions are regarding the in-plane displacements or membrane forces n_{xx}, n_{xy}. The boundaries concerning the out-of-plane behavior affects the as called edge disturbance of the shell. Depending on the bending boundaries the edge disturbance or the intensity and distribution of the moments will be higher or lower. The figures below show different bending boundary conditions. The second boundary of the free edge is obtained through the *Kirchhoff theory for thin plates*.

$\frac{\partial u_t}{\partial n} = 0 \quad u_t = 0$

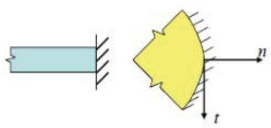

Figure 2.13 - Clamped Edge

$m_n = 0 \quad u_t = 0$

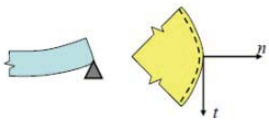

Figure 2.14 - Hinged Edge

$m_n = 0 \quad \frac{\partial m_{nt}}{\partial t} + v_n = 0$

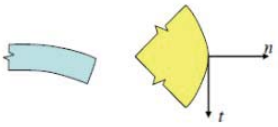

Figure 2.15 - Free Edge

(Petr Kabele, SAHC lectures, 2016)

All these considerations on the theory of shallow shells are applied in the Analytical Solution of the Nakashima Arts Building where the geometry and boundary conditions are taken into account properly, in order to describe in the best way possible the real structural configuration.

3. ANALYTICAL SOLUTION OF HYPERBOLIC PARABOLOID SHELLS

Solving directly the eight order partial differential equation (39) coming out from considering the coupled states, in plane and out of plane behavior, for one displacement can result extremely complicated and time consuming. The problem is solved by considering separately the membrane solution and the out of plane solution or bending solution. As mentioned in the Chapter 2 (Theory of Shallow Shells – Donnell Theory) the membrane solution is obtained from the force method, instead the out of plane solution is obtained from the stiffness method.

$$D_b \cdot \Delta\Delta\Delta\Delta u_z + D_m \cdot \Gamma^2 = \Delta\Delta P_z \tag{39}$$

3.1 Membrane Solution for Uniform Load

The membrane solution starts from solving the equilibrium equations by the introduction of the Airy stress function Φ (3).

$$n_{xx} = \frac{\partial^2 \Phi}{\partial y^2} - \int p_x dx \; ; \; n_{xx} = \frac{\partial^2 \Phi}{\partial y^2} - \int p_x dx; \; n_{xy} = -\frac{\partial^2 \Phi}{\partial y \partial x} \tag{40}$$

As explained in the Chapter 2 (Theory of Shallow Shells – Donnell Theory) above the third equilibrium equation and the airy function yield to a differential equation which, in case of Px and Py equal to zero and for a hyperbolic paraboloid shell surface has as a general solution the equation (41) from which is possible to obtained the equations for n_{xx}, n_{yy} and the shear n_{xy} (42).

$$\Phi = \frac{1}{2} a p_z xy + f_1(x) + f_2(y) \tag{41}$$

$$n_{xx} = \sqrt{\frac{a^2+y^2}{a^2+x^2}} \frac{d^2 f_2}{dy^2} \; ; \; n_{yy} = \sqrt{\frac{a^2+x^2}{a^2+y^2}} \frac{d^2 f_1}{dx^2} \; ; \; n_{xy} = -\frac{1}{2} a p_z \tag{42}$$

The solution shows that the shear stress is constant throughout the shell and the normal stresses are each constant along those straight lines that generates the shell surface (x=const. or y=const) and may vary only from one such straight line to the other. Assuming that the edge boundaries of the structure are not able to support normal stresses n_{xx} and n_{yy} coming from the shell, which means that they have zero flexural and torsion rigidity, the final solution represented by the following equations (43).

$$n_{xx} = 0 \; ; \; n_{xx} = 0; \; n_{xy} = -\frac{1}{2} \, a p_z \tag{43}$$

Combining the solution with the constitutive equations is possible to determine the normal and shear strains (44). The normal strains are zero and the shear strain is constant.

$$\begin{gathered}\mathcal{E}_{xx} + v\mathcal{E}_{yy} = 0 \\ \mathcal{E}_{yy} + v\mathcal{E}_{xx} = 0 \\ \gamma_{xy} = \frac{2n_{xy}}{2D_m(1-v)} = -\frac{1}{D_m(1-v)} a p_z\end{gathered} \tag{44}$$

The displacements are obtained through the kinematic equations using the strains obtained from the constitutive equations (44). The displacement expression are the following:

$$\begin{gathered}\frac{\partial \mathrm{u_x}}{\partial x} = 0 \\ \frac{\partial \mathrm{u_y}}{\partial y} = 0 \\ \gamma_{xy} = \frac{\partial \mathrm{u_x}}{\partial y} + \frac{\partial \mathrm{u_y}}{\partial x} - 2k_{xy}u_z = -\frac{2}{a}u_z\end{gathered} \tag{45}$$

From the first two equations is possible to deduce that the tangential displacements are constant and for hyper structures supported at angular points these displacements must be zero. The vertical displacement is obtained by combining together the third equations of (44) and (45).

$$\begin{gathered}\mathrm{u_x} = 0 \\ u_y = 0 \\ u_z = \frac{1}{2D_m(1-v)}\, a^2 p_z\end{gathered} \tag{46}$$

The membrane solution obtained is considered to be the inhomogeneous solution of the eight order partial differential equation (39). Summing up the membrane solution includes three important assumptions that make the response of the shallow shell rather simple. The first simplification considers the own self weight of the structure acting as normal to the surface. This assumption can be taken only when the elevation is small compared with the span. The second assumption is related to the first and the in-plane load is considered to be zero and the normal load is uniformly distributed over the shell surface. The third assumption involves the edges and they are considered to be infinitely stiff in the axial direction and zero flexural and torsion rigidities.

3.2 Bending Solution

The out of plane solution is considered as the homogeneous solution of the differential equation (39) and represents the edge disturbance needed to compensate the shortcomings (in terms of stresses) of the membrane response at the boundaries. The exact solution of the homogeneous differential equation is difficult to obtain and not suitable for application in structural design. In this case an approximate solution has been considered according to (Blaauwendraad and Hoefakker, 2014).
The approximation is due to two considerations. The edge load or edge displacement, which is necessary to compensate the shortcomings of the membrane solution, is described by a smooth function in the direction of the straight edge. The second assumption is that for such an edge load the stress resultant and the displacement vary rapidly in the direction normal to the straight edge. Because of the two assumption mentioned above, for an edge normal to X-direction with length Ly, the derivatives respect to Y are negligibly small compared to those with respect to X and only the highest derivative with respect X has to be retained and the differential equation (3 becomes the equation (47). This assumptions involve only the bending behavior and in the differential equation (39) they can be made only in the part that describes the bending action which is Δ, instead the operator Γ describes the membrane action so this last term should not be neglected or adapted.

$$D_b \frac{\partial^8 u_z}{\partial x^8} + \frac{4D_m(1-v^2)}{a^2} \frac{\partial^4 u_z}{\partial x^2 \partial y^2} = 0 \tag{47}$$

The reduced differential equation is obtained by integrating twice with respect X and dividing by D_b:

$$\frac{\partial^6 u_z}{\partial x^6} + \frac{4D_m(1-v^2)}{D_b a^2} \frac{\partial^2 u_z}{\partial y^2} = 0 \tag{48}$$

By introducing the parameters λ and α_n the reduced equation becomes:

$$\lambda^4 = \frac{4D_m(1-v^2)}{D_b a^2} = \frac{48(1-v^2)}{(at)^2};\ \alpha_n = \frac{n\pi}{L} \tag{49}$$

$$\frac{\partial^6 u_z}{\partial x^6} + \lambda^4 \frac{\partial^2 u_z}{\partial y^2} = 0 \tag{50}$$

The trial solution for an edge with X- constant is represent by the equation (51) where α=π/L, r are the roots to be determined and A is a constant which depends on the boundary conditions.

$$u_z(x;y) = Ae^{rx}\cos(\alpha y) \tag{51}$$

The equation (52) is the result of substituting the trial solution in the reduced differential equation and is characterized by six roots (54). The additional parameter β (53) is introduced.

$$r^6 - \lambda^4 \alpha^2 = 0 \tag{52}$$

$$\beta = \sqrt[6]{r} = \sqrt[r]{\lambda^4 \alpha^2} = \frac{\sqrt[6]{48\pi^2(1-v^2)}}{\sqrt[3]{(a+l)}} \tag{53}$$

$$r_{1,4} = \pm\beta;\ r_{2,5} = \pm\frac{1}{2}\beta(1+i\sqrt{3});\ r_{3,6} = \pm\frac{1}{2}\beta(-1+i\sqrt{3}) \tag{54}$$

The u_z function is composed by two parts, one that decays for an X- coordinate that starts at the edge and one that increases. This means that is equivalent to a solution part that decays from the considered edge and one that decays from the opposite edge. It is assumed that the edges are far enough to avoid superposition of effects so both decaying parts have vanished at the opposite edge (Figure 3.1) so only the negative roots are considered (55).

$$\begin{aligned} r_1 &= -\beta \\ r_2 &= -\frac{1}{2}\beta(1+i\sqrt{3}) \\ r_3 &= -\frac{1}{2}\beta(-1+i\sqrt{3}) \end{aligned} \tag{55}$$



Figure 3.1 – Assumption about the edge disturbance

From the three roots the final solution in terms of u_z is obtained (56), and the values of the constants A_1, A_2 and A_3 depend on the boundary conditions at the edge.

$$u_z = \left\{A_1 e^{-\beta x} + \mathrm{e}^{-\frac{1}{2}\beta x}\left(\mathrm{A}_2 \mathrm{e}^{\frac{1}{2}\beta i\sqrt{3}x} + A_3 \mathrm{e}^{-\frac{1}{2}\beta i\sqrt{3}x}\right)\right\}\cos(\alpha y) \tag{56}$$

Through this differential equation and the boundary conditions the moments, shear forces or membrane forces can be computed, but as an edge disturbance the most relevant plot is the one regarding the moments. This is due to the fact that the normal stresses close to the edges are reflected by bending moments that will create the so called *edge disturbance*. Before presenting the solution in terms of moments is convenient to define the meaning of the influence length l_i. The influence length represents the distance between the roots of the differential equation defined above. In other words l_i is the distance from a zero value to a zero value and at a distance larger than l_i the edges disturbance can be considered as finished. As the differential equations are solved in according to the geometry of the structure, the influence length will also vary depending on the structure geometry the Figure 3.2 shows the influence length in different type of geometries.

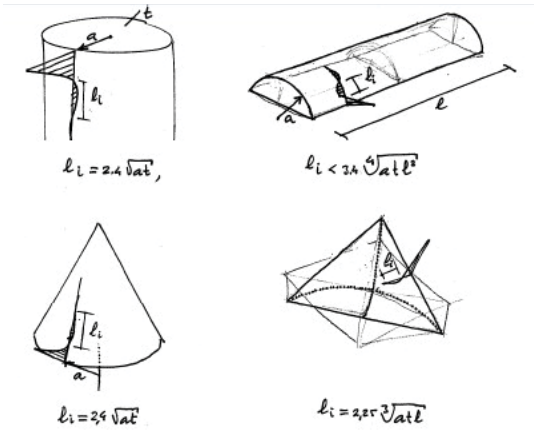

Figure 3.2- Influence length in different structures

The influence length is also defined as the ration *2π/β* and in the case of an hyperbolic paraboloid structure it is almost equal to $2.25\sqrt[3]{atl}$. Often in literature the characteristic length is used too and is defined as $l_c = \sqrt[3]{atl}$. The influence length can also be used for the determination of the mesh density in a numerical model in order to have a good accuracy of the edge disturbance in term of moments.
Concerning the solution of the differential equation in terms of moments, Loof(Loof, 1961) has developed simplified formulas, according to the theory explained in this report, for bending disturbance of hyppar roofs under uniform load p_z. The solution is provided for two types of boundary conditions, clamped and hinged edges, and it has been used for the verification of the numerical model. The following formulas are regarding and edge oriented in the Y-direction and show the values of the moment mxx and shear vx in the corresponding distance X.
For clamped edge:

$$m_{xx} = 0.511\xi^4 p_z l^2 \qquad v_x = 1.732\xi p_z l \qquad x = 0$$
$$m_{xx} = -0.617\xi^4 p_z l^2 \qquad x = 0.85\, l_c \tag{57}$$

For hinged edge:

$$v_x = 0.577\xi p_z l \qquad x = 0$$
$$m_{xx} = -0.149\xi^4 p_z l^2 \qquad x = 0.55\, l_c \tag{58}$$

where:

- $\xi = \frac{l_c}{l}$

Figure 3.3 and Figure 3.4 show the distribution of the moments, for the two different boundary conditions considered, in the direction perpendicular to the edge.

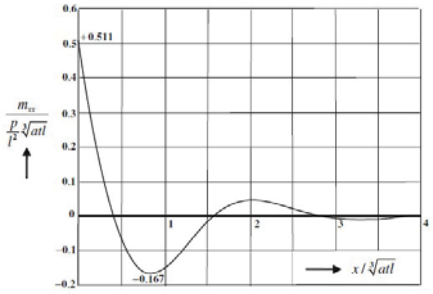

Figure 3.3 - m_{xx} distribution in clamped edge (Loof, 1961)

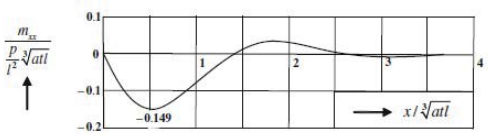

Figure 3.4 - m_{xx} distribution in hinged edge (Loof, 1961)

3.3 Analytical Solution for the Nakashima Arts Building Roof

Based on the theory of shallow shells and on the approximate solution explained in the chapters above the analytical solution, regarding the roof of Nakashima Arts Building, was performed. The geometrical parameters are summarized in the Table 3.1. It is important to underline that in this analytical solution the parameter $k_{xy}=1/a$ is indicated as c, and with a is indicated the length of the horizontal edge beam as in the Figure 3.5.

Table 3.1- Geometrical parameters

Geometrical parameters	[m]
a	10,668
b	10,668
h	4,2672
c	26,67
l	11,49
t (thickness)	0,054

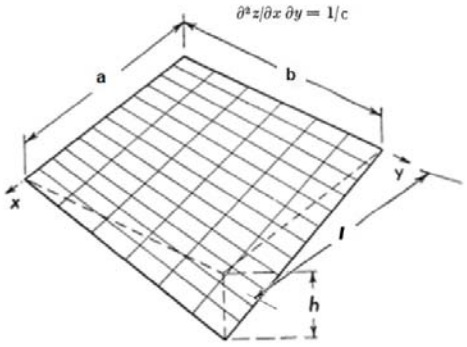

Figure 3.5 - Annotation of the geometrical parameters (Flügge, 2013)

The load applied is the same as the simplified solution and it has been determined considering the weight of the plywood layers, covering material, ribs and a uniform distribution of the snow (Table 3.2). The solution is in accordance with the approximate solution, and considers that the in-plane loads (px and py) as zero and that the normal stresses n_{xx} and n_{yy} are zero far from the edges that are affected by the boundary conditions (a and b). This assumption has been made because the tilted edge beams are considered to have zero bending and torsional stiffness as their cross sections goes decreasing from the support to the free edge.

Close to the horizontal edges (a and b) the bending behavior is more relevant and its has to be referred to this areas.

The determination of the moments m_{xx} or m_{yy} due to the edge disturbance has been provided for two type of boundary conditions, clamped and hinged. Since the structure, boundary conditions and the load are symmetric the bending solution for the edge *a* will be the same as for the edge *b*.

One of the most important assumptions of the bending behavior is that the edges are far enough to avoid superposition of effects but in the case of Nakashima Arts Building this assumption is not valid as the two edge beams a and b share a corner (Figure 3.6). In this report this effect has not been taken into account and the distribution of the moments along the edges is considered to constant or with low variation. This problem of superposition of effects in the shared corner can be taken into account by the finite element modeling.

In the following Table **3.4** and Table 3.5 the solutions obtained, respectively for membrane and bending behavior (for two type of boundary conditions), are shown and the critical length l_c, influence length l_i and the ξ parameter for the horizontal edge beams, a and b, are the following:

Table 3.2 - Load definition

Load Type	[kN/m^2]	
Plywood (3layers)	0,287	
Ribs	0,024	
Celotex (2 layers)	0,024	
Aspfalt felts	0,096	
Marble chips	0,718	
Snow load	1,436	30 psf
TOT	**2,585**	54 psf

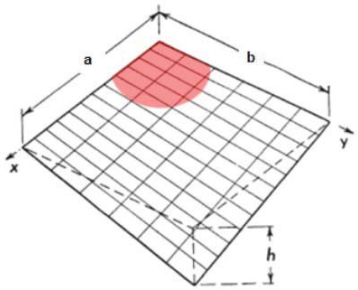

Figure 3.6 – Corner affected by superposition of effects

$$\xi = \frac{l_c}{l} = 0.22$$

$$l_c = \sqrt[3]{atl} = 2.49\ [\mathrm{m}] \qquad (59)$$

$$l_i = 2.25\sqrt[3]{atl} = 5.60\ [m]$$

The mechanical parameters used for the determination of the solution are summarized in the Table 3.3:

Table 3.3 - Mechanical properties

E	7500000	[kPa]
v	0	
$D_m = \frac{Et}{(1-v^2)}$	405000	[kN/m]
$D_b = \frac{Et^3}{12(1-v^2)}$	98,415	[kN/m]

Table 3.4 - Membrane solution

$n_{xy} = \frac{cp_z}{2}$	34,47	[kN/m]
$\sigma_{xy} = \frac{n_{xy}}{t}$	638,35	[kN/m^2]
$u_z = \frac{c^2 p_z}{2D_m(1-v)}$	0,002270	[m]
γ_{xy} = -c*pz/(Dm*(1-v))	-0,0001702	[-]

Table 3.5 - Bending solution

Clamped Edge				
Y=0		$m_{xx} = 0{,}511\xi^4 p_z l^2$	0,329	[kN*m/m]
		$v_x = 1{,}732\xi p_z l$	10,593	[kN/m]
Y=0,85*lc	2,1131	$m_{xx} = -0{,}167\xi^4 p_z l^2$	-0,108	[kN*m/m]
Hinged Edge				
Y=0		$v_x = 0{,}577\xi p_z l$	3,4427	[kN/m]
Y=0,55*lc	1,3673	$m_{xx} = -0{,}149\xi^4 p_z l^2$	-0,09606	[kN*m/m]

The Figure 3.7 shows the distribution of the moments in the edge disturbance for the two different boundary conditions, clamped and hinged edge. It can be noticed that the effect of the edge disturbance is negligible at a distance of around 6 meters from the edge and this is in accordance with the influence length determined above that is 5.60 meters.

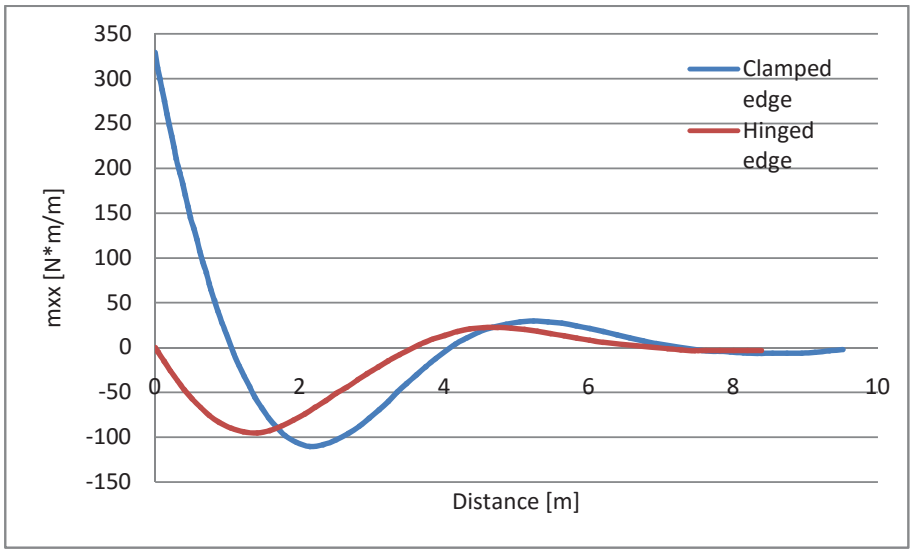

Figure 3.7– Moments distribution

4. SIMPLIFIED DESIGN METHOD

Due to the complex understanding of the behavior of hyper shell structures and its complex designing process simplified rules for the determination of the stresses have been developed. The reference used for the understanding of this simplified rules is (West Coast Lumbermen's Association, 1964). This reference was useful not only for the understanding of the simplified design process used but also for the construction process which is strongly related with the stress distribution in a structure. The structure analyzed is an hyperbolic-paraboloid shell of lumber. The article refers specifically to the forest production pavilion designed by the architect John Storrs and designed by the structural engineer James G. Pierson (Figure 4.1).



Figure 4.1- Forest Productions Pavilion - John Storrs (West Coast Lumbermen's Association, 1964)

The construction process is composed by different steps and it start at first with the placing of the edge beams of the hyperbolic-paraboliods in order to create the skeletal frame (Figure 4.2). When the skeleton is completed the following step is the introduction of the temporary purlins which will allow the application of the double layer diaphragm. The double diaphragm is composed by two layers oriented in opposite direction and glued together. The connection between the boards is tongue and groove and over the edge stiffener the layers are glued and helix nailed. The weakest parts of the shells structure are the edges and is needed to ensure a proper connection between the edge beams and the shell's layers and that is why the edge beams are thickened by adding more boards nailed and glued around the perimeter. The structure is completed by making thicker the edge beams removing the temporary purlins. The figures below shows briefly the building steps followed in this case.



Figure 4.2* - 1st: Placing the edge beams



Figure 4.3* - 2nd: Placing the purlins



Figure 4.4* - 3rd: Application of the double layer shell



Figure 4.5* - 4th: Edge beams thickened



Figure 4.6* - 5th: Removing of the temporary purlins

*Pictures reference: (West Coast Lumbermen's Association, 1964)

The structural analysis starts from the assumption that the dead load for this kind of structures as is very small compared to the live load and the non-uniform distribution of it is neglected. The forces considered and computed are the reactions, the compression in the perimeter members, the shear forces at the junction of the sheathing and the perimeter members, and the tensile and compression forces in the sheathing. These forces are solved by simple proportions rules.

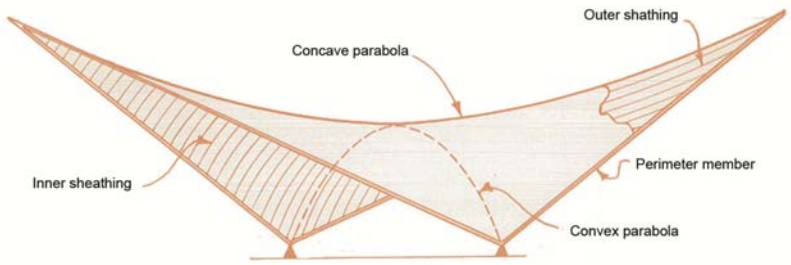

Figure 4.7 - Hyperbolic-Parabolid Shell (West Coast Lumbermen's Association, 1964)

The following Figure 4.8 is an isometric view of the hyperbolic-parabolid shell where all the where:

- a length of one side
- a' length of the horizontal projection of a
- h vertical distance from a support to the highest point of the shell
- k Inclined distance from a support to the midpoint of the length l
- l_1 length along longitudinal axis
- l_2 length along transversal axis
- H horizontal thrust
- R vertical reaction
- F resultant of the vertical reaction R and the horizontal thrust H
- C total compression force in perimeter member
- c principal compressive force in sheathing per meter
- t principal tension force in the sheathing per meter
- v boundary shear force per meter

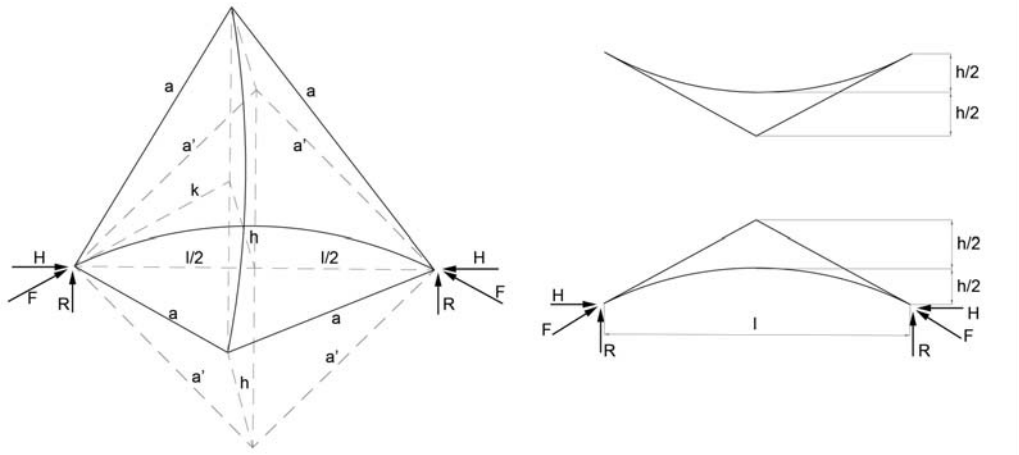

Figure 4.8 - Isometric view of the shell

Reaction Forces and Compression in the Edge members

Each of the vertical reactions for balanced live and dead loads are quiet easy to compute and consist on one-half the sum of the vertical loads. The horizontal thrust, H, and the force F are calculated by the following proportions:

$$\frac{R}{h} = \frac{H}{l/2} \text{ --> } H = \frac{Rl}{2h} \qquad \frac{F}{k} = \frac{R}{h} \text{ --> } F = \frac{Rk}{h} \tag{60}$$

The compressive force in the edge members is determined as the component parallel to the perimeter members of the force F.

$$\frac{F/2}{k} = \frac{C}{a} \text{ --> } C = \frac{aF/2}{k} \tag{61}$$

Stress in Sheathing and Boundary Shear

One of the assumption in the determination of the stress distribution in the shell is that the structure is working in pure shear so the principal forces are tensile forces, t, parallel to the direction of the concave parabolas; and compressive forces, c, parallel to the direction of the convex parabolas (Figure 4.9). This assumption leads to a shearing force acting along the length of the perimeter members at the junction of the sheathing and the perimeter members. This boundary shear, v, will be transferred to the perimeter members as a compression force. This assumption is respected if the flexural and torsional rigidity are much lower than the axial rigidity which for this type of structures is common. Referring to the Figure 4.9 the principal forces are:

$$\frac{t}{v} = \frac{l_1/2}{a\prime} \text{ --> } t = \frac{l_1 v}{2a\prime}; \qquad \frac{c}{v} = \frac{l_2/2}{a\prime} \text{ --> } c = \frac{l_2 v}{2a\prime}; \qquad v = \frac{C}{a} \tag{62}$$

If the projection of the hyperbolic-paraboloid structure is a square, the principal tension and compression forces will be equal in magnitude. The unit tensile and compressive stresses are equal to the principal forces, t and c, divided by the thickness of the shell.

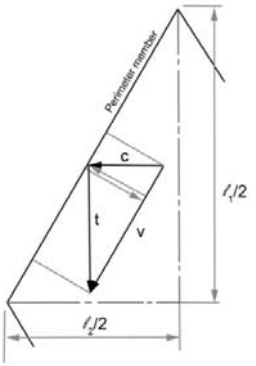

Figure 4.9 - Stress in Sheathing

As mentioned above the construction process affects the distribution of the internal forces in the structure, indeed if the sheathing is placed in the direction parallel to the longitudinal and transverse axes, each layer acts independently, one is taking the compression and one the tension. In this case nailing or stapling between the layers is not needed for strength but just for preventing the buckling of the compression layer and for increasing the stiffness of the shell.

When the layers are placed with the boards parallel to the sides, each layer is resisting to a portion of the principal compression force and to a portion of the principal tension force. This behavior result in a shear between the two layers and the resistance to this shear is given by the type of fastening between the two layers.

For a better understanding and verification of the simplified rules, a numerical example was solved by both the simplified method and the finite element (FE) method. The dimensions of the structure were adopted from those of the Nakashima Arts Building. It should be noted, however, that the simplified rules are derived for a leveled hyppar (with opposite apexes at the same height, Figure 4.7), while the roof of Nakashima Arts Building is inclined (Figure 1.8). Therefore, first a leveled shell is considered, to be consistent with the assumptions of the simplified model. Secondly, an inclined shell is analyzed to verify, whether the simplified method can be used for this case as well.

The first leveled structure with dimensions adopted from the Nakashima Arts Building is obtained by rotating it around the axis AB as shown in the Figure 4.10. The edges of this roof are not equal (the two horizontal are 10.668 [m] instead the other two inclined 11.49 [m]) but in order to be able to apply the simplified formulas this difference is neglected and the edges are considered all the same with a length of 11.49 [m]. The Table 4.1 summarizes the geometrical properties of the analyzed structure.

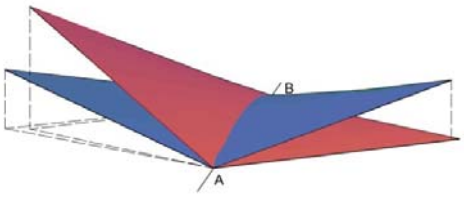

Figure 4.10 - Rotation axis of the Nakashima Arts Building roof

Table 4.1- Geometrical properties of the first leveled structure

a	11,49	[m]
a'	11,30	[m]
h	2,05	[m]
k	8,25	[m]
l	15,98	[m]
Shell Area	129,08	[m^2]
Shell thickness b	0,05	[m]

The load applied in the structure includes the plywood, covering materials, ribs and the snow load. The Table 4.2 shows their intensities and the total load.

Table 4.2 - Loads definition

Load Type	**[kN/m^2]**
Plywood (3layers)	0,287
Ribs	0,024
Celotex (2 layers)	0,024
Aspfalt felts	0,096
Marble chips	0,718
Snow	1,436
Tot	**2,585**

By defining the geometrical dimensions the simplified analysis explained above was computed and the results in terms of reaction and stresses in the edge members and in the shell are shown in the Table 4.3.

Table 4.3 - Results obtained from the simplified solution

R	166,84	[kN]
H	649,32	[kN]
F	670,41	[kN]
C	466,86	[kN]
v	40,63	[kN/m]
t	28,73	[kN/m]
c	28,73	[kN/m]
P. stress – t	574,62	[kN/m^2]
P. stress - c	574,62	[kN/m^2]

The result in terms of stresses are in the principal direction and as one of the assumption was that the shell is working just in pure shear the shear stress XY is obtained by multiplying the principal stress by the root of two.

$$\vartheta_{XY} = t * \sqrt{2} = 812.63\ [kN/m^2] \tag{63}$$

5. FEM CONCEPT

The structural analysis of shells is characterized by difficult and complex governing equation to solve. This, in the seventies, was reflected directly in the process of deign where engineers had to put considerable effort to verify their designs in accordance to the rigorous methods. Many approximate methods were developed. Cylindrical shell for example was approached as beam when extended in the long direction, while was considered as an arch when was shortened in the same direction (Bradshaw et al., 2002). Another famous method, adopted also by famous architects as Antoni Gaudi in the Sagrada Familia, was to obtain the funicular shape of the shell by hanging weights from a mesh.

The development of the finite element helped on the understanding of the structural behavior of these structures and it also made the design process more simple. The concept of the finite element method is to describe the structure by a certain number of elements which are "reassembled" using the equilibrium and compatibility equations (Bradshaw et al., 2002). In each element, the displacement is approximated by a function of suitable type as for example linear or quadratic. From this approximation of the displacements are calculated the kinematic and constitutive equations. In FE method the relation generalized stresses-external forces is not obtained through the equilibrium equations but through principle of virtual work or of total potential energy. Through this steps the discretized weak form for every element is obtained (64). In this equation K is the stiffness matrix, d vector of nodal degrees of freedom and f_{ext} is the external force vector.

$$K_e d_e = f_{ext} \tag{64}$$

The most suitable elements used for modeling shell structures are triangular or quadrilateral plane elements. In the case of hyperbolic paraboloid shell obtained as a ruled surface the quadrilateral elements are the most suitable.

In this thesis the structure is modeled using the ADINA (Automatic Dynamic Incremental Nonlinear Analysis). The elements used to describe the structural parts of the building are listed in the following:

- *4- Node isoparametric shell elements:* these elements are used to describe the plywood shell structure. The shell element is formulated treating the shell as a three-dimensional continuum with the assumptions used in the Timoshenko beam theory and the Reissner/Mindlin plate theory (ADINA R&D, 2016). At every shell element midsurface node are assigned 5 degree of freedom in according to the recommendations given by the ADINA manual. The 4-node element has been chosen because "it does not lock and has a high predictive capability and hence can be used for effective analysis of thin shells" (ADINA R&D, 2016). The numerical integration used is the Gauss integration and three integrations point through the thickness were adopted, in order to catch the bending behavior (Figure 5.2). The definition of the elements local axis is shown in Figure 5.1.

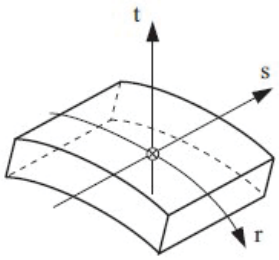

Figure 5.1 - Definition of the local Cartesian System (r, s, t) (ADINA R&D, 2016)

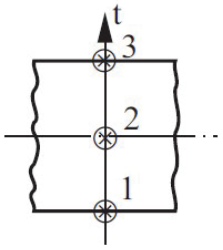

Figure 5.2 - Integration points through the thickness in the Gauss integration (ADINA R&D, 2016)

- *2-Node truss elements:* these elements are used to describe the edge beams in the numerical analysis concerning the verification of the model and the comparison with the simplified designing rules.

  The choice of these elements aims to have the same assumptions between the numerical modeling and the analytical solutions carried out from the theory of thin shells. In the truss element the only force that can be transmitted is the longitudinal force and in the case of 2-node truss, this force is constant. Only one integration point is used (Figure 5.3) and the Gauss numerical integration has been adopted (ADINA R&D, 2016).

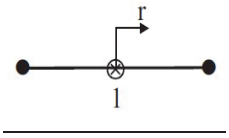

Figure 5.3 - One-point Gauss integration (ADINA R&D, 2016)

- *2-Node Hermitian beam elements:* these elements are used in the analysis concerning the boundaries and load cases effects on the Nakashima Arts Building.

  Through these elements are described the tilted edge beams, since it was needed to take into account the effective cross section properties. The formulation of the beam is a generalization of the Euler-Bernoulli beam formulation (ADINA R&D, 2016). The Figure 5.4 shows the local Cartesian system and the degrees of freedom. In the r direction is used a 5 – integration order.

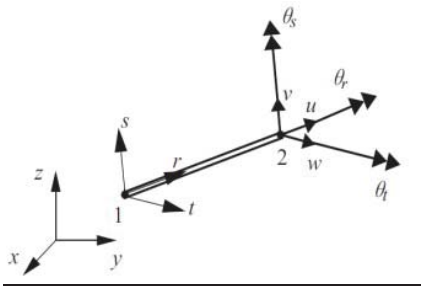

Figure 5.4 - Local Cartesian system and DOF of beam element (ADINA R&D, 2016)

6. VERIFICATION OF THE FE MODELING

With the aim of verifying the FE modeling a comparison between the analytical solution and the FE solution has been done. The numerical model is developed using the software ADINA.

Once the geometry was created the mechanical properties have been assigned. Since the analysis is linear elastic and the material is considered as isotropic, only the Young's modulus defines the mechanical behavior of the material. At this step of the thesis work, a grading of the plywood and edge beams materials was not yet available. Due to this reason the Young's modulus of the plywood was adopted as $E = 7{,}5\ [GPa]$ from the Table 2 of the article "*Effect of weathering on surface quality and structural properties of six species of untreated commercial plywood siding after 6 years of exposure in Alabama"* (Biblis, 2000).

One of the assumption in the simplified solution is that the edge beams are infinitely rigid in the axial direction and zero flexural and torsion rigidity. To take this assumption in account into the FE model the Young's modulus assigned to the edge beams is the one of the shell increased by a magnitude order of three. Moreover as elements that describes the behavior of these edge beams have been used truss elements (Chapter 5 – FEM Concept). Through those measures the edge beams are considered to be infinitely stiff in the axial direction. The plywood shell surface is modeled by 4-node shell elements (Chapter 5 – FEM Concept).

The load, which has the same intensity as in the analytical solution, has been applied in the direction normal to the surface.

Concerning the boundary conditions, two different configurations have been solved. In the first the horizontal edges are fixed in displacements and rotations, instead in the second case they are fixed only in displacements.

The two different configurations are compared with the analytical solution in terms of shear stresses concerning the membrane behavior, and in terms of moment distribution perpendicular to the edge concerning the bending behavior. In order to have a good accuracy of the edge disturbance the mesh has a density of 100x100 elements. The figures below show the two different case of boundary conditions analyzed (Figure 6.2 and Figure 6.3), the mesh density (Figure 6.5) and load applied as normal to the surface (Figure 6.4).

The band plots showed in the following chapters refer to the orientation of the shell as in figure Figure 6.1 (x and y are the global axis).

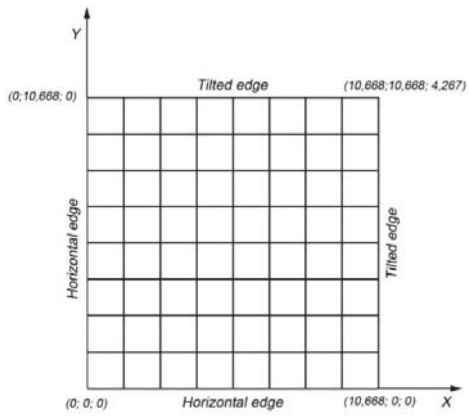

Figure 6.1 - Orientation reference for the band plots

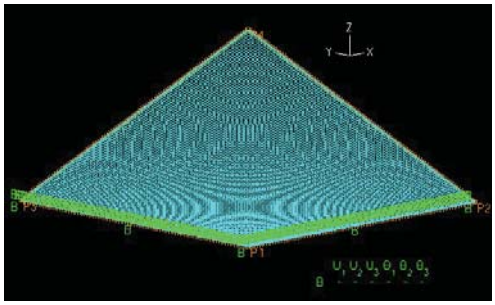

Figure 6.2 - Boundary conditions - Clamped Edges

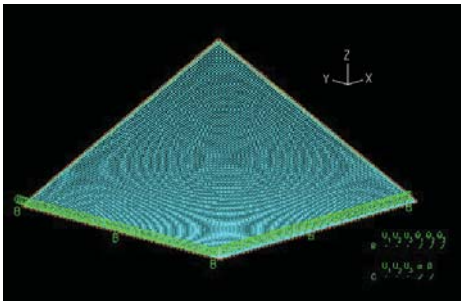

Figure 6.3 –Boundary conditions – Hinged edges

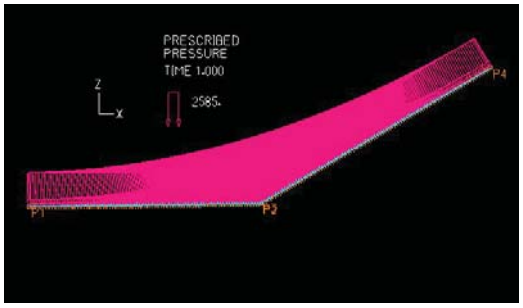

Figure 6.4 - Load normal to the surface

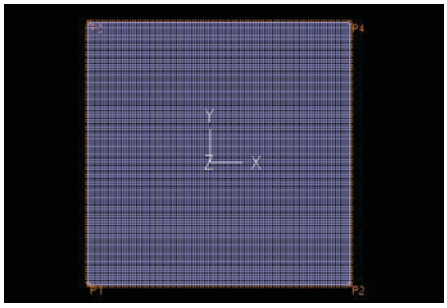

Figure 6.5 - Mesh density

6.1 Clamped Horizontal Edges

The deformation of the structure and the band plot of the vertical displacement (Figure 6.6) underline that apart from the area of the free edges and nearby the horizontal edge, the displacement is around 0.002 [m] (the average in all the structure is 0.00281 [m]) which is the almost the same result as predicted in the membrane solution (u_z=0.00227 [m]).

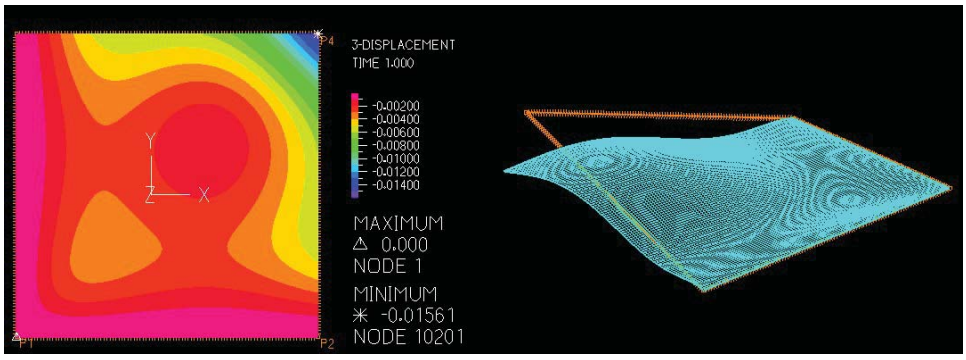

Figure 6.6 - Vertical displacement and structure deformation (magnification factor 150)

Concerning the membrane shear stresses (T_{rs}), the Figure 6.7 explains clearly the influence of the boundary conditions. Far from the edges the distribution is almost uniform and varies in a range 660 [kPa] and 849 [kPa] (Figure 6.8). Considering a quantitative comparison the average value of the

shear stresses in the numerical analysis is 740 [kPa] which differs from the analytical solution (638 [kPa]) by 13%. This difference is acceptable and is due to the fact that the FE model does not impose a-priori any assumption concerning the stress distribution and the stiffness of the edge beams and it provides an approximate numerical result of the original differential equation.

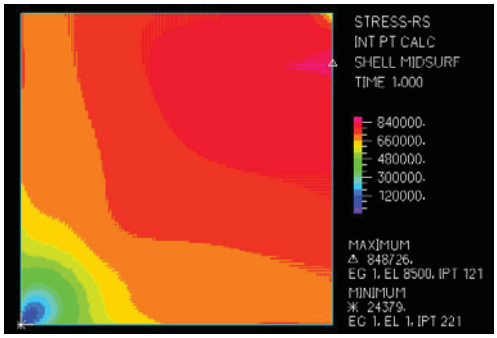

Figure 6.7 – Distribution of shear stresses rs

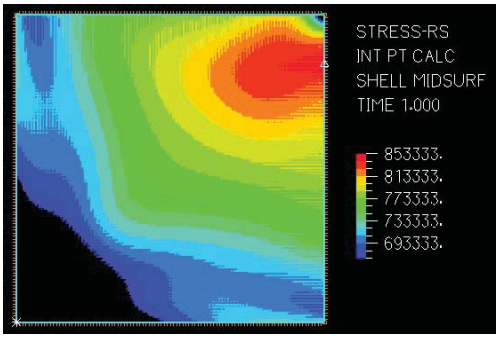

Figure 6.8 – Distribution of shear stresses rs – Range 660/850 [kPa]

The last step of comparison is regarding the bending moment distribution. In the Figure 6.10 is shown the distribution of the bending moment M_{rr} (Figure 6.9), where the axis r, s and t are the local axis of the shell element (Chapter 5 –FEM Concept).

The bending plot underlines immediately that there are two areas where there is a much higher concentration of moments. The first is in the corner A (Figure 6.10) between the two horizontal edges and this is due to the superposition of effects. In this area is also localized the maximum value of the moment.

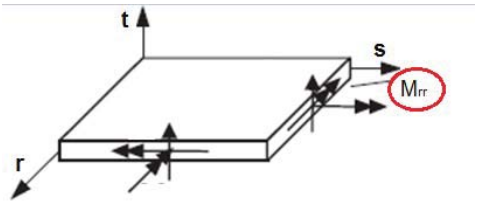

Figure 6.9 – M_{rr} in the shell element

The same thing is happening in the corner B (Figure 6.10) between the two tilted edges. Since these two edges are not affected by boundary conditions and are modeled as trusses the superposition of the effects is much lower than the corner between the horizontal edges.

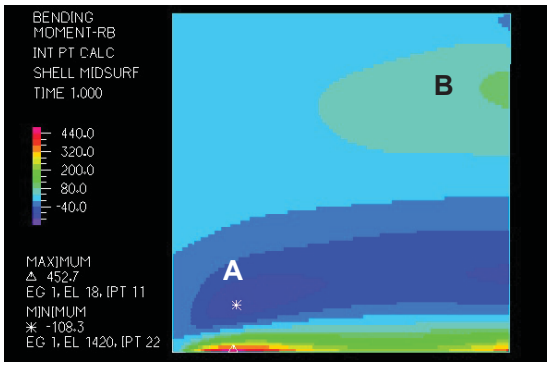

Figure 6.10 – Distribution of moments M_{rr}

The superposition of effects is also reflected in the distribution of moments along the edge beams. In the analytical solution one assumption was that this distribution is a smooth function that for the case that we solved means constant along the edge. The Figure 6.11 shows the distribution of moment M_{rr} along the edge oriented in Y=0 and the

constant value obtained from the analytical solution. From the comparison the solution obtained analytically seems to be close to the numerical in the central area of the edge beams. This is due to the fact that the central area is at the maximum distance from the corners and so here the superposition of effects is lower than the other areas.

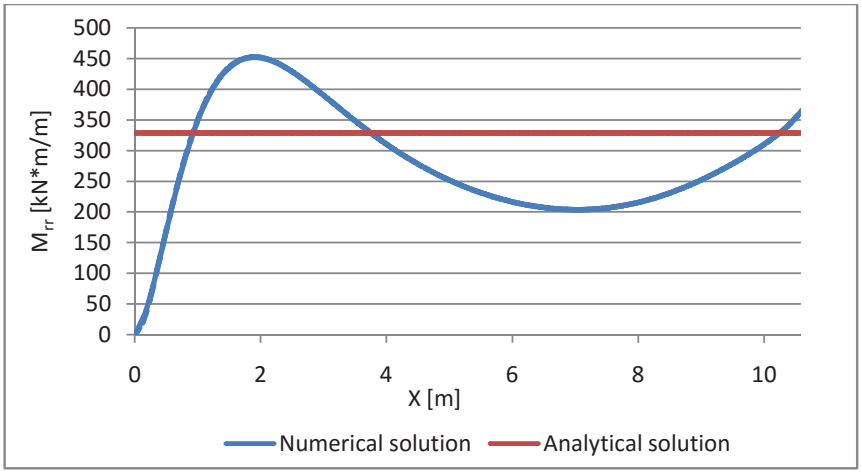

Figure 6.11 - Distribution of moments in the edge Y=0

In order to have a further understanding, have been computed the moments in the direction perpendicular to the horizontal edge Y=0. Three directions have been considered: the first is passing through the maximum and minimum moments close to the corner A; the second is at a distance of almost 5 meter (half of the edge); the last is almost at the end of the edge (X=8 [m]) in order to get the superposition of the effects in the corner B. These three sections (Max, Middle, Min), Figure 6.12, have been plotted in the same graph of the analytical solution (Figure 6.13).

The comparison shows that the more the distance X is increasing the more the superposition of effects is vanishing in the area close to the support (Y=0) and the numerical distribution of moments is below the curve determined in the analytic way.

On the other side (Y=0) the superposition is increasing with the increasing of the distance X. As mentioned above this effect is not taken into account in the analytical model and far from those areas the trend between the analytical and numerical is very similar and also the influence lengths are almost the same.

From this comparison is carried out that analytical and numerical solution show the same trend of behavior when compared in areas where the conditions are the same.

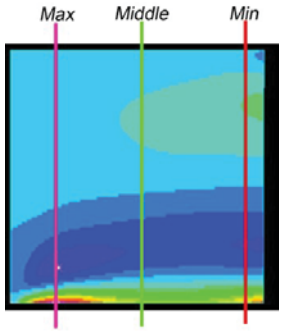

Figure 6.12 - Sections of edge disturbance plotting

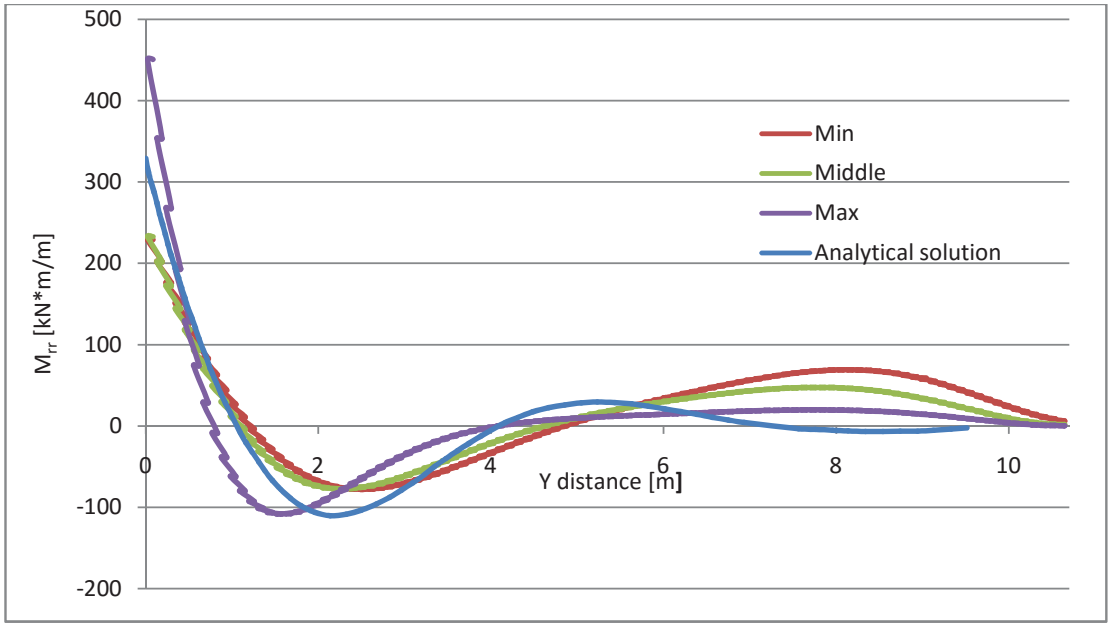

Figure 6.13 - Comparison Edge disturbance at the edge (Y=0)

6.2 Hinged Horizontal Edges

In the same way as for the clamped edges, the numerical analysis was performed also considering the horizontal edges as hinged so fixed only in displacement. A brief comparison of the results is shown in this chapter.

The changing of the boundary conditions is not affected significantly the vertical displacement Figure 6.14; the average values is 0.00286 [m] and the distribution pattern is almost the same as in the case with clamped edges.

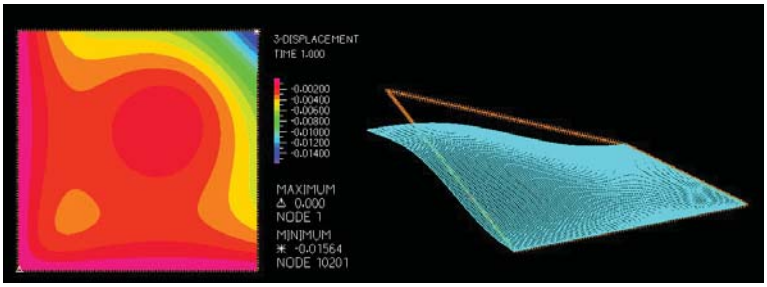

Figure 6.14 - Vertical displacement and structure deformation (magnification factor 150)

Also the shear stress distribution (τ_{rs}) is not changing significantly. The average value is 755 [kPa] which is 15% different from the analytical results. Also in this case this difference is considered to be acceptable and is due to the same reasons explained above (the FE model does not impose a-priori any assumption concerning the stress distribution and the stiffness of the edge beam). The range of

stresses qualitatively defined in the case of clamped edges, is now interesting a wider area, confirming that in this case its distribution is becoming more uniform but not in a significant way (Figure 6.16).

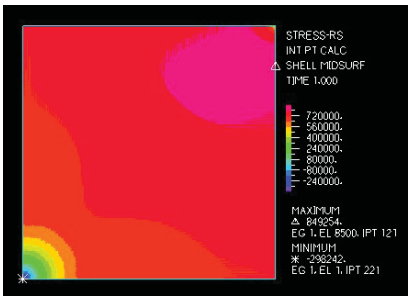

Figure 6.15 - Distribution of shear stresses rs

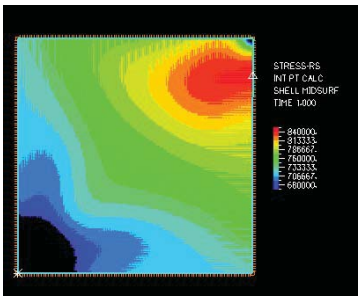

Figure 6.16 - Distribution of shear stresses rs – Range 660/850 [kPa]

Regarding the bending behavior the same considerations made before about the areas affected by the superposition of effects are valid also in this case and can be noticed in the plot of the bending moment M_{rr} (Figure 6.17). In this case the distribution of moments M_{rr} along the horizontal edges are zero, as the boundary conditions allows rotations. The edge disturbance has been plotted in the same sections (Max, Middle and Min) defined previously (Figure 6.12) and in the Figure 6.18 are compared with the analytical solution obtained for hinged edges.

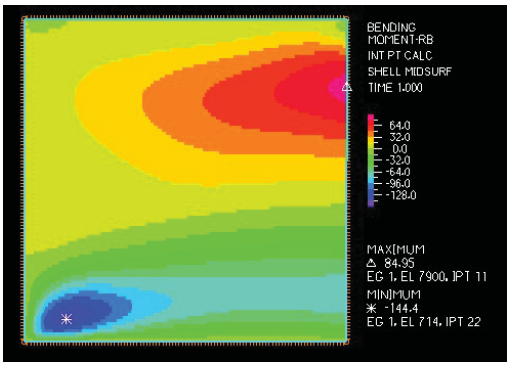

Figure 6.17 - Distribution of moments M_{rr}

From the comparison is possible to notice that, as in the previous case, the analytical and numerical solution have similar trend and influence length in the areas not affected by the superposition of the effects of edge disturbances.

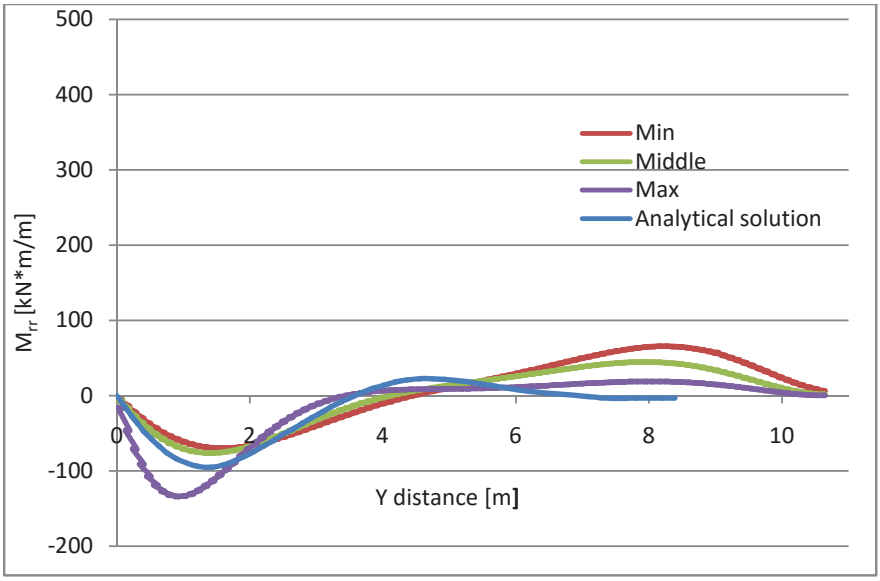

Figure 6.18 - Comparison Edge disturbance at the edge (Y=0)

6.3 Conclusions

In addition to the calibration of the model, its verification is also a very important step in any structural assessment since from this step depends the accuracy of the results. This allows to know if the model is following the theory that governs the problem. The comparison explained above underlines that the FE modeling process and its results show the same trend as the analytical solution. The shear stress differs between the two solution by 15% (maximum). Concerning the bending behavior, the graphs showing the edge disturbances in the two different boundary conditions, confirm the similar trend and influence lengths for the two solution. This similarity is considered in the areas less affected by the superposition effects as mentioned in the previous chapter.

The differences between the two methods find their reason in the fact that the analytical solution adopts certain simplifying assumptions, such as:

- constant distribution of shear stresses along the shell
- zero flexural and torsional rigidity of the edge beams
- bending moment constant along the edge
- edges far enough to avoid superposition of bending effects

Through this assumptions the analytical solution provides the exact result for the mathematical problem. The FE solution, on the contrary, does not impose a-priori these assumptions and it provides a approximate numerical result of the original differential equation. Since, the comparison showed that the percentage of difference of shear stresses is not significantly high (max 15% of difference is considered acceptable) and the results are close to each other in areas where the simplifying assumptions of the analytical solution are valid, the FE solution is considered verified by the analytical one.

7. COMPARISON SIMPLIFIED DESIGN METHOD AND NUMERICAL SOLUTION

As already explained in the Chapter 4 (Simplified Design Method) a numerical example was solved by both the simplified and the finite element method. The simplified solution is derived for a leveled structure, while the numerical solution through the finite element method is derived firstly for a leveled structure (as the simplified solution) and secondly for an inclined structure in order to evaluate if the simplified method can be used also for this case.

The mechanical properties of the plywood and of the edge beams and the elements used to describe them are the same as in the numerical model used for the verification process (Chapter 6 –Verification of the FE Modeling).

7.1 Leveled Shell surface

The load is applied as a vertical pressure on the shell along because in the simplified solution the vertical reactions are calculated as the distributed load (2.59 [kN/m^2]) times the area of the curved shell divided by two.

The boundary conditions of the structure consists in totally fixed displacements in the two points P1 and P4. With this boundary conditions the system is isostatic because the load and the structure are symmetric. In order to avoid rigid body motions during the numerical solution a kinematic relation was assigned to the points P2 and P3. This relation is expressed in the following equations and it means that the rotation of the point P2 has the same magnitude of the P3 rotation but opposite direction. This relation avoids the rigid body motion of the structure.

$$\varphi_{P2} = -\varphi_{P3} \tag{65}$$

The figures below show the generated mesh (Figure 7.1 and Figure 7.2) and the applied load (Figure 7.3).

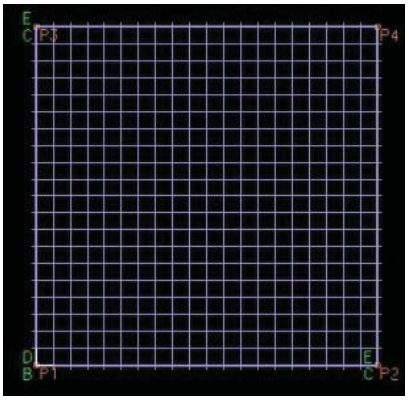

Figure 7.1 - Mesh - Top view

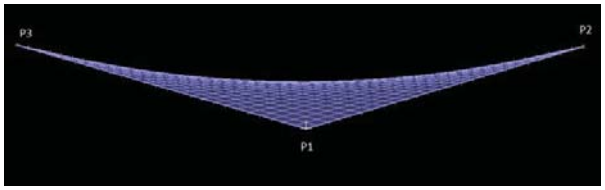

Figure 7.2 - Mesh - Frontal view

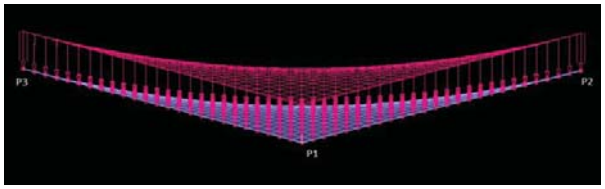

Figure 7.3 - Applied load - Frontal view

Through the deformation plot (Figure 7.5) is possible to notice how the kinematic relation avoids the rigid body rotation of the structure. The maximum displacement is localized in the vertices P2 and P3 and is around 0.42 [cm] (Figure 7.4).

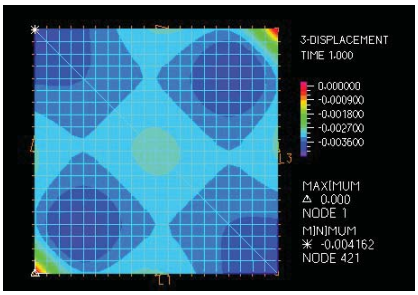

Figure 7.4 - Displacement Band Plot

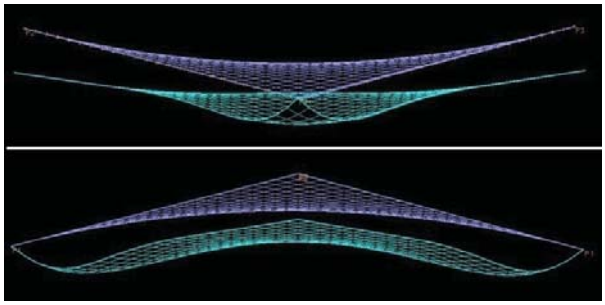

Figure 7.5 - Deformation of the structure (magnification factor 400)

The first step of the comparison between the numerical solution and the simplified solutions starts from the reaction forces. The Figure 7.6 shows that the reaction force F in the numerical solution is 669 [kN] and this result differ from the simplified solution by 0.2% instead the maximum compression of the edge members in the ADINA solution (Figure 7.7) is 2 % lower than the simplified solution (ADINA 457 [kN]; simplified solution 467 [kN]). This is mainly due to the fact that in the simplified solution the shear stress is considered constant in all the shell instead in the numerical solution it is not constant and it decreases close to the supports.

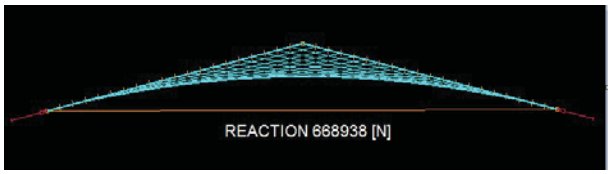

Figure 7.6 - Reaction force F

The next comparison step passes through the shear (rs) and normal (rr, ss) stresses (local coordinate system in Figure 5.2 – Chapter 5). The distribution of shear stress is shown in the Figure 7.8 and is uniform far from the supports, instead close to the supports (P1 and P4) it decreases due to the boundary effects.

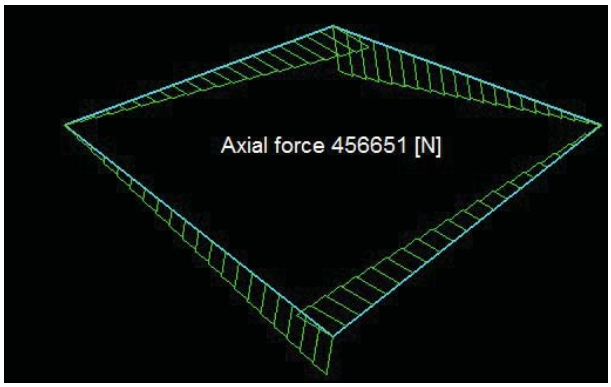

Figure 7.7 - Compression in the Edge members

The qualitative comparison with the simplified solution has to be done with the stresses far from the supports since in the simplified solution the boundary effects are not taken into account. For this purpose in the Figure 7.9 is plotted the range of shear stresses in the area far from the supports. This range varies from -800 [kPa] to -822 [kPa], instead the result of the simplified solution (813 [kPa]) and the extreme values of this range differ from the simplified solution respectively by 1% and 1.5%.

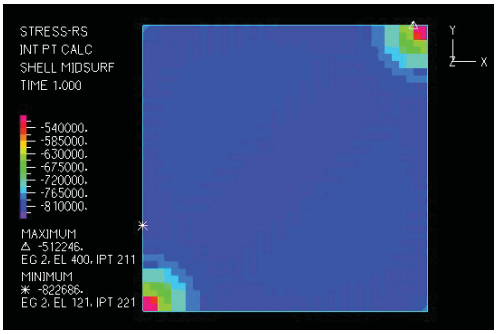

Figure 7.8 - Distribution of shear Stresses rs

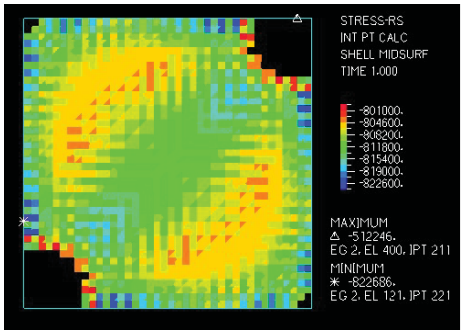

Figure 7.9 - Distribution of shear stresses rs - Range -800/825 [kPa]

Concerning the normal stresses in rr (the stresses rr are not plotted because are symmetric with stresses ss) and ss (Figure 7.10 – ss stresses) they increase near the supports and the maximum value (in the supports P1 and P4) is 182 [kPa] and the minimum (in the central area of the shell) is -25 [kPa]. These two values are respectively 22% and 3% of the shear stress obtained by the simplified solution. This shows how the normal stresses are not negligible in the supports. The main area far from the supports is affected by stresses (rr and ss which vary from 50 [kPa] to -25 [kPa] (Figure 7.11). The extreme values of this range represent respectively the 6% and 3% of the shear stress obtained by the simplified solution. This highlights that the assumption of the shell working only in pure shear does not induce to considerable error in the main area far from the supports instead close to the supports the stresses rr and ss are between 22% and 3% of the shear stress and the assumption leads to an higher error bit still acceptable for a first and simple assessment of the behavior of the structure.

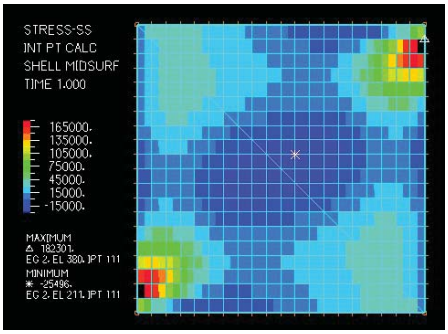

Figure 7.10 - Distribution of normal stresses ss

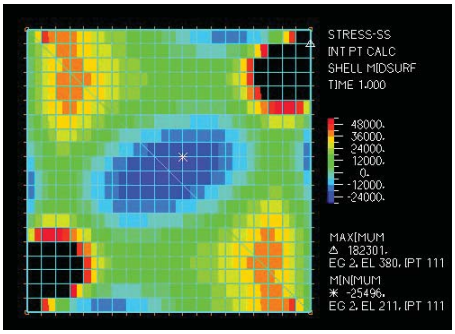

Figure 7.11 - Distribution of normal stresses ss, range 50/-25 [kPa]

This qualitative comparison shows that the simplified solution provides results which are really close to the numerical solution in the main area far from the supports and the edges, instead close to this areas, mainly in the supports, the error increases. The Table 7.1 summarizes a quantitative comparison where all the values are taken into account (supports values are not excluded) for the computations of the average stresses. Is possible to notice that the average values of the stresses in the numerical model are almost the same as the simplified solution and this confirms the accuracy of

the simplified rules for structures that present the same configuration as the one analyzed in this chapter.

Table 7.1 - Comparison Simplified solution - Numerical solution

		Simplified solution	Numerical solution		% of difference
Reaction **F**	[kN]	670,41	669		0,2%
Edge compression **C**	[kN]	466,86	459		2%
Shear stress **rs**	[kN/m^2]	813	Max	-512	[-]
			Min	-823	[-]
			Average	-811	0,2%
Normal stress **rr - ss**	[kN/m^2]	0	Max	182	[-]
			Min	-25	[-]
			Average	10	1,2%*
* indicates that is not a percentage of difference but the percentage of the shear stress.					

7.2 Inclined Shell Surface

In order to have a further understanding on the reliability and accuracy of the simplified solution, the comparison process explained above was made also with the structure numerically solved in its real position and dimensions, so no rotated but tilted as shown in the Figure 7.12.

The mechanical properties and the load applied are the same as in the previous model (structure rotated in horizontal position), instead the boundary conditions are different. In the point P1 and P3 all the displacement components are fixed instead in the point one is fixed only the vertical displacement. The Figure 7.13 shows the boundary conditions and the load applied.

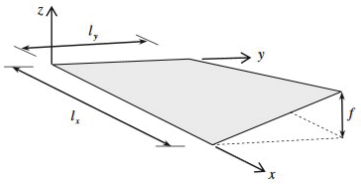

Figure 7.12 – Inclined Shell Surface

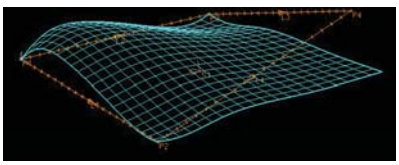

Figure 7.14 - Structure deformation

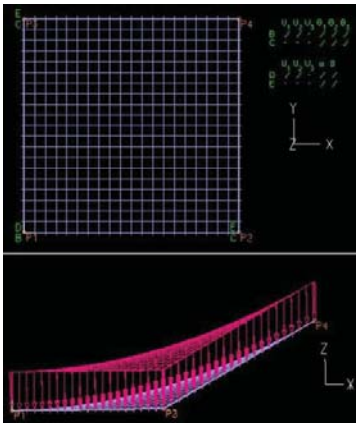

Figure 7.13 - Boundary conditions (above) and applied load (below)

This structure configuration is characterized by three reactions, two in the supports P2 and P3 and one vertical in the support P1 (Table 7.2).

Table 7.2 - Reaction magnitude

Support	Reaction magnitude	
P1	3,714	[kN]
P2	568,496	[kN]
P3	568,496	[kN]

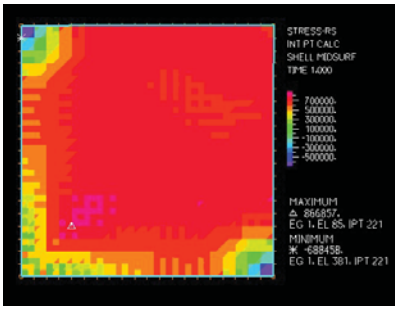

Figure 7.15 - Shear stress rs distribution

The force reaction in P1 is 0.7% of the reactions in P2 and P3, this highlights how the influence of the support P1 is low (in terms of reaction forces) and that the forces in the supports P2 and P3 does not change significantly (15%) respect the previous case (structure rotated in horizontal position F is 669 [kN]).The maximum compression in the edge members has a maximum value of 417 [kN] which differs by 11% from the simplified solution.

Due to the configuration and boundary conditions of the structure the deformation is different from the previous case and is shown in the Figure 7.14.

Regarding the shear stress (rs) the Figure 7.15 shows an overview of its distribution, and is possible to observe that also in this case shear stresses decrease close to the supports P1 and P2, instead the maximum value (867 kPa) is close to the support P1 and this is due to the deformation of the structure that concentrates the in-plane maximum shear strain in this area.

Concerning the main area far from the supports, it is interested by a range of stress from 550 [kPa] to 850 [kPa] (Figure 7.16). Comparing with the previous case the range is getting wider, pointing out that the assumption of constant shear stress in the shell is affected by higher error in this case, but still the value of the simplified solution is inside this range.

As it was for the shear stress, also concerning normal stresses rr and ss (Figure 7.17) the area close to the support P1 is affected by concentration of stresses and the maximum value is -1304 [kPa] which is 60% bigger than the shear stress and this means that those stresses can not be neglected. Considering only the area far from the supports the range of normal stresses is from 350 [kPa] to -450 [kPa] (Figure 7.18). The two extreme values of the range represent respectively the 43% and the 55% of the shear stress obtained by the simplified solution,

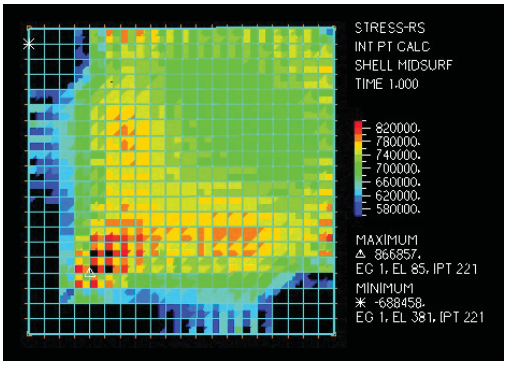

Figure 7.16 - Distribution of shear stresses RS - Range 550-850 [kPa]

so the assumption of no presence of normal stresses lead to a significant error. Particular relevance have the negative values which correspond to compression because the compression stresses can lead to buckling.

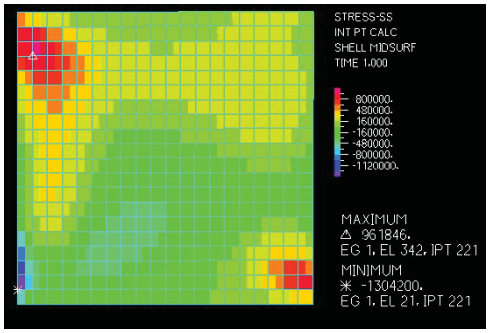

Figure 7.17 - Distribution of normal stresses ss

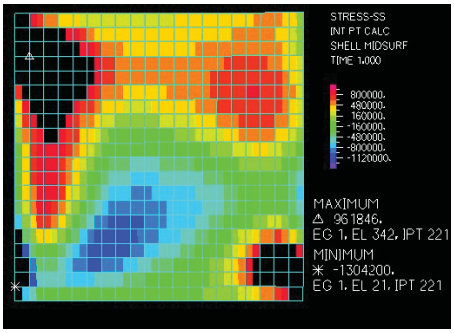

Figure 7.18 - Distribution of normal stresses ss, range 350/-450 [kPa]

The Table 7.3 represent the quantitative comparison between numerical and simplified results, as it has been done in the previous case of the horizontal structure.

Table 7.3 - Comparison Simplified solution - Numerical solution

		Simplified solution	**Numerical solution**		% of difference
Reaction **F**	[kN]	670,41	568		15%
Edge compression **C**	[kN]	466,86	417		11%
Shear stress **rs**	[kN/m^2]	813	Max	867	[-]
			Min	-688	[-]
			Average	726	11%
Normal stress **rr - ss**	[kN/m^2]	0	Max	962	[-]
			Min	-1304	[-]
			Average	146	18%*

* indicates that is not a percentage of difference but the percentage of the shear stress.

7.3 Conclusions

The aim of the comparison between the simplified solution and the numerical solution is to verify the reliability of the simplified designing method that can be very convenient as a fast structural assessment of stresses and reaction forces.

The first case of comparison (Leveled Shell Surface) shows that the simplified solution seems to be a perfect tool for obtaining a first idea of the behavior and stress distribution of structures that presents boundary conditions and geometry similar to the hyperbolic-paraboloid shell structure analyzed in this

case, for which the simplified solution has been developed. The values summarized in the Table 7.1 present a maximum difference between the two solutions of 2%.

In the second case the comparison was done with the inclined structure and the numerical results obtained showed the limits of the simplified method. In this case the normal stresses increase significantly (due to the slope and to the boundary conditions) and they can not be neglected, in particular when they correspond to compression.

The limit of the simplified solution is represented by the geometrical conditions, as it can be applied only to leveled structures. Taking this into account it still remains a fast way to have a first approximation of the shear stresses, reactions and compression in the edge members, but further structural analysis are needed for structural designing or assessments.

8. NAKASHIMA ARTS BUILDING

8.1 Historical Context

The Nakashima Arts Building was born in the years when timber shell structures where reaching the peak of popularity (1950-1970) in the United State and Europe (specially in Britain). The interest on this type of structures was on their functional qualities, efficiency (in terms of material and span), and elegant shapes. Until these years, the shell structures were mainly in reinforced concrete, since their behavior and concept was well established in Europe by 1939. In a process of innovation, the studies started to be more focused on the application of new material as timber. Important was the case of Britain where the studies on timber hyperbolic paraboloid roofs were carried out by the Timber Development Association (TDA). This association was transformed from a publicity body of the timber trade into a research and development organization (Booth, 1997).

In the same way, university researches and conferences increased the interest in hyperbolic paraboloid structures in the United States. A result of this period of researches and studies is the hyper roof built by Catalano in Raleigh, North Carolina. In the same years of Nakashima's work, the Department of Architecture and Architectural Engineering of the University of Kansas started a research project on hyperbolic paraboloids using plywood (Ballester, 2015).



Figure 8.1 - Catalano's hyperbolic paraboloid roof (Ballester, 2015)

This brief introduction of the historical context is meant to explain that the Nakashima Arts Building was built in a period of a continuous innovation process through research projects and real applications as the Catalano's roof.

8.2 Architectural Description

The Nakashima Arts Building is part of woodworking complex built between 1960 and 1975 in new Hope, Philadelphia (Figure 8.2). The Arts Building, Cloister, Pool House and Reception House are clear examples of the skills and abilities of the furniture designer and architect George Nakashima. The architect's work represent a fusion between the traditional Japanese craft and the modern architectural influences of the mid-twentieth century.

The Arts Building and the Cloister were built, as art gallery and museum, between 1964 and 1967, and they are directly connected by a covered path.

Both buildings are located in an isolated area, in the east part of the property where the slope starts to decrease.

The Arts Building is composed by a hyperbolic paraboloid shell roof made of plywood. The two main facades are oriented respectively in west and south directions, and the main entrance is located in the corner between the two facades.

This building shows the architect's mastery on the use of different material. Stone masonry, reinforced concrete slab, plywood shell and timber edge beams find in this building a perfect equilibrium and harmony between them. The maximum high of the Arts building is around 6,83 meters. The main entrance represent a transition area from the exterior to the interior space. It is characterized by height of 2,50 meters, covered by a ceiling in reinforced concrete grid. The same ceiling is a terrace in the upper level.

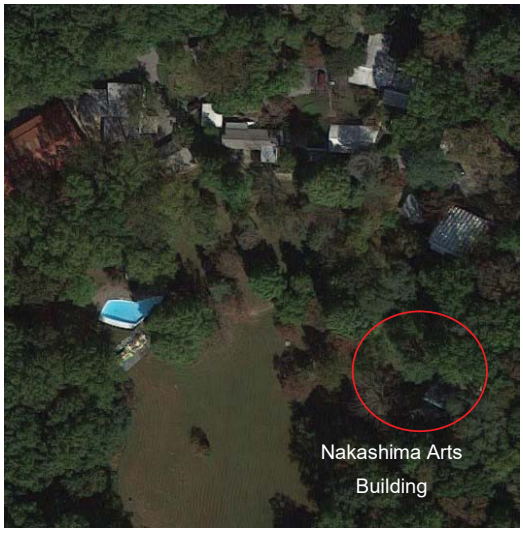

Figure 8.2 - Nakashima's property in New Hope (www.google.it/maps)

The two facades, west and south, emphasize the lightness of this structure. The sliding doors and windows ensure a bright inner space where the relation with the exterior environment is always present through the view and the material (timber).

In the 2014 the Nakashima's property was included on the World Monuments Watch, and World Monuments Fund is collaborating with the Nakashima Foundation for Peace with the aim of creating a sustainable plan, according to the original idea of George Nakashima (World Monuments Fund, 2016).

The elegance and the integration between the materials is shown in the Figure 8.3 (south elevation) and Figure 8.4 (internal view).



Figure 8.3 - South elevation (www.nakashimawoodworker.com)



Figure 8.4 - Internal view (www.nakashimawoodworker.com)

8.3 Geometrical Description

The geometrical survey has been carried out by Mr. Cesar Bargues Ballester and the drawings were provided through the professor David Biggs. The Arts Building is about 6,83 meter tall and in plan has a square shape of 10,67 meters wide. The structure of the building is composed by different elements that interact together. The structural elements can be listed as the following:

- *Plywood shell roof:* the shell roof has an hyperbolic paraboloid shape and is obtained by lifting the southwestern corner 4,27 meters high (Figure 8.5). The structure consist of three plywood layers (each 1,6 cm thick) overlapping each other's according to the pattern defined in the Figure 8.6.



Figure 8.5 – Dimensions of the shell roof

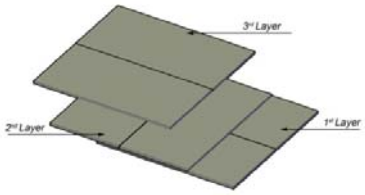

Figure 8.6 – Pattern of the plywood layers

- *Buttresses:* the two buttresses aims as supports for the two taped timber beams. The thrust coming from the edge beams as compression is directly transferred to the stone masonry buttress. Their thickness is around 0,5 meters and they present a triangular shape as is common for this type of structural elements.
- *North and East external walls:* on the north and east side the roof is supported by two external masonry walls. Their height is around 2,50 meters and a thickness of around 0,45 meters.
- *Tilted edge beams:* in the south and western part the roof is supported by two tapered and tilted edge beams. The beams are in timber and they present different cross section from the bottom to the top. This is due to two facts: firstly for having less mass far from the buttress support, and the second reason is because the beam needs to follow the geometry of the shell. The Figure 8.7 shows two sections (bottom and top) of the tapered edge beams.

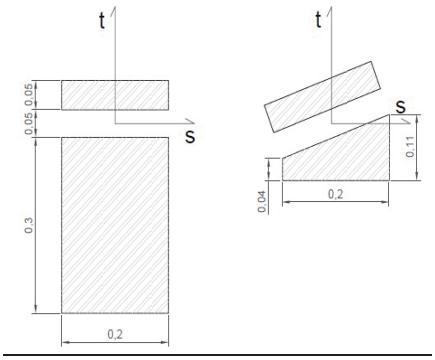

Figure 8.7 – Bottom (left) and Top (right) sections of the tilted edge beams (measures in meters)

- *Vertical Posts:* beneath the two tilted edges are placed three vertical timber posts. Their efficiency is investigated through the numerical analysis. One is placed in the southwestern corner of the shell and is characterized by a cross section of 0,10 x 0,15 meters. The other two posts have same cross section of 0,10 x 0,10

meters and are, respectively, placed beneath the two tilted edges at a distance of 4,57 meter from the southwestern corner.

- *Walls and slab of the main entrance:* the main entrance of the building is in the southwestern corner of the building. The south exterior wall is made by 30 cm concrete block units (Bargues Ballester, 2015). On the west side the wall is a concrete slab reinforced by concrete ribs. The interior wall of the main entrance is a stone masonry wall. This space is 2,50 meters high and is covered by a ceiling of reinforced concrete grid.

In Figure 8.8 is shown an axonometric exploded view of the structural elements that compose the structure. In Apendix 1 is shown the plan and a cross section (drawings developed by Mr. Bargues Ballester and provided by professor David Biggs) of the Nakashima Arts Building.

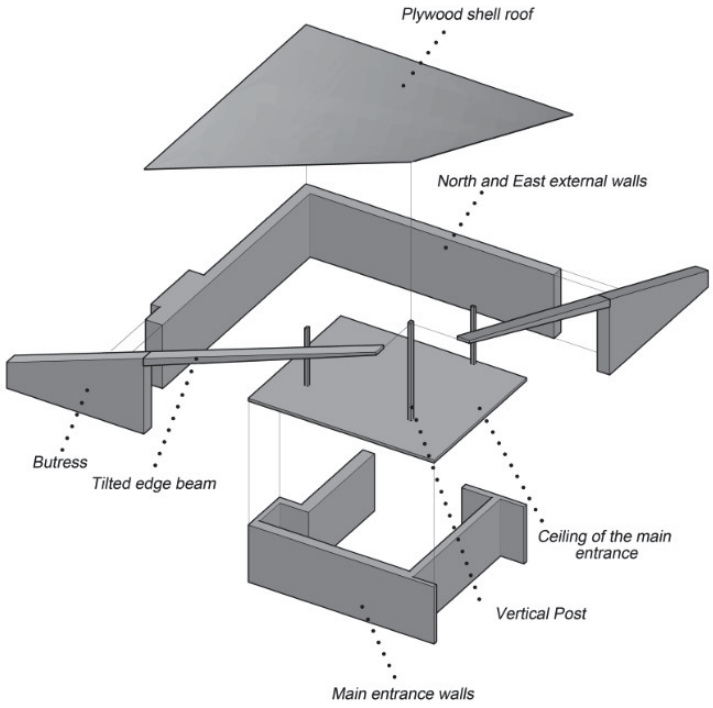

Figure 8.8 – Exploded view

8.4 Damage Survey

The damage survey is more focused on the timber elements with the aim of defining the condition of specific wood elements in the building. The work has been carried out by the wood scientist for A&A, Mr. Ron Anthiny and Mr. Cesar Bargues Ballester of the University of Pennsylvania School of Design. The work has been focused on the following elements:

- South and West edge beams
- Southwest corner post
- Plywood roof diaphragm

The condition assessment of the timber elements is carried out through different methods as: species identification, visual inspection, probing, moisture diagnosis and deterioration quantification though a limited resistance drilling technique.

In this chapter are merely expressed the results of the work done by the experts mentioned above and provided by the professor David Biggs in a report form (Anthony & Associates, 2016).

Findings:

- The flowing wood species characterize the elements analysed:
    - Douglas-Fir: edge beams
    - Eastern White Pine: corner post
    - Baldcypress: ceiling ribs
- Patches of moss have been detected in the roof. However they are not connected to the membrane or diaphragm below, but only looely connected to the gravel. Is suggested to remove them periodically in prevent the developing of vulnerable situations(Figure 8.9 and Figure 8.10).



Figure 8.9 – Patches of moss on the roof (Anthony & Associates, 2016)



Figure 8.10 - Moss in-situ, with awl for scale (Anthony & Associates, 2016)

- West and South tilted edge beams , and the southwest corner post seems to be in good condition and no deterioration process is affecting them. Edge beams are classified as Douglas-fir Select Structural, Beams and Stringers. The corner post is classified as Eastern White Pine Select Structural, Structural Joists and Planks.
- Four posts in the south façade are characterized by deterioration at the base (Figure 8.11). The southeast is the one affected more and a repair work is suggested.



Figure 8.11 - Damage at the base of the southeast post
(Anthony & Associates, 2016)

- Due to heavy rain, it was not advisable to investigate the plywood diaphragm by opening a probe area. Is suggested to proceed with this investigation after the structural analysis and when the weather conditions do not compromise the integrity of the structure.
- Ribs are placed in the interior surface of the shell roof and aims to cover the connection between the plywood panels. They are in good condition, except for a joint failure in one rib (Figure 8.12). Since they have no structural meaning the behavior of the roof is not affected by this failure.



Figure 8.12 - Joint failure in the rib (Anthony & Associates, 2016)

- The environmental conditions did not allow a proper investigation of the connection between the southwestern corner post and the edge beams (Figure 8.13). Is suggested to assess this connection in order to ensure the structural function and integrity of the post.



Figure 8.13 - Connection between edge beams and corner post (Anthony & Associates, 2016)

9. MECHANICAL CHARACTERIZATION

The roof of Nakashima Arts Building is composed by plywood layers bounded together with adhesive and nails for the shell structure. The knowledge of the mechanical properties is of critical importance for their proper use and for the understanding of their behavior. The structural elements that define the behavior of the roof structure are:

- Plywood roof diaphragm
- Tilted edges beams
- Vertical posts

The mechanical properties are defined thorough the identification of the wood species and then its grading. This last step depend on the size, specie, growth characteristics, exposure and load condition. The procedures have been done by Mr. Ron Anthony, Mr. Cesar Bargues and Mr. David Biggs. The results were provided by the Professor David Biggs. The following Table 9.1 summarize the species of the structural elements mentioned above and the codes used for their structural grading and determination of the allowable design values. The allowable design values are based on test data and procedures defined by the America Society for Testing and Materials (ASTM) and are shown in the Table 9.2 and Table 9.3 for all the structural elements.

Table 9.1 - Species and Referring codes of the structural elements

Structural element	Specie	Code
South Edge beam	Douglas-fir	Western Lumber Grading Rules (2011)
West Edge beam	Douglas-fir	Western Lumber Grading Rules (2011)
Posts	Eastern White Pine	Standard Grading Rules for Northeastern Lumber (2013)
Plywood	Ponderosa Pine	Plywood Design Specification (1997) - APA

Table 9.2 - Mechanical properties for Edge Beams and Posts

		Extreme Fiber Stress in Bending Single Member	Tension Parallel to Grain	Horizontal Shear	Compression Perpendicula - Parallel to Grain		Modulus of elasticity
Structural Element	Grade	Fb	Ft	Fv	Fc⊥	Fc	E
		[kPa]	[kPa]	[kPa]	[kPa]	[kPa]	[Gpa]
South and West edge beams	No.1	8963	4309	1137	3585	5654	8,274
Posts	No.2	3103	2068	862	2413	2241	6,205

Table 9.3 - Mechanical Properties of the Plywood

Structural Element	Grade	Fb	Ft	Fv	Fs	Fc⊥	Fc	G	E
		[kPa]	[kPa]	[kPa]	[kPa]	[kPa]	[kPa]	[Gpa]	[Gpa]
Plywood	EXP 1,2 or INT	8274	8274	827	331	1448	6825	0,379	8,274

Fb: Extreme Fiber stress in Bending

Ft: Tension in Plane of Plies (ar 45° to face grain use 1/6 Ft)

Fv: Shear Through the Thickness (at 45° to face grain use 2Fv)

Fs: Rolling Shear in the Plane of Plies (at 45° to face grain use 1-1/3 Fs)

Fc⊥: Bearing on Face (perpendicular to Plane Plies)

Fc: Compression in Plane of Plies (at 45° to face grain use 1/3 Fc)

G: Shear Modulus Through the Thickness (at 45° to face grain use 4G)

E: Modulus of Elasticity in Bending in Plane of Plies

10. DEFINITION OF LOADS AND LOAD CASES

10.1 Definition of Acting Loads Type

The loads that acts in the roof structure of the Nakashima Arts Building are mainly three types: the dead load of the plywood, the permanent load of all the covering materials, snow load and the wind load. Since the roof is not practicable there is no live load acting. Moreover, is considered also the load of the ribs placed underneath the roof with the aim of covering the connections between the plywood panels. Table 10.1 shows the intensities of all the loads considered.

Table 10.1 – Load Type and related intensity

Load Type	[kN/m2]
Plywood (3layers)	0,287
Ribs	0,024
Celotex (2 layers)	0,024
Asphalt felts	0,096
Marble chips	0,718
Snow	1,436
Wind	1,197

10.2 Definition of the Load Cases

The linear elastic analysis are performed considering five different configurations of load cases. The first three load cases involve the snow load, instead the last two concern the wind load. They are defined as following:

- LC1: full dead load and snow load uniformly distributer all over the shell roof.
- LC2: full dead load and quarter of the snow load swept into the northeast half area of the roof (Figure 10.1)
- LC3: full dead load and half of the snow load swept into the northeast half area of the roof (Figure 10.2)
- LC4: full dead load and sixty percent of the wind load acting as uplift uniformly all over the shell roof
- Lc5: full dead and the wind load acting as downward into the southwestern half area of the roof (Figure 10.3)

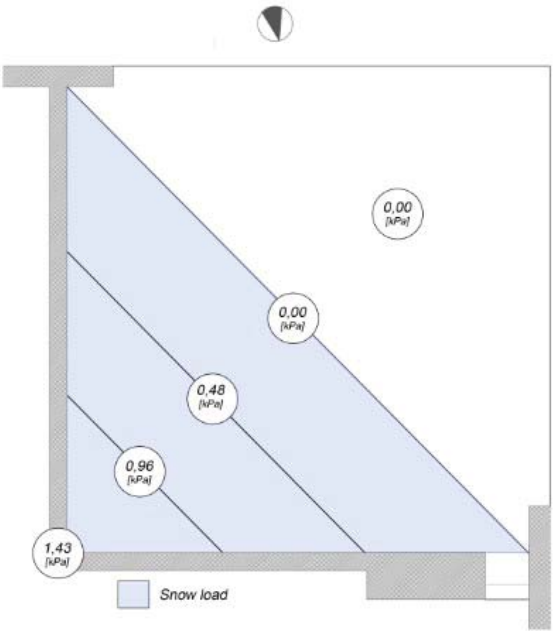

Figure 10.1 - LC2

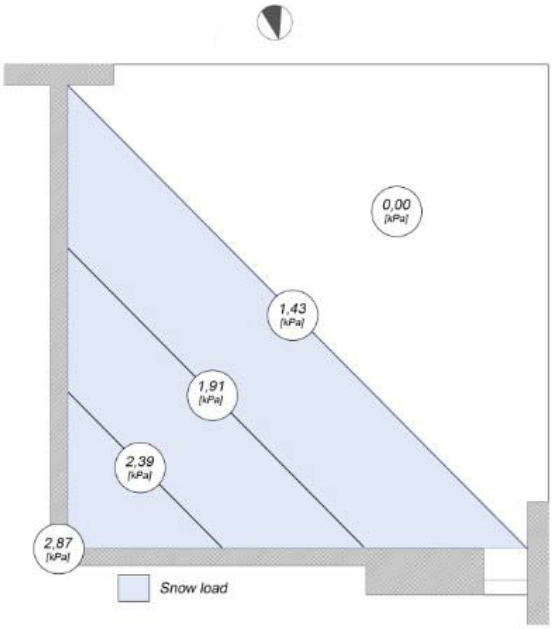

Figure 10.2 - LC3

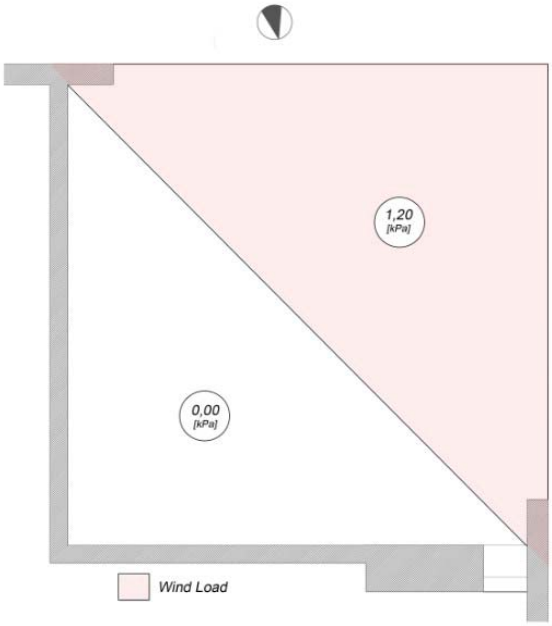

Figure 10.3 - LC5

11. FE MODELING AND ANALYSIS

The modeling and the analysis are computed, through the software ADINA, as already mentioned in the chapters above. The structural analysis of the structure is preceded by the important step of the model verification (Chapter 6 – Verification of the FE Modeling) which consists on comparing the numerical results with the analytical ones. Once the model was verified, it was possible to proceed with the structural assessment of the structure in different configurations and subjected to different load cases. Since the modeling needs to describe in the best way possible the real behavior of the structure, different aspects are taken into account and shown in the following chapter *Modeling strategy*.

More important than obtaining the results is their interpretation and discussion, indeed the following chapter *Methodology of results analysis* explains the different steps through which the results are analyzed.

Through the strategy of modeling and the methodology of interpretation, the results of the linear elastic analysis are shown in the chapter *Effect of boundary conditions and load cases in the structural behavior of the shell*.

11.1 Modeling Strategy

The proper structural analysis and “sensitivity” analysis required a refined model where different aspects (simplified in the step of verification of the model) are considered in order to simulate as much as possible the real structural behavior of the roof.

The model used in the “sensitivity” analysis has a density of 72x72 in order to catch with a good approximation the bending behavior. The plywood shell structure is modeled by 4-nodes shell elements, while the edge beams by 2-node Hermitian beam elements (Chapter 5 – FEM concept).

The second aspect that is taken into account in the refined modeling concern the edge beams. The two tilted edge beams present a variable cross section along their length (Figure 11.1). Moreover, the edge beam is shaped in the way to follow the geometry of the hyperbolic-paraboloid roof and the connection between this edge beams and the plywood shell is stiffened by the addition of boards above the shell.

Due to this, the moment of inertia, which influence the rigidity of the beam, is different in every section of the beam. This was taken into account by discretizing the beam in twelve part and every part is described by the median section (Figure 11.2). For the twelve sections the moments of inertia I_t, I_s and the product of inertia I_{ts} have been calculated and implemented in ADINA software as a beam element with generic section (local axis of the beam elements shown on Figure 5.4 Chapter 5). In the Appendix 2 is shown the table with the inertial properties of every cross section considered.

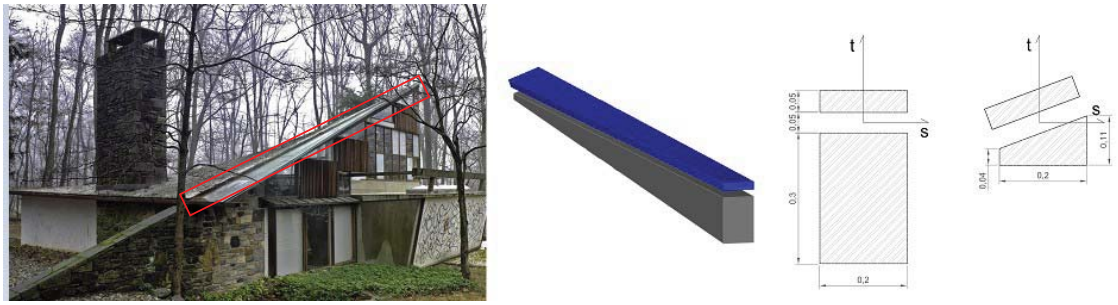

Figure 11.1– Localization of the tilted edge beams (left); scheme of tapered edge beam (center); top and bottom cross sections (right)

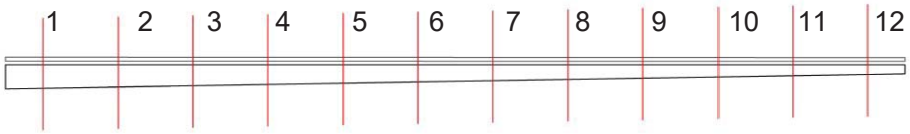

Figure 11.2 – Discretization of the edge beam

In the two previous preliminary model all the loads are applied respectively in the global z-direction (for comparison with the simplified solution) and normal to the surface (for the model verification with the analytical solution). In the refined analysis concerning the effect of the different configurations the loads are treated depending their type.

The dead load is applied in the global z-direction, the wind load is applied as normal to the surface, while the snow load is given as force intensity per projection of area on which it acts to horizontal plane. For curved surface the snow acts with a higher intensity where the curvature is almost zero (Figure 11.3). In the modeling this distribution is considered by applying the load as z component only which correspond to the distribution defined in the Figure 11.4.

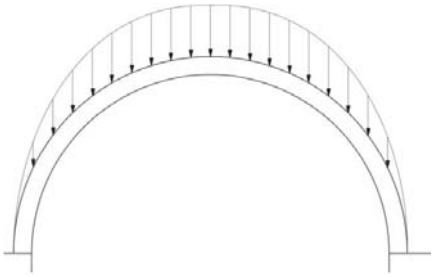

Figure 11.3 - Distribution of snow in the Arch

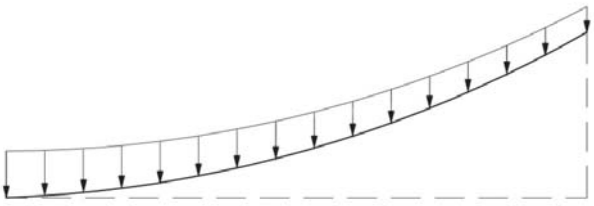

Figure 11.4 - Distribution of snow in the Shell

The last aspect that have been considered in the refined model concern the post. In the configurations where they are considered as structural elements the description of their behavior is done by 2-node truss elements (Chapter 5 – FEM Concept).

11.2 Methodology of Results Analysis

The results of the linear elastic analysis are shown through four different parameters:

- Maximum and minimum principal stresses (denoted as stress P1 and stress P3)
- Vertical displacement of the diagonal
- Shear through the thickness τ_{st}
- Axial force in the Posts

The principal stresses P1 and P3 are analyzed and compared between the different load cases and boundary conditions in two different steps:

- *Qualitative comparison*: where the stresses are plotted on top, mid and bottom surface and their distribution is analyzed in order to find the maximum ones and also the ones that can represent critical situation due to their location and concentration. Moreover the stresses are analyzed also in regarding to the principal direction in which are acting since the APA () defines the strength of the plywood as a function of the direction in which the stress is acting.
- *Quantitative comparison*: in this step the values defined through the qualitative comparison are compared with the strengths of the plywood material (defined in the Chapter 11 – Mechanical Characterization). The APA (The Engineered Wood Association, 1997) used as a reference for the definition of the mechanical properties defines the compressive (Fc) and tension (Ft) strengths depending on the direction of the principal stress. When it is acting at 45° to face grain the tensile strength to be used is Ft/6, while the compression is Fc/3. Concerning the tensile behavior the principal stress has been compared only with the strength Ft/6 since in every configuration and every load case the critical or maximum tensile stress is acting at 45° to the face grain of the ply wood.
  In compression behavior two maximum values are considered: one where the stress is acting perpendicular to the face grain (Max P3) and one where is acting at 45° (Max 45P3). Thorough this quantitative comparison the critical configurations are identified.

The shear through the thickness is analyzed by comparing the maximum values with the material strength. The band plots are shown in the Appendix 3.

Concerning the posts their results are analyzed in terms of maximum compressive force between the all configurations and load cases. Since the sections of the posts are different, the maximum compressive force is evaluated for the post in the corner between the tilted edges and for the two lateral posts. The maximum compression is than compared with the strength and also with the critical buckling load.

11.3 Effects of Boundary Conditions and Load Cases in the Structural Behavior of the Shell Roof

The configurations studied through the linear elastic analysis are four and depend on the boundary conditions of the horizontal edges and if the posts are considered as structural elements or not. For every configuration is subjected to five load cases. The band plots of the results are shown always in the plan X-Y and all the considerations on localization of stresses are referred to the orientation shown in the Figure 11.5.

The first three load cases concern the different distribution of the snow load, while the remaining two (LC4-LC5) refer to the wind load. For this reason the analysis and the comparison of the results is done between the load cases that involve the same type of load (Snow – LC1, LC2, LC3; Wind – LC4-LC5).

As mentioned in the chapters above the wind is considered as acting in two different ways. The first is a uniform uplifting of the roof (LC4). The second is a uniform downward on half area of the roof (LC5).

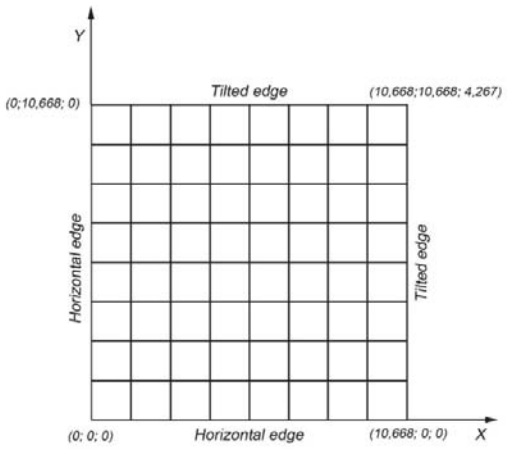

Figure 11.5 - Orientation of results band plots

Concerning the first wind load case (LC4) its intensity is not enough to have a real uplifting because the dead load of the roof has a higher value. However this load case has been analyzed anyway because the wind and the dead load act in different way. The first is acting in the global z-direction, while the second is acting normal to the surface so the final load will have a different direction in every point of the shell.

The load cases are analyzed for each configuration, with the configurations summarized as following:

- *1st Configuration*: clamped horizontal edges and posts not considered
- *2nd Configuration*: hinged horizontal edges and posts not considered
- *3rd Configuration*: clamped horizontal edges and posts considered
- *4th Configuration*: hinged horizontal edges and posts considered

These configurations were considered because they represent extreme cases as it is not clear how the connection to the supporting walls actually works and whether the posts provide any structural support.

11.3.1 First Configuration - 1st

LC1-LC2-LC3

As a first step the principal stresses P1 and P3 has been computed for all the three load cases and the results in term of maximum values are shown in the Table 11.1.

Table 11.1- Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% difference between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC1	Max	-3,60	1,02	72	0	0
	Min	0	0			
LC2	Max	-1,80	0,60	67	-50	-42
	Min	0	0			
LC3	Max	-1,87	0,92	51	-48	-10
	Min	0	0			

The uniform distribution of the snow load causes the maximum values of the principal stresses (P3 – compression; P1 – tension). This load case is also characterized by the highest percentage of difference between the two principal stresses. Moving from the uniform distribution to the distribution where half of the snow load is swept with a triangular distribution onto half of roofs area (LC3) the maximum stresses decrease (-48%) and the difference between each other's is getting lower (passing from 72% in LC1 to 51% in LC3). The comparison can not be done only in terms of maximum stresses because they are concentrated in one area and a wider view in all the structure is needed. For this purpose the band plots of the principal stresses (in the middle surface of the shell structure) for all the load cases have been computed and are shown in Figure 11.6, Figure 11.7 and Figure 11.8. The same range of stresses is used in all the contour plots and is defined through the maximum values.

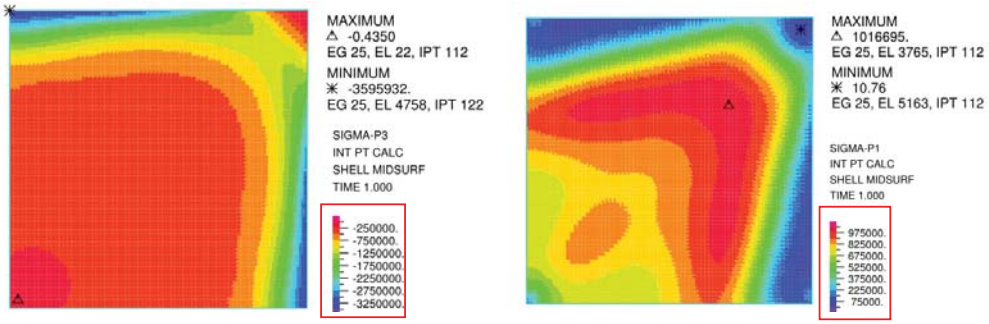

Figure 11.6 - LC1 (P3 left, P1 right) Midsurface [Pa]

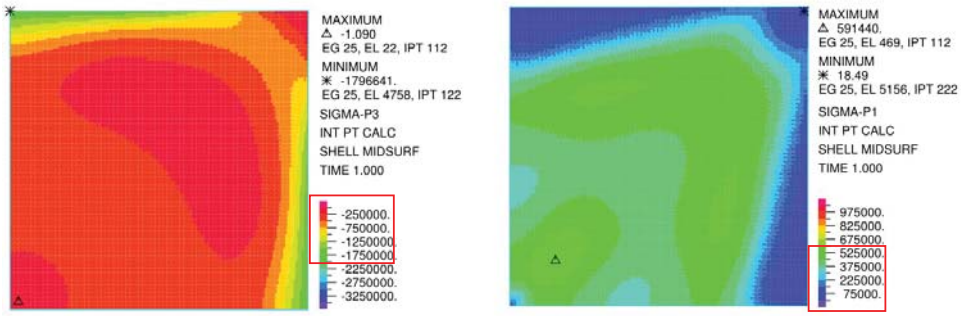

Figure 11.7 – LC2 (P3 left, P1 right) Midsurface [Pa]

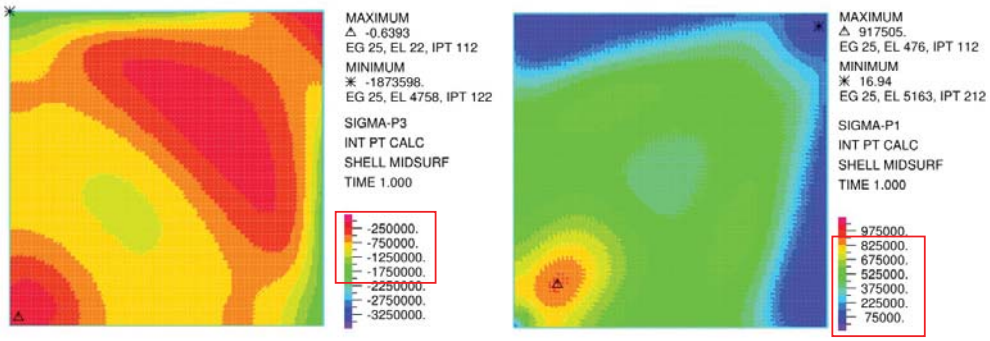

Figure 11.8 – LC3 (P3 left, P1 right) Midsurface [Pa]

The mid surface band plots evidence that in the first load case the compression is more concentrated in the supports between the tilted and horizontal edges, while in the main of the rest area, the compression is quite low and uniform. The stress P1 which concerns the tension, in the load case LC1 is spread in two main areas, perpendicular to the horizontal edge beams and the maximum value is in the corner between the two tilted edge beams. From the figures above is possible to underline that moving from the LC1 to the LC3, the compression is becoming more heterogeneous and is interesting not only the area of the supports between the tilted and horizontal edge beams but also the central area of the shell. The tension P1 is becoming more concentrated in the corner between the two horizontal edges.

For a better understanding of the behavior and also of the bending effects the principal stresses have been plotted also on top and bottom surfaces for load cases LC1, LC2 and LC3 (Figure 11.9, Figure 11.10 and Figure 11.11).

The band plots through the thickness highlights that in all the load cases the compression is concentrated close to the supports between tilted and horizontal edges.

Concerning tension, the first load case is concentrating the stresses differently on top and bottom surface. On top surface is more concentrated in the corner between the tilted edges (indicated by A in Figure 11.9), while on bottom surface is more concentrated in the opposite corner (B in Figure 11.9). The concentration of tensile stresses in two opposite areas underlines the structures' bending behavior for this load case.

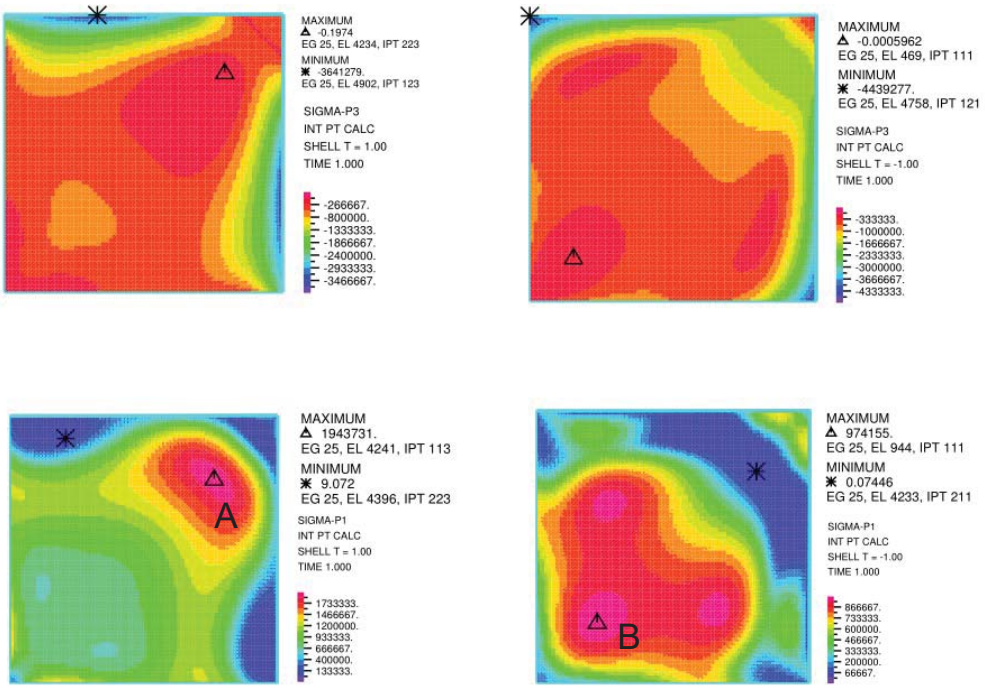

Figure 11.9 - LC1: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

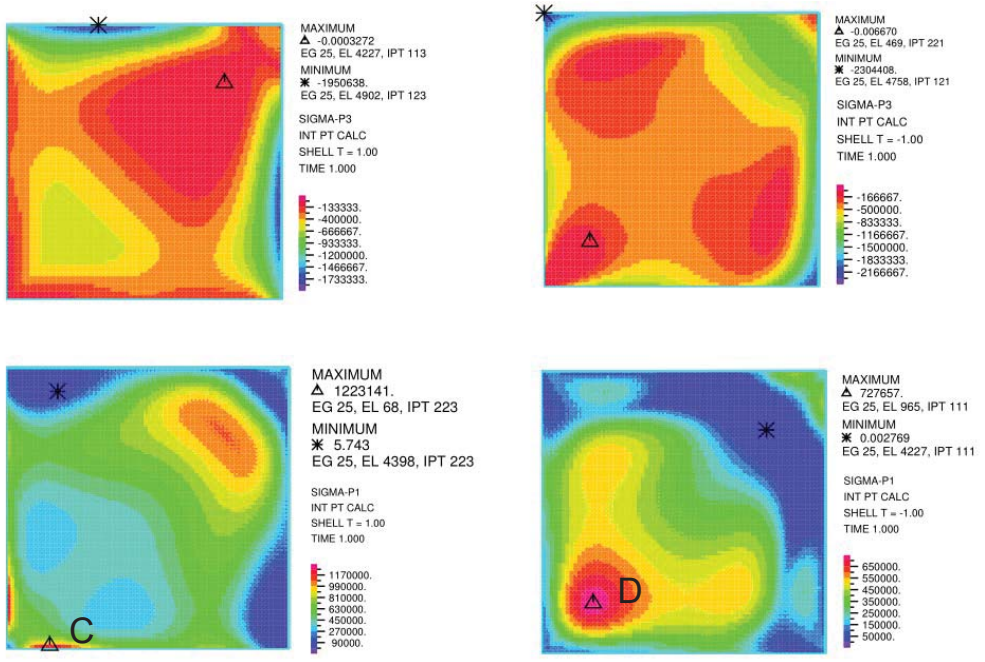

Figure 11.10 – LC2: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

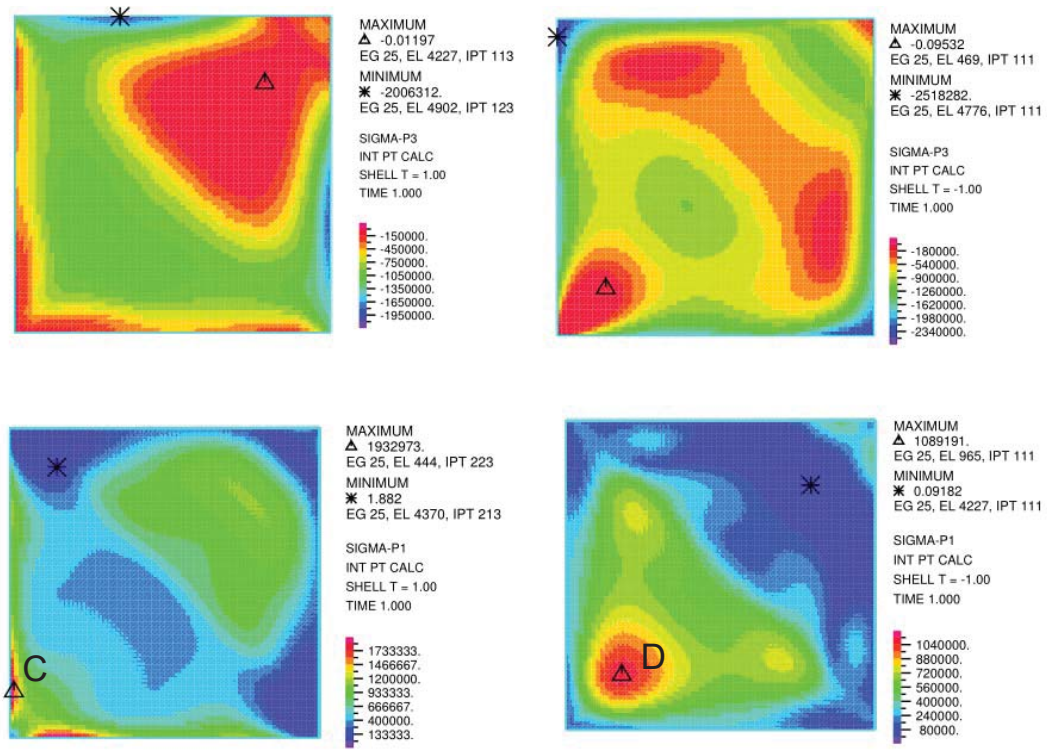

Figure 11.11 - LC2: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

The second and third load cases show similar behavior and distribution of stresses. In terms of tension it is localized differently on top and bottom surface. On top surface is concentrated in the horizontal edges close to the support (C in Figure 11.10 and Figure 11.11), while in bottom surface is not in the horizontal edges but close to their shared corner (D in Figure 11.10 and Figure 11.11). The highest value is on top surface but in the quantitative comparison with the strengths is considered also the maximum tension at bottom surface in LC3 due to its concentration and intensity. Figure 11.12, Figure 11.13 and Figure 11.14 show the location of the maximum stresses for every load case and the points that are considered as critical. In the same figures are shown also the principal directions. In the Table 11.2, Table 11.3 and Table 11.4 the stresses in the critical points are compared with the related strengths of the plywood defined according the APA (The Engineered Wood Association, 1997) specifications.

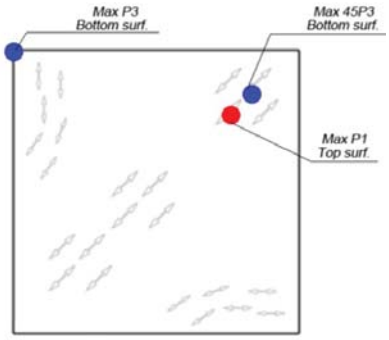

Figure 11.12 – Principal directions and location of maximum stresses LC1

Table 11.2 - Comparison stresses/strength LC1

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-4,44	-6,83	**0,65**
Max 45P3	**Fc/3**	**3P3/Fc**
-2,00	-2,28	**0,88**
Max P1	**Ft/6**	**6P1/Ft**
1,94	1,38	**1,41**

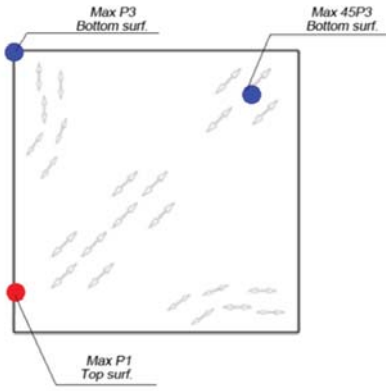

Figure 11.13 – Principal directions and location of maximum stresses LC2

Table 11.3- Comparison stresses/strength LC2

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,3	-6,83	**0,34**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,00	-2,28	**0,44**
Max P1	**Ft/6**	**6P1/Ft**
1,22	1,38	**0,89**

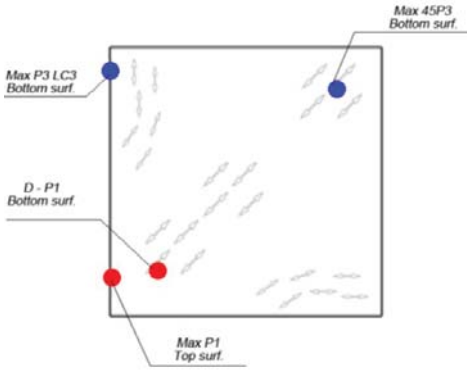

Figure 11.14– Principal directions and location of maximum stresses LC3

Table 11.4 - Comparison stresses/strength LC3

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,52	-6,83	**0,37**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,08	-2,28	**0,47**
Max P1	**Ft/6**	**6P1/Ft**
1,93	1,38	**1,4**
D-P1	**Ft/6**	**6D/Ft**
1,08	1,38	**0,78**

In all the three load cases the compression does not lead to any critical situation as the maximum stresses are lower than the strengths. The comparison with the strength underlines that the tensile strength is exceeded in the LC1 and LC3 and the ratio stress/strength is almost the same in the two load cases. What differentiates them is the localization of this stresses.

In LC1 the highest tensile strength is in the corner between the two tilted edges (A in Figure 11.9) but is spread along a larger area than in the case of LC3. In third load case the maximum tensile stress is extremely localized in the horizontal edges close to the corner between them (C in Figure 11.11).

From the fact that the allowable stress in tension is exceeded and that the tensile stresses are extremely localized in a small area make possible to deduce that the load case LC3 is the most critical.

The vertical displacement of the diagonal of the structures that goes from the corner of the horizontal edges to the corner of the free edges highlights that LC1 leads to the larges deflection.

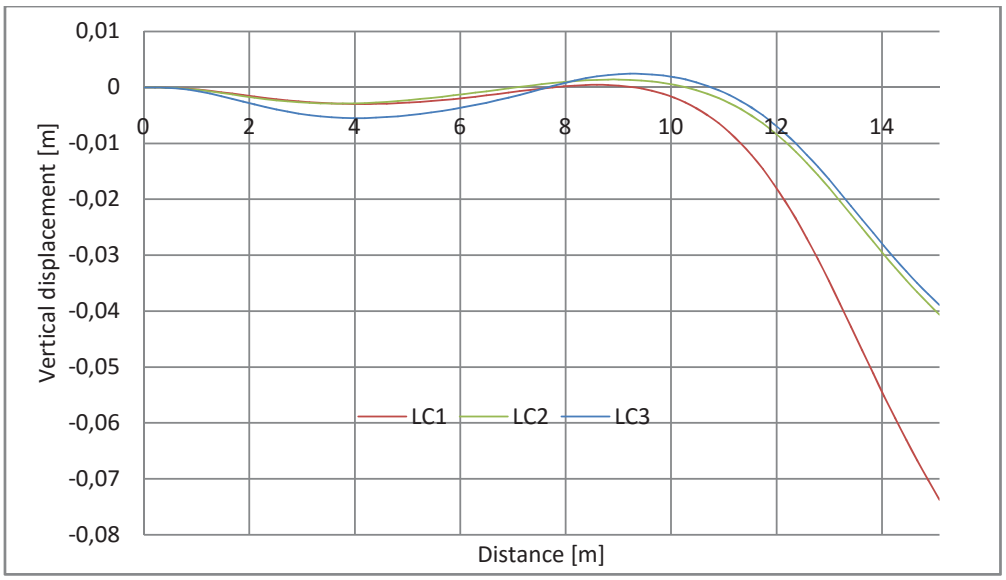

Figure 11.15 - Vertical displacement of the diagonal

LC4-LC5

Following the same methodology of comparison of the results showed in the previous case of the snow load, the maximum principal stresses in the mid surface are computed and shown in the Table 11.5 for the both snow load cases.

Table 11.5 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% difference between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC4	Max	-0,71	0,17	76	0	0
	Min	0	0			
LC5	Max	-3,48	1,02	71	389	496
	Min	0	0			

The table above highlights immediately the big difference between the maximum principal stresses induced by the LC4 and LC5. This is due to the fact that the LC4 has a low intensity. Their difference can be observed also in the band plot of the stresses. They have the same scale and is defined by the fifth load case as it present the highest values of stresses.

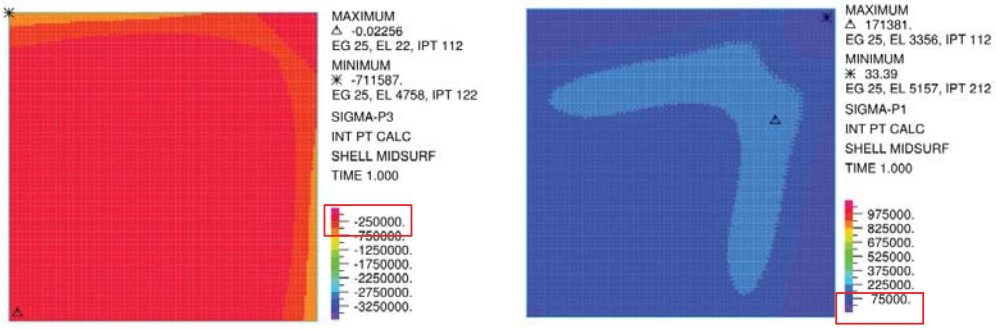

Figure 11.16 – LC4 (P3 left, P1 right) Midsurface [Pa]

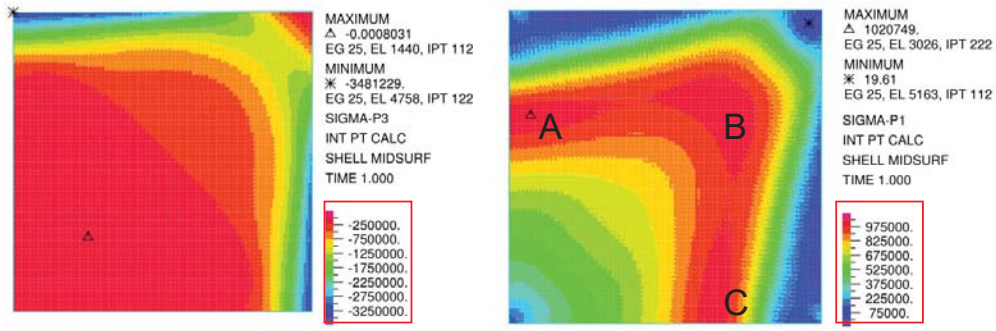

Figure 11.17 – LC5 (P3 left, P1 right) Midsurface [Pa]

The mid surface band plots show how the range of principal stresses is small in the LC4 compared with LC5. The LC5 distributes the compression stresses mainly in half area of the structure, where the load is acting, with a higher concentration in the tilted edges close to the supports. Concerning the tension, it is mainly distributed in two areas, perpendicular to the horizontal edge beams, and with a higher concentration in three areas indicated with A,B and C in the Figure 11.17.

The distribution of the stresses along the thickness (top and bottom surface) for both load cases are shown in the Figure 11.18 and Figure 11.19.

From these last band plots is possible to conclude that concerning the compression the behavior of the structure under the two load is similar; on top surface the maximum compression is concentrated in the tilted edges (point A in Figure 11.18 and Figure 11.19) , while in the bottom surface is concentrated in the support (point B in Figure 11.18 and Figure 11.19).

The main difference between the two load cases is in tension behavior. In the fourth load case the tension is concentrated in two areas (C and D in the Figure 11.18). The tension (D in Figure 11.18) in the tilted edges close to the free corner is a consequence of the fact that here the final load is almost tangent to the surface and this is reflected in tension in the edge connection.

In the LC5, the concentration of tensile behavior at the top surface is in the same area as previously (C in Figure 11.19), while at the bottom surface the wind downward in half area of the shell (in the side of the tilted edge beams) induces to high concentration of tensile stresses (P1) in the horizontal edges (area indicated by E in the Figure 11.19).

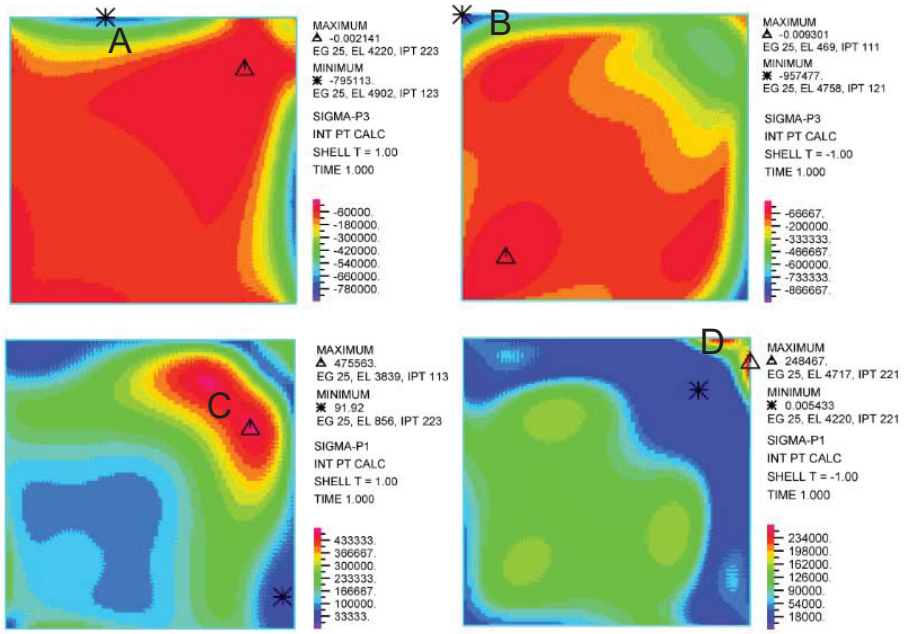

Figure 11.18 – LC4: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

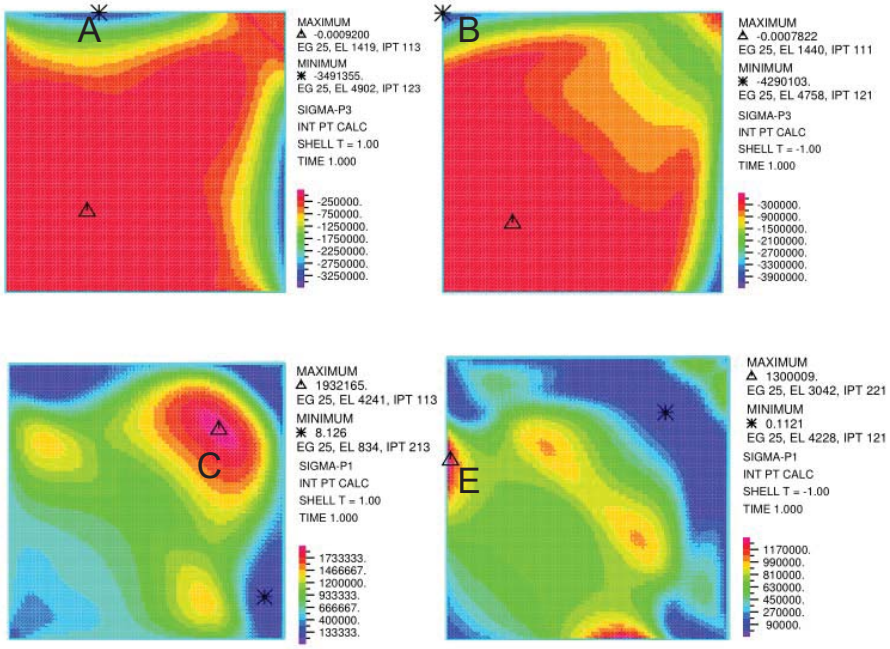

Figure 11.19 – LC5: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

The maximum principal stresses in compression and tension (P3 and P1) are compared with the allowable stresses (Table 11.6 and Table 11.7) taking always into account the principal direction (Figure 11.20 and Figure 11.21).

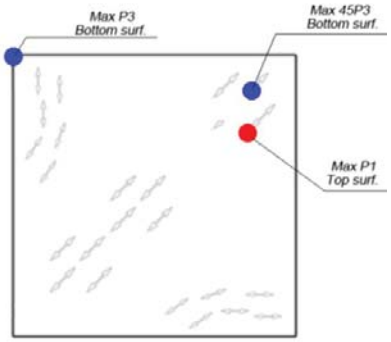

Figure 11.20 – Principal directions and location of maximum stresses LC4

Table 11.6 - Comparison stresses/strength LC4

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-0,96	-6,83	**0,14**
Max 45P3	**Fc/3**	**3P3/Fc**
-0,47	-2,28	**0,21**
Max P1	**Ft/6**	**6P1/Ft**
0,48	1,38	**0,35**

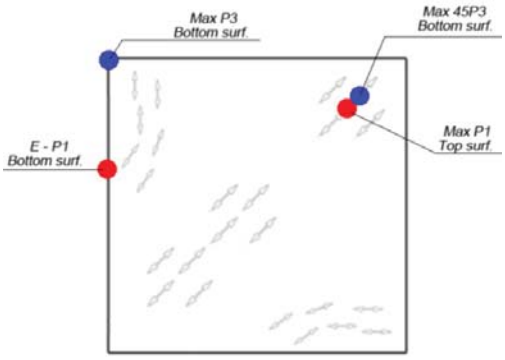

Figure 11.21– Principal directions and location of maximum stresses LC5

Table 11.7 - Comparison stresses/strength LC5

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-4,29	-6,83	**0,63**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,80	-2,28	**0,79**
Max P1	**Ft/6**	**6P1/Ft**
1,93	1,38	**1,4**
E-P1	**Ft/6**	**6D/Ft**
1,3	1,38	**0,94**

The quantitative comparison shows that fourth load case does not induce to critical situations for both compression and tension behavior. The fifth load case is characterized by an exceedance of the allowable stress in tension. The stress exceeds the strength of about 40% in the area indicated by C in the (Figure 11.19). Moreover, a critic situation is also on the bottom surface in the area E indicated in Figure 11.19, since here the stress is similar to the strength (the ratio stress/strength is 0,94) and is highly localized in the horizontal edges.

The high difference in term of stresses between the two load cases is also confirmed by the graph (Figure 11.22) that shows the vertical displacement of the diagonal that is on the symmetric axis. In the LC4 the maximum displacement is around 1 cm while in the second load case is 7,4 cm.

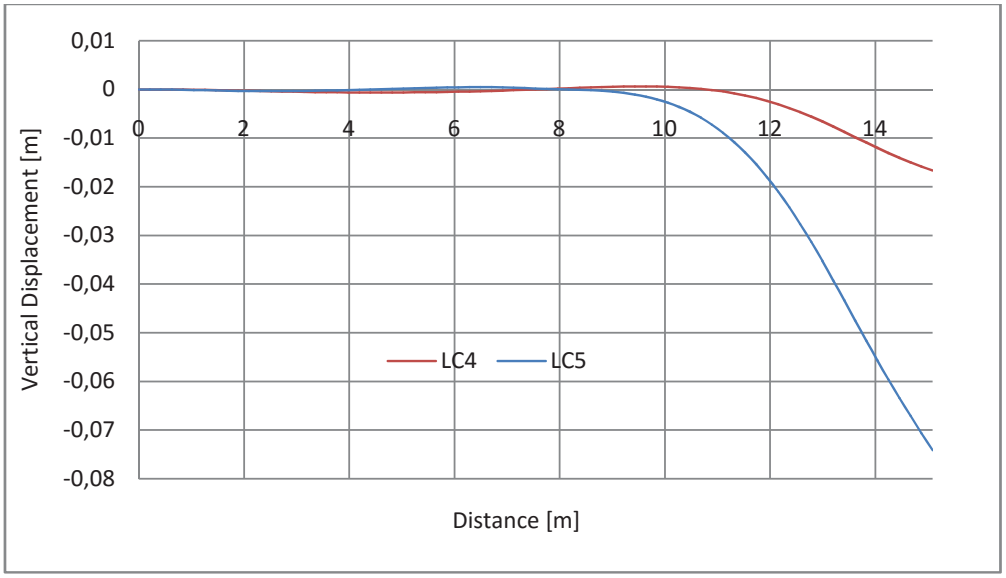

Figure 11.22 - Vertical displacement of the diagonal

11.3.2 Second Configuration - 2nd

LC1-LC2-LC3

The same method defined in the comparison of the previous results, concerning the clamped edge as boundary conditions, is used for the comparison where the horizontal edges are hinged. The maximum principal stresses in the mid surface are shown in the Table 11.8.

Table 11.8 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% differentce between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC1	Max	-4,31	1,03	76	20	2
	Min	0	0			
LC2	Max	-2,21	0,59	73	-49	-43
	Min	0	0			
LC3	Max	-2,27	0,91	60	-47	-12
	Min	0	0			

As in the case of clamped edges, the LC1 induces the highest stresses in the structure and it present the highest percentage of difference between P3 and P1. The Table 11.9 compares the maximum stresses in the case of clamped edges (1st Configuration) with the ones considering the edges hinged. The values are not differing significantly but the configuration with hinged edges is presenting higher values, except for the stresses P1 in LC2 and LC3.

Table 11.9 - Comparison of maximum stresses on mid surface between 1st and 2nd configurations

		1st Configuration Clamped Edges		2nd Configuration Hinged edges			
		P3C [MPa]	P1C [MPa]	P3H [MPa]	P1H [MPa]	P3C/P3H	P1C/P1H
LC1	Max	-3,60	1,02	-4,31	1,03	**0,83**	**0,98**
	Min	0	0	0	0		
LC2	Max	-1,80	0,60	-2,21	0,59	**0,81**	**1,01**
	Min	0	0	0	0		
LC3	Max	-1,87	0,92	-2,27	0,91	**0,82**	**1,01**
	Min	0	0	0	0		

Figure 11.23, Figure 11.24 and Figure 11.25 show the distribution of the principal stresses, in the mid surface, for the three load cases. All the band plot have the same range and is defined from the LC1 that present the highest values.

The band plot of the principal stresses in the mid surface, show almost the same trend of behavior as in the case of clamped edges. The mainly difference is that the compression in the LC3 is more

homogeneous than the case with clamped edges and this is mainly due to the deformed shape. Still the maximum values of compression interest corners between the horizontal and tilted edges. The tension is getting more localized, as in the previous case, in the corner between the two horizontal edge beams but with lower magnitude than the case of clamped edges.

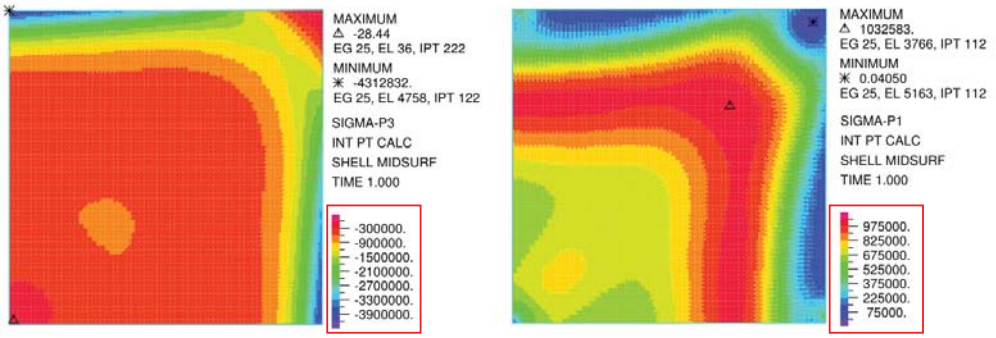

Figure 11.23 - LC1 (P3 left, P1 right) Midsurface [Pa]

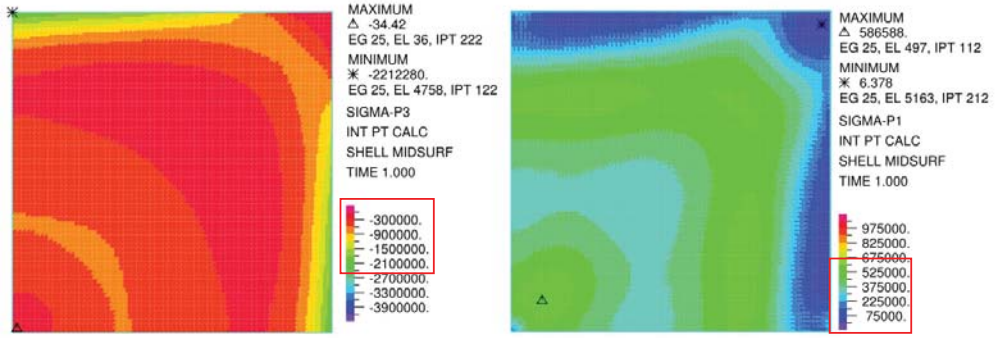

Figure 11.24 - LC2 (P3 left, P1 right) Midsurface [Pa]

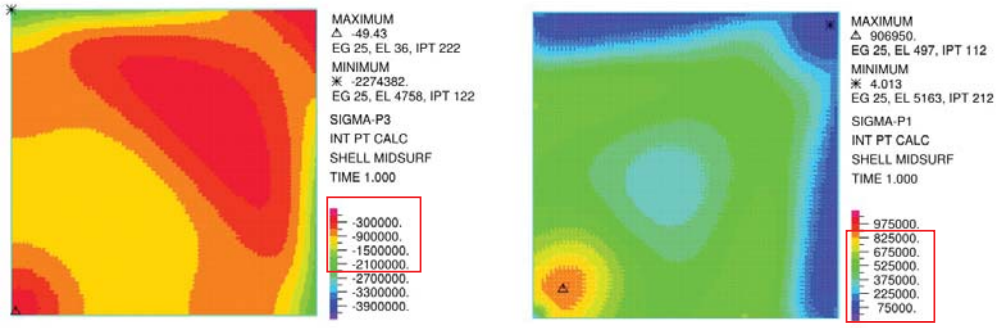

Figure 11.25 - LC3 (P3 left, P1 right) Midsurface [Pa]

In addition to the stresses in the mid surface, also the stresses in the top and bottom surface are processed (Figure 11.28, Figure 11.29 and Figure 11.30). The maximum compression is always in the supports that connects the horizontal edges with the tilted as in the previous case. The most important difference concern the concentration of the tensile stresses in the load case LC3. In the previous case the tensile stress P1 on top surface was concentrated in the horizontal edges close to the support,

while in this case the concentration of tensile stresses is not along the edges but in the support between the two horizontal edges (A in Figure 11.30). The Figure 11.26 and Figure 11.27 shows the difference in the two cases.

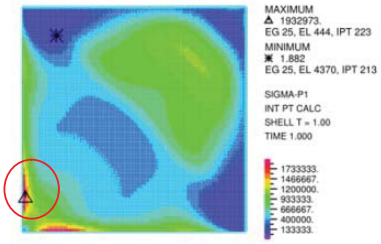

Figure 11.26 – 1st Configuration LC3- P1 Top

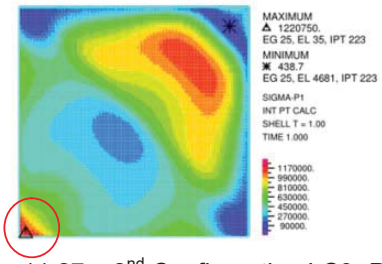

Figure 11.27 – 2nd Configuration LC3- P1 Top

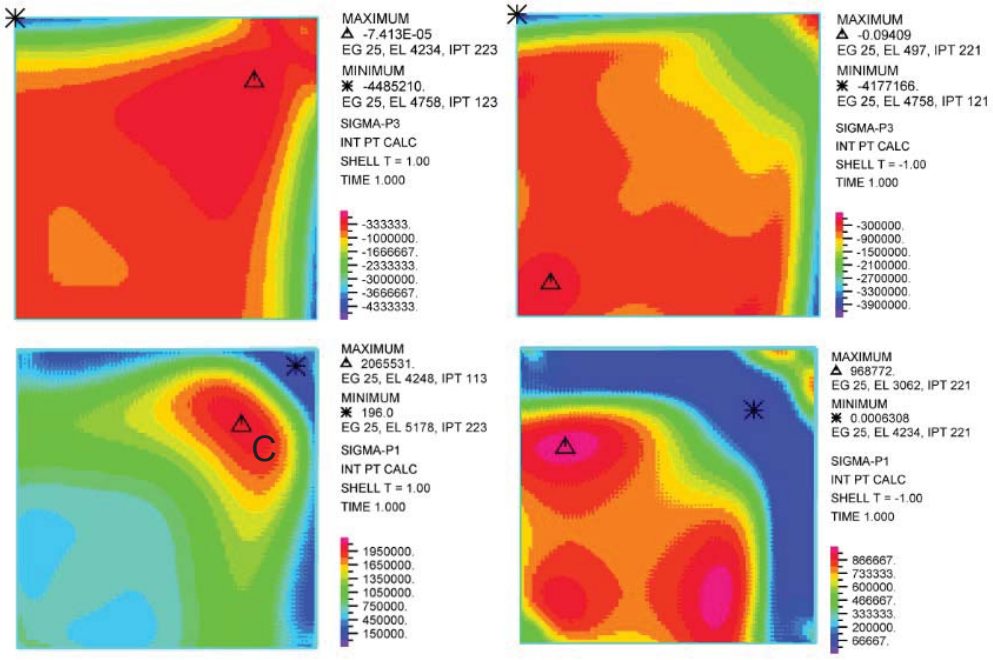

Figure 11.28 - LC1: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

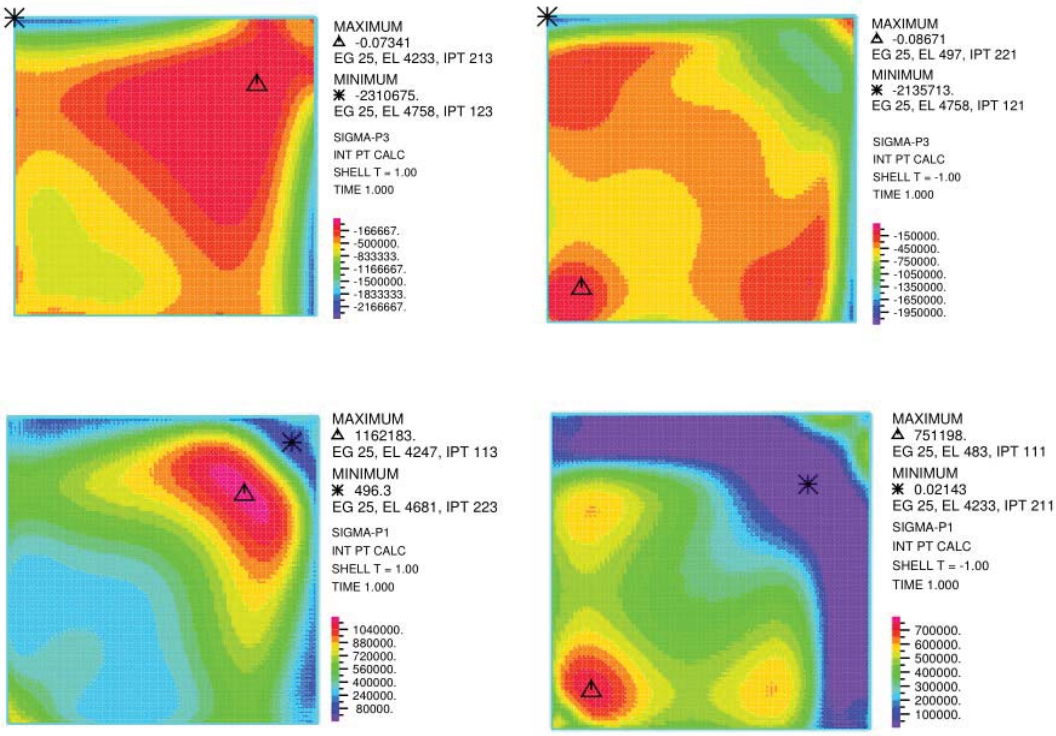

Figure 11.29 – LC2: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

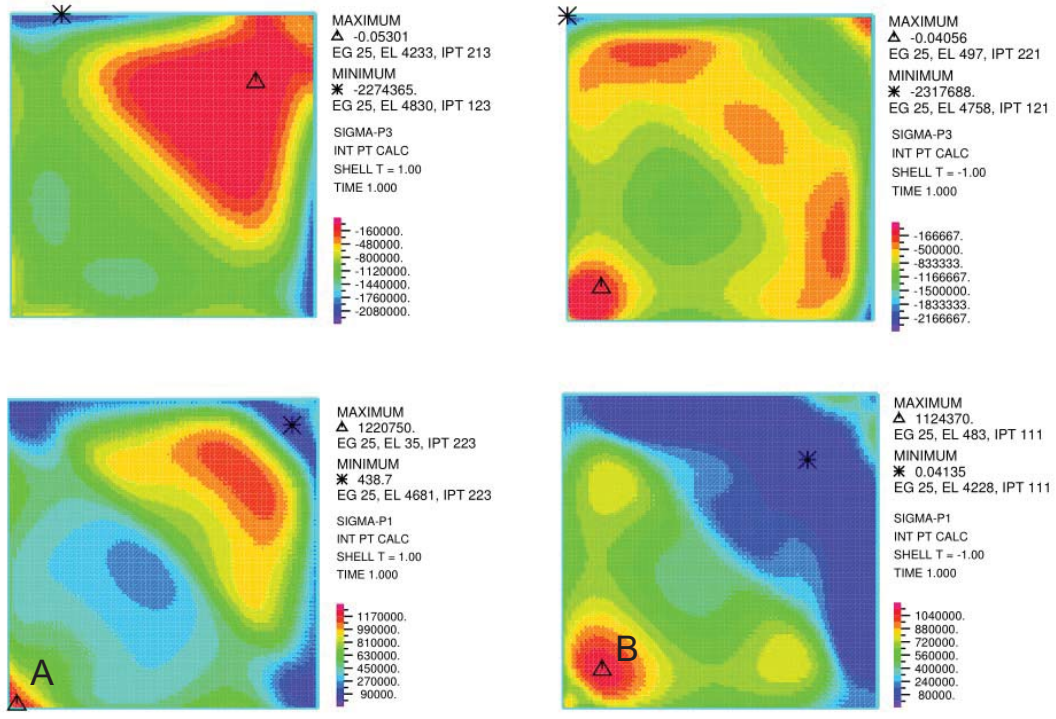

Figure 11.30 - LC3: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

The qualitative analysis shows that the behavior is not changing significantly passing from clamped edges to hinged. As in the previous case the maximum stresses, compression and tension, are compared with the allowable stresses, relating always the stress with its principal direction. Figure 11.31, Figure 11.32 and Figure 11.33 shows the location of the principal stresses and the scheme of the principal directions, which is not changing significantly from the previous case.

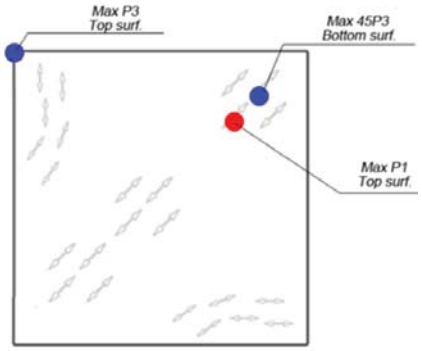

Figure 11.31– Principal directions and location of maximum stresses LC5

Table 11.10 - Comparison stresses/strength LC1

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-4,49	-6,83	**0,65**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,80	-2,28	**0,79**
Max P1	**Ft/6**	**6P1/Ft**
2,06	1,38	**1,5**

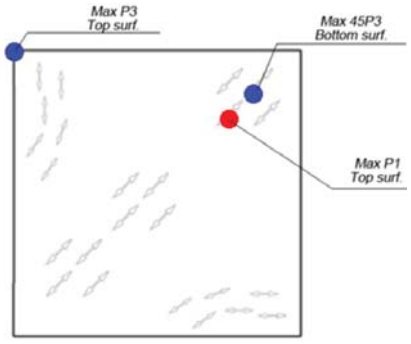

Figure 11.32– Principal directions and location of maximum stresses LC5

Table 11.11 - Comparison stresses/strength LC2

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,31	-6,83	**0,34**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,50	-2,28	**0,66**
Max P1	**Ft/6**	**6P1/Ft**
1,16	1,38	**0,84**

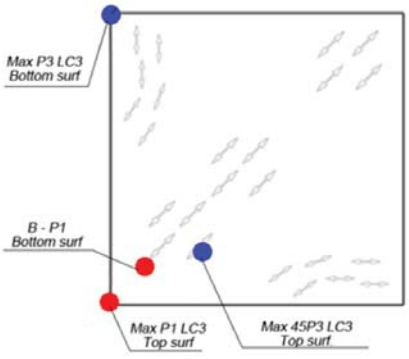

Figure 11.33 – Principal directions and location of maximum stresses LC5

Table 11.12 - Comparison stresses/strength LC3

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,32	-6,83	**0,34**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,60	-2,28	**0,7**
Max P1	**Ft/6**	**6P1/Ft**
1,22	1,38	**0,88**
B-P1	**Ft/6**	**6D/Ft**
1,12	1,38	**0,81**

Figure 11.31, Figure 11.32 and Figure 11.33 underline that in the first two load cases the maximum stresses coincide in the same location and surface. Moving from those two load cases to the third the behavior is changing as the maximum concerning the compression P3 is remaining in the same corner but is moving in the bottom surface. The maximum tensile stress is moving in the opposite corner of the load cases LC1 and LC2 and with a higher concentration in the support.

In Table 11.10, Table 11.11 and Table 11.12 the maximum stresses are compared with the allowable stresses. The ratios stress/strength evidence that the most critical load case is the LC1, with a special regard to the tensile stress that exceeds the strength by 50%. Comparing with the previous configuration, the ratios stress/strength are getting lower in the load cases 2 and 3, especially in the last one, that previously was the most critical.

Summarizing in the configuration with hinged horizontal edges the most critical load case is the first were the snow is uniformly distributed all over the surface. The criticality concern the tensile stress and is localized in the corner between the two tilted edges (C in Figure 11.28).

Changing from clamped edges (1st Configuration) to hinged edges (2nd Configuration) is not affected significantly the displacement, as is possible to notice in the Figure 11.34.

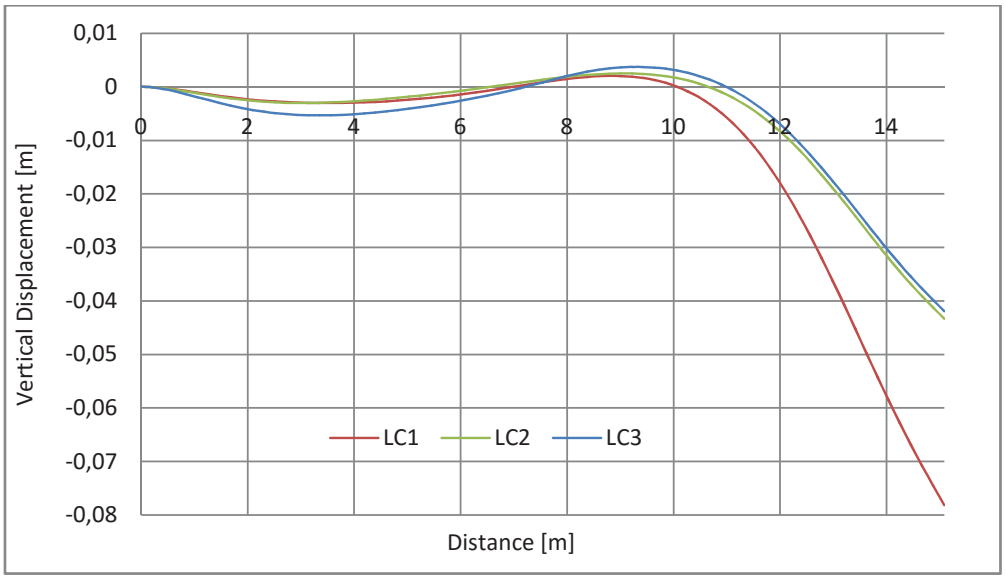

Figure 11.34 – Vertical displacement of the diagonal

LC4-LC5

Considering the horizontal edges as hinged the principal stresses in the mid surface increase (Table 11.14) compared with the clamped edges (1st Configuration). However, in LC4 they still remain quite low (Table 11.13) due to the small intensity of the final pressure.

Table 11.13 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% difference between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC4	Max	-0,93	0,19	79	0	0
	Min	0	0			
LC5	Max	-4,22	1,10	74	352	469
	Min	0	0			

Table 11.14 - Comparison of maximum stresses on mid surface between 1st and 2nd configurations

		1st Configuration Clamped Edges		2nd Configuration Hinged edges			
		P3C [MPa]	P1C [MPa]	P3H [MPa]	P1H [MPa]	P3C/P3H	P1C/P1H
LC4	Max	-0,71	0,17	-0,93	0,19	0,76	0,88
	Min	0	0	0	0		
LC5	Max	-3,48	1,02	-4,22	1,10	0,83	0,92
	Min	0	0	0	0		

Concerning the fifth load case, the principal stresses increase of around 17% in compression and 8% in tension, respect the case where the edges were clamped. The band plots (Figure 11.35 and Figure 11.36) show the low influence of the LC4 in comparison with the LC5 (the band plots are referred to the same range defined from the LC5 since has the highest values). In LC5 the behavior in the mid surface is similar to the previous case with clamped edges. The main difference is regarding the principal tension P1 that is distributed in a similar way, but in this case the concentration in three main areas (A,B and C in Figure 11.36) is more evident.

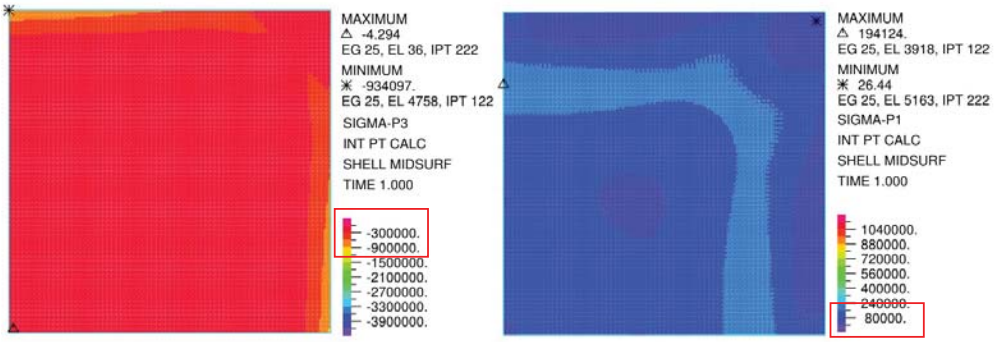

Figure 11.35 - LC4 (P3 left, P1 right) Midsurface [Pa]

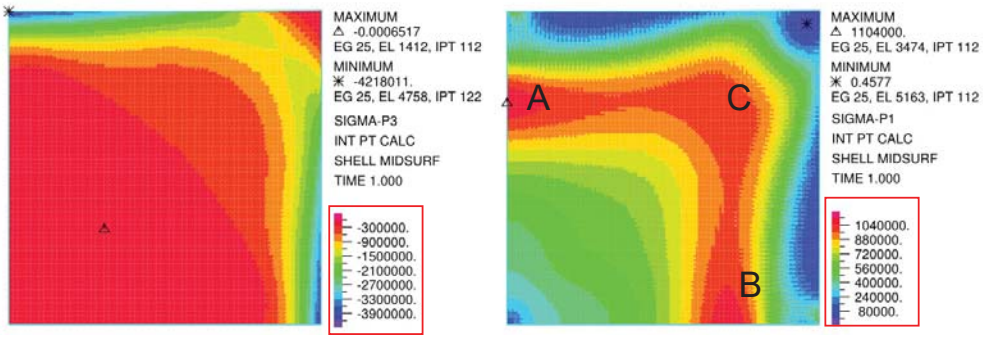

Figure 11.36 – LC5 (P3 left, P1 right) Midsurface [Pa]

From the band plots through the thickness (top and bottom, Figure 11.37 and Figure 11.38) is possible to notice that in the case of hinged edges the behavior of the structure does not change significantly respect the case of the clamped edges.

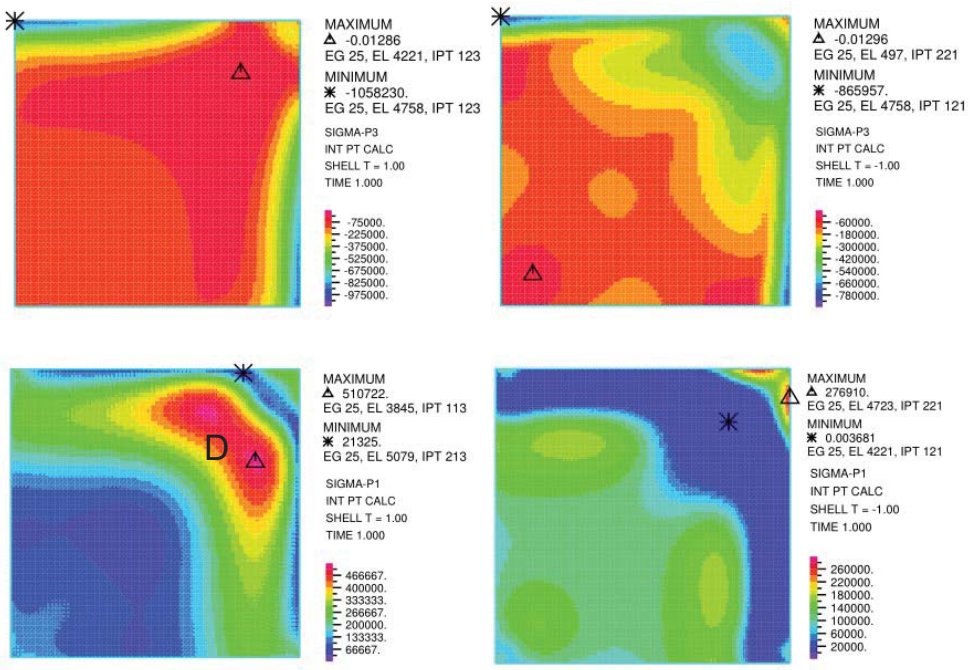

Figure 11.37 – LC4: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

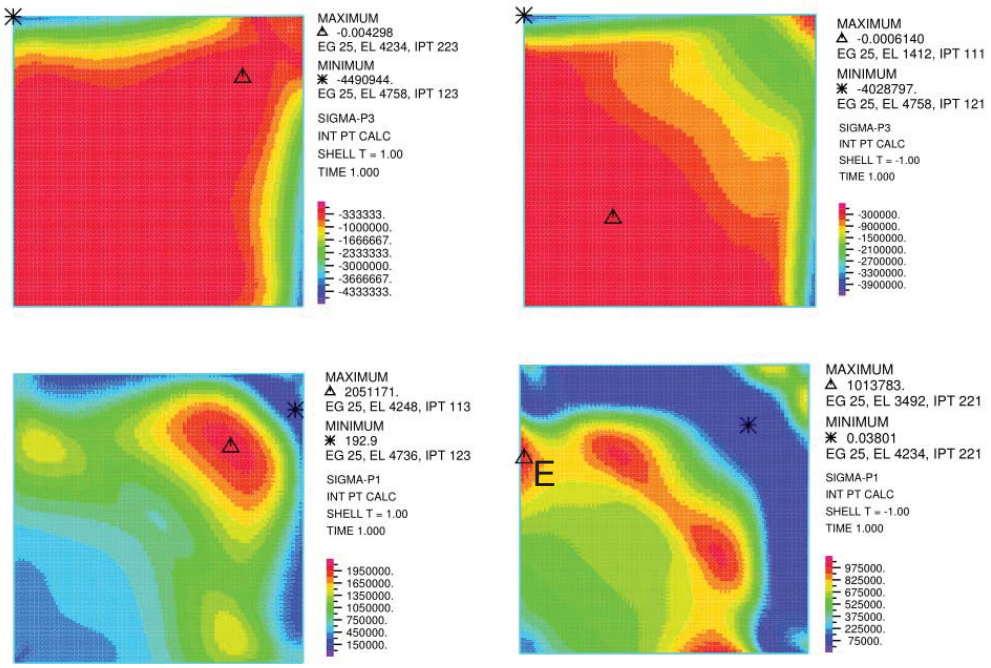

Figure 11.38 – LC5: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

The maximum values of principal stresses are almost in the same areas as in the previous configuration. Compression is, in both load cases, concentrated in the supports between tilted and horizontal edges. The difference between the two load cases, in tension behavior, regards the bottom surface; in the fourth load case is concentrated in the tilted edges close to their shared corner (D in Figure 11.37), while in the fifth load case is concentrated in the horizontal edge beam (E in Figure 11.38). Table 11.15 and Table 11.16 compare the maximum principal stresses with the allowable stresses depending on the principal directions (Figure 11.39 and Figure 11.40). In the quantitative comparison is considered also the principal tensile stress in the bottom surface of the fifth load case because is highly concentrated and present a high value.

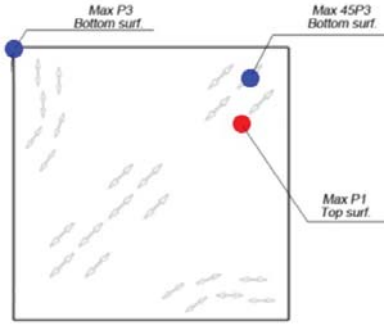

Figure 11.39 – Principal directions and location of maximum stresses LC4

Table 11.15 - Comparison stresses/strength LC4

Point	**Stress**	**P/S**
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-1,06	-6,83	**0,15**
Max 45P3	**Fc/3**	**3P3/Fc**
-0,42	-2,28	**0,18**
Max P1	**Ft/6**	**6P1/Ft**
0,51	1,38	**0,37**

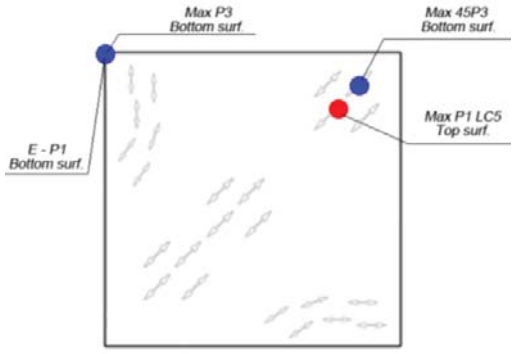

Figure 11.40 – Principal directions and location of maximum stresses LC5

Table 11.16 - Comparison stresses/strength LC5

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-4,49	-6,83	**0,66**
Max 45P3	**Fc/3**	**3P3/Fc**
-2,10	-2,28	**0,92**
Max P1	**Ft/6**	**6P1/Ft**
2,05	1,38	**1,48**
E-P1	**Ft/6**	**6D/Ft**
1,01	1,38	**0,73**

The quantitative and qualitative comparison of the results concerning the load case evidence that passing from clamped to hinged edges the principal stresses increases, but the structural response of the structure remains almost the same. The distribution of stresses and the localization of the maximum values are similar to the previous case. The most critical situation is due to the fifth load case since the tensile strength behavior is exceeded of about 50% in the area close to the corner between the tilted edges. The point E, in the configuration with clamped edges, was characterized by a ratio of 0,94 highlighting its critical situation, while in this case the ratio decreases (0,73), meaning that the only critic situation is the one mentioned before where the tensile strength is exceeded of about 50%.

The Figure 11.41 compares the two wind load cases in terms of displacement of the diagonal that connects the corner between the horizontal edges with the opposite one. The comparison confirms the high difference of the two load cases.

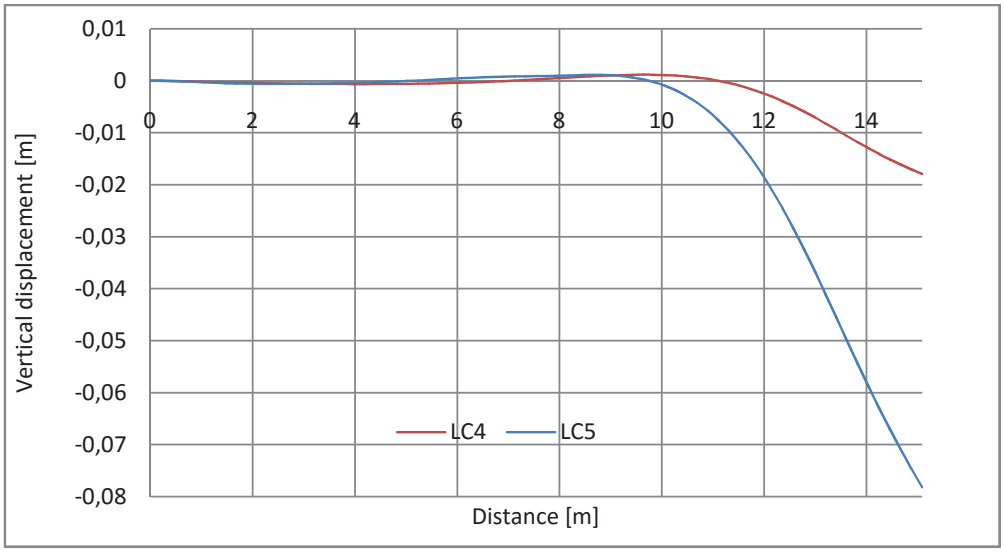

Figure 11.41 - Vertical displacement of the diagonal

11.3.3 Third Configuration - 3rd

LC1-LC2-LC3

From the linear elastic analysis the maximum principal stresses, in the mid surface, are computed and shown in the following table.

Table 11.17 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% difference between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC1	Max	-2,41	0,82	66	0	0
	Min	0	0			
LC2	Max	-1,13	0,57	49	-53	-30
	Min	0	0			
LC3	Max	-1,27	0,90	29	-47	10
	Min	0	0			

The Table 11.17 underlines that the LC1 induces the highest compressive stress in the mid surface, while the LC3 the highest tensile stress. Moving from the LC1 to LC3 the difference between the tensile and compressive principal stresses (P3 and P1) is getting lower, which is reflected in a more homogeneous distribution of the maximum stresses.

Comparing the maximum stresses in the mid surface for this configuration with the configuration where posts are not taken into account the values are lower in a significant way, especially concerning the compression values (P3)Table 11.18.

Table 11.18 - Comparison of maximum stresses on mid surface between 1st and 3rd configurations

		1st Configuration No Posts - Clamped Edges		3rd Configuration Yes Posts - Clamped edges			
		P3C [MPa]	P1C [MPa]	P3H [MPa]	P1H [MPa]	P3C/P3H	P1C/P1H
LC1	Max	-3,60	1,02	-2,41	0,82	**1,49**	**1,25**
	Min	0	0	0	0		
LC2	Max	-1,80	0,60	-1,13	0,57	**1,59**	**1,04**
	Min	0	0	0	0		
LC3	Max	-1,87	0,92	-1,27	0,90	**1,47**	**1,02**
	Min	0	0	0	0		

The localization of the maximum stresses in the mid surface is shown in Figure 11.42, Figure 11.43 and Figure 11.44.

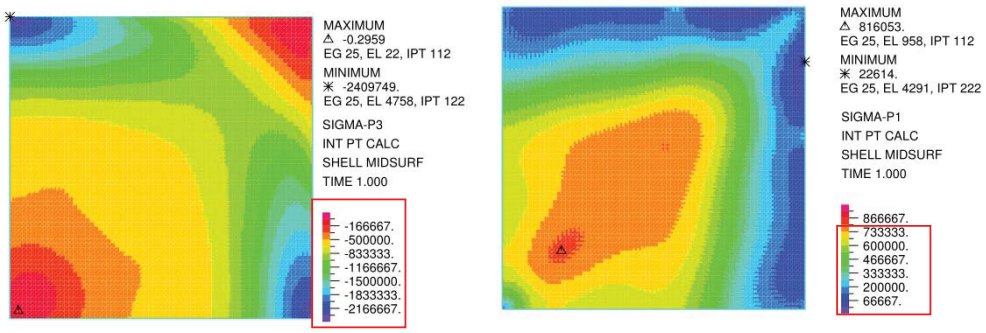

Figure 11.42 - LC1 (P3 left, P1 right) Midsurface [Pa]

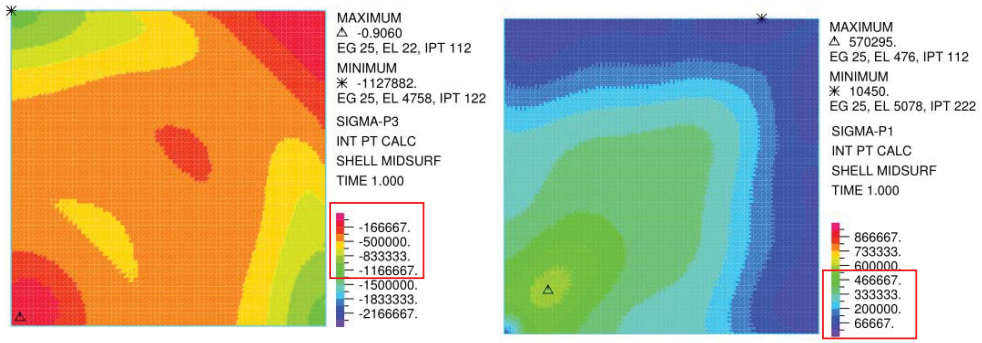

Figure 11.43 – LC2 (P3 left, P1 right) Midsurface [Pa]

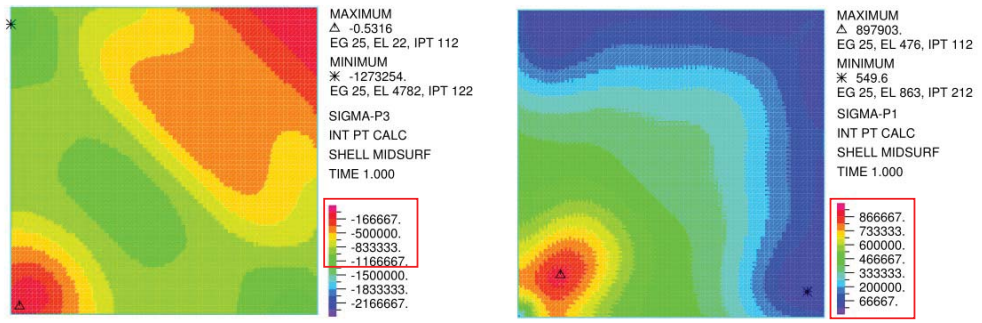

Figure 11.44 – LC3 (P3 left, P1 right) Midsurface [Pa]

From the band plots is possible to notice that the maximum values are almost in the same areas in all the load cases, meanwhile in the previous cases the maximum tension in the mid surface of LC1 was located in the corner between the two tilted edges. Moreover, always regarding the LC1, in this configuration the compression in the mid surface is extended also in the central area of the shell structure. Also the behavior on tension is changing as in this case is not perpendicular to the horizontal edges but is more distributed along the diagonal the connects the two corners from the horizontal edges to the tilted edges. Moving from LC1 to LC3 the tension is getting more localized in

the corner between the horizontal edges and also the compression is moving from the area between the tilted edges to the area between the horizontal ones.

A wider view of the behavior of the structure is obtained by plotting the stresses not only in the mid surface but also on the top and bottom surface (Figure 11.45, Figure 11.46 and Figure 11.47).

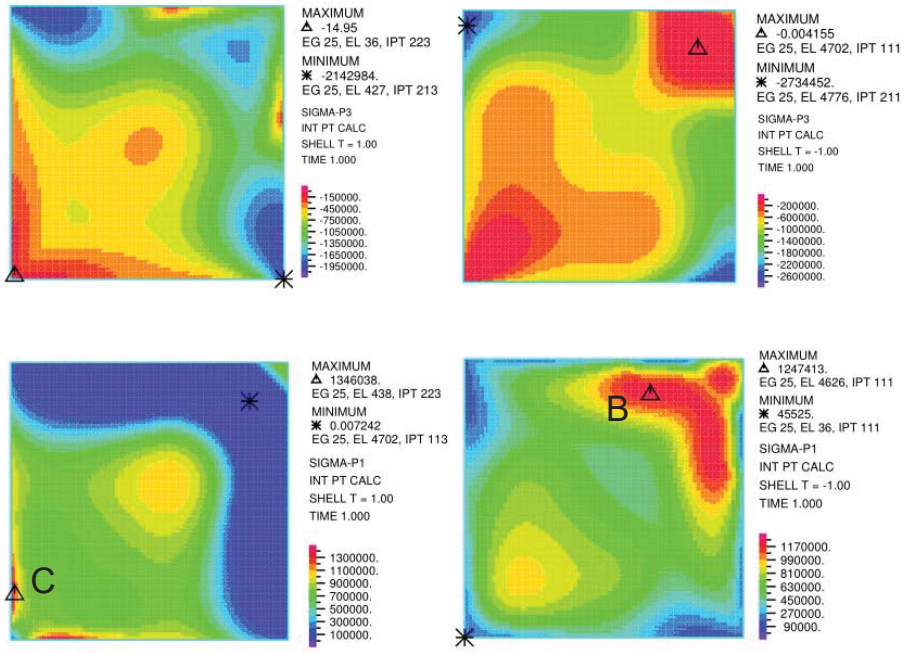

Figure 11.45 – LC1: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

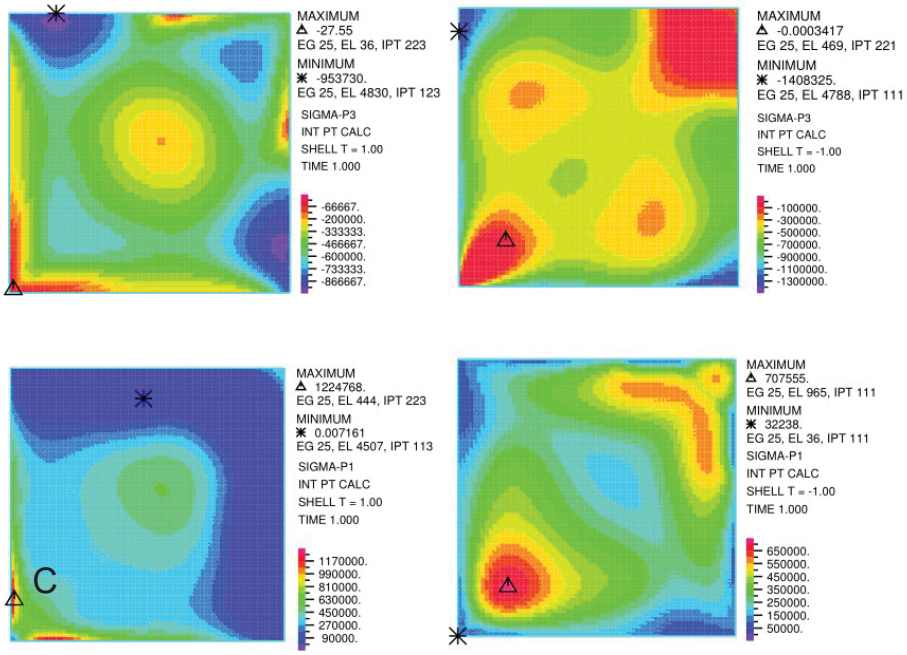

Figure 11.46 – LC2: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

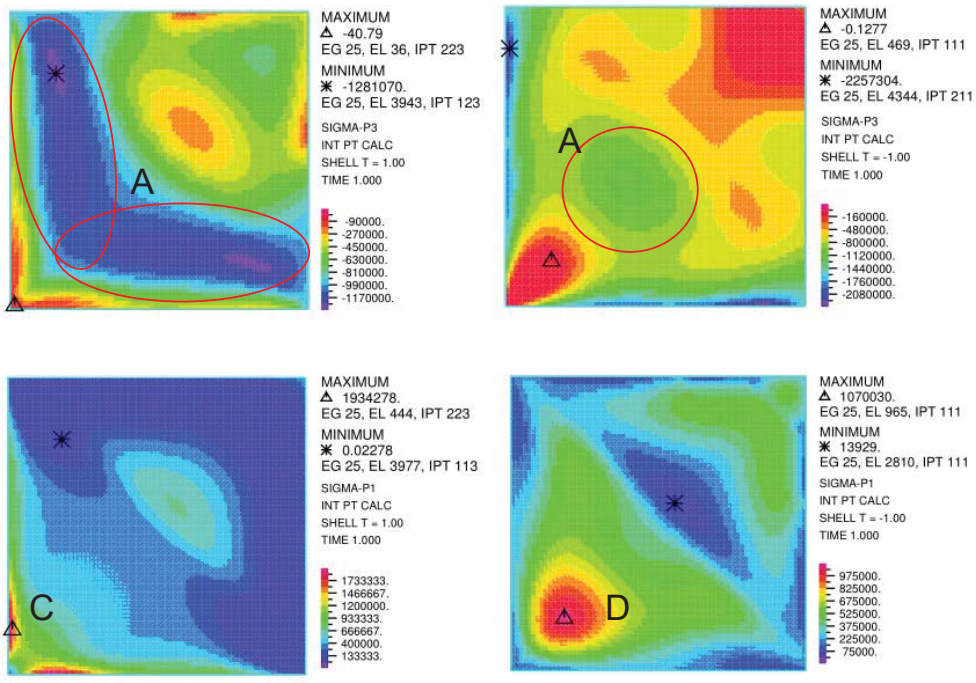

Figure 11.47 - LC3: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

The figures above underlines that the addition of the posts as structural elements changes the behavior of the structure both in compression and tension.

Concerning the compression, in this configuration, it is not concentrated mainly in the supports but its high intensity distribution is getting wider in the central area of the shell, where the principal directions are at 45° and the strength is divided by three. This wider distribution is clearly highlighted in the third load case on the top surface (indicated by A in Figure 11.47).

Regarding the tension behavior in LC1 there are two main areas with the highest localization of the tensile behavior. The first is localized in the corner between the two tilted edges (indicated by B in Figure 11.45), while the second area is in the horizontal edges close to the support between them (indicated by C in Figure 11.45). Moving from LC1 to LC2 and LC3 the difference between tensile stresses in the areas indicated by B and C is increasing and getting higher in the last one as the load is increasing. Indeed, the highest value of tensile stress P1 is located in this area and concern the third load case.

From this qualitative comparison is possible to say that in LC1 two main areas of the shell are subjected to high concentration of tensile stresses. Moving forward in the following load cases, LC2 and LC3, the concentration is mainly affecting only the corner between the horizontal edges.

Moreover the weakness in the horizontal edges close to the support (indicated by C in the Figure 11.45) is shown immediately from the first Load case. In the first configuration (clamped edges and no posts) this weakness was coming out clearly only in the third load case.

Figure 11.48, Figure 11.49 and Figure 11.50 shows the stresses considered in the quantitative comparison and the related principal directions. These values are compared with the allowable stresses in Table 11.19, Table 11.20 and Table 11.21.

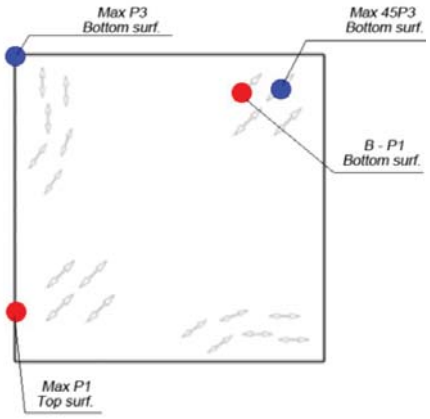

Figure 11.48 – Principal directions and location of maximum stresses LC1

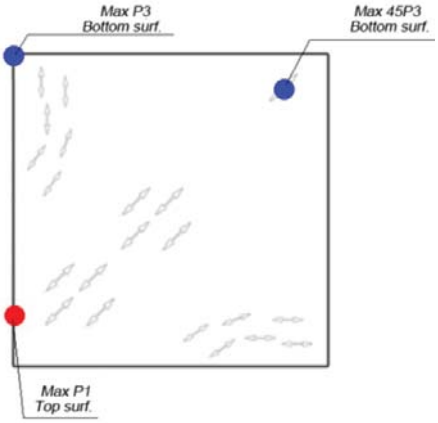

Figure 11.49 – Principal directions and location of maximum stresses LC2

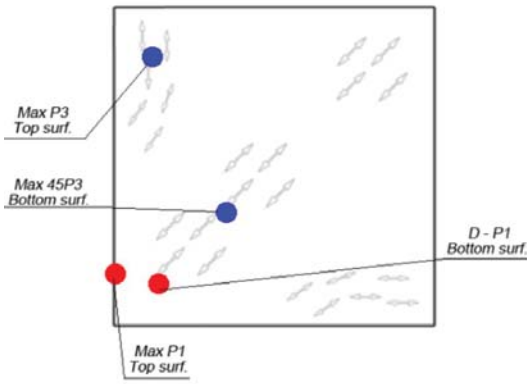

Figure 11.50 – Principal directions and location of maximum stresses LC3

Table 11.19 - Comparison stresses/strength LC1

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,73	-6,83	**0,40**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,80	-2,28	**0,79**
Max P1	**Ft/6**	**6P1/Ft**
1,35	1,38	**0,98**
B-P1	**Ft/6**	**6D/Ft**
1,25	1,38	**0,90**

Table 11.20 - Comparison stresses/strength LC2

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-1,41	-6,83	**0,21**
Max 45P3	**Fc/3**	**3P3/Fc**
-0,80	-2,28	**0,35**
Max P1	**Ft/6**	**6P1/Ft**
1,22	1,38	**0,89**

Table 11.21 - Comparison stresses/strength LC3

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-1,28	-6,83	**0,19**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,28	-2,28	**0,56**
Max P1	**Ft/6**	**6P1/Ft**
1,93	1,38	**1,4**
D-P1	**Ft/6**	**6D/Ft**
1,07	1,38	**0,77**

Concerning the compression the ratios stress/strength are the lowest between all the configurations analyzed until now and this underlines that P3 does not induce in critical situation in all the three load cases.

Regarding P1, the second load case has the lowest ratio stress/strength indicating that this load case does not represent a critic situation. In the first load case is close to the limit as its ratio is 0,98. Moreover, as explained before, this load case has also another area where the high value of tension is concentrated (point B in the Figure 11.45: 1247 [kPa]) and the related ratio stress strength is 0,90. In the third load case the strength is even exceeded by the stress and it is strongly localized in a small area accentuating the dangerous situation (C in Figure 11.47).

In terms of displacement (Figure 11.51) the configuration where the post are structurally considered is inducing to lower deflection values. The LC1 concentrates the highest deflection in the area close to the corner between the tilted edges, and the value is 1,7 cm. With the adding of the snow load in the opposite area (LC2 and LC3) the deflection is getting more uniform between the two areas. The changing of curvature of the deflection graph at around 8 meters is mainly due to the presence of the two lateral posts. In these posts is also the reason to why in the LC1 there are two areas where the tensile stress has high values.

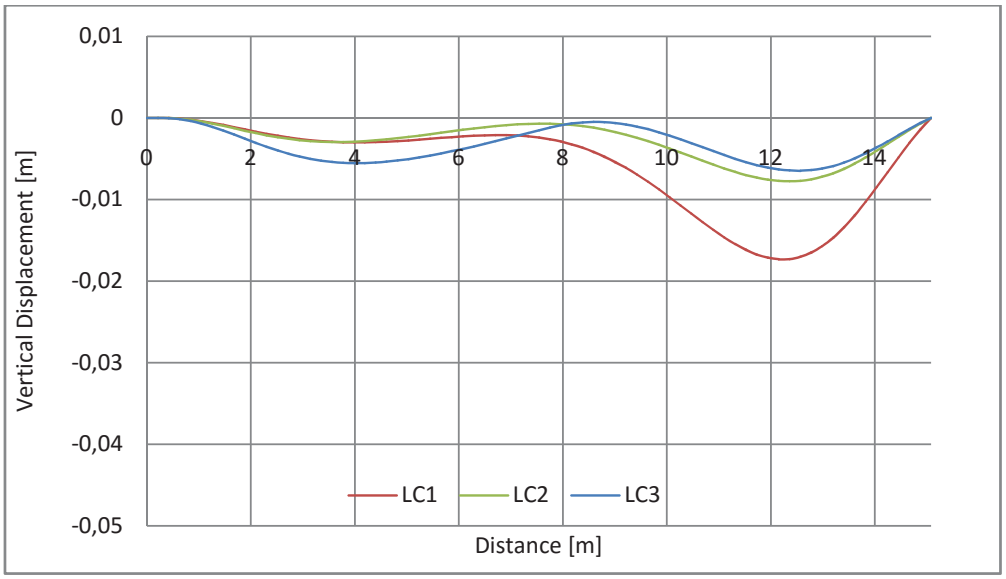

Figure 11.51 – Vertical Displacement of the diagonal

LC4-LC5

The introduction of the posts as structural elements is reducing the maximum stresses also in the case of the wind load. The Table 11.22 summarizes the maximum principal stresses in the mid surface and those stresses are also compared (in the Table 11.23) with the configuration where the edges are clamped and the posts are not considered.

Table 11.22 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% differentce between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC4	Max	-0,43	0,13	70	0	0
	Min	0	0			
LC5	Max	-2,32	0,83	64	437	549
	Min	0	0			

Table 11.23 - Comparison of maximum stresses on mid surface between 1st and 3rd configurations

		1st Configuration		3rd Configuration			
		P3C [MPa]	P1C [MPa]	P3H [MPa]	P1H [MPa]	P3C/P3H	P1C/P1H
LC4	Max	-0,71	0,17	-0,43	0,13	**1,65**	**1,33**
	Min	0	0	0	0		
LC5	Max	-3,48	1,02	-2,32	0,83	**1,50**	**1,22**
	Min	0	0	0	0		

The comparison in the Table 11.23 shows that the addition of the posts is reducing both, tensile and compressive, principal stresses and in a significant way the second ones. The band plots of the principal stresses in the mid surface (Figure 11.52 and Figure 11.53) point out the high difference between the stresses induced by the fourth and fifth load case. The stresses of the fourth load case are much more lower (as already shown in Table 11.22) than the fifth.

In terms of stress distribution in the mid surface the main difference between the two load cases is in tension, since the compression in both load cases is concentrated in the supports between tilted and horizontal edges. The difference in tension is that in the fourth load case is more concentrated in the corner between the horizontal edges (indicated by A in the Figure 11.52), while the fifth load case concentrate the highest intensity in the center of the shell (indicate by B in the Figure 11.53).

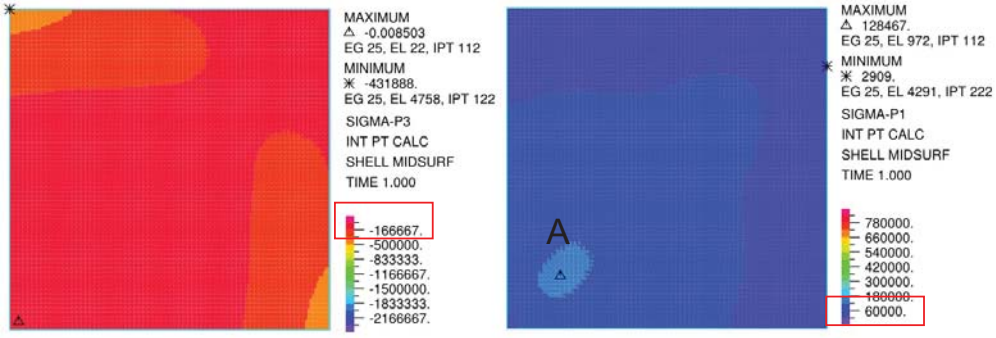

Figure 11.52 – LC4 (P3 left, P1 right) Midsurface [Pa]

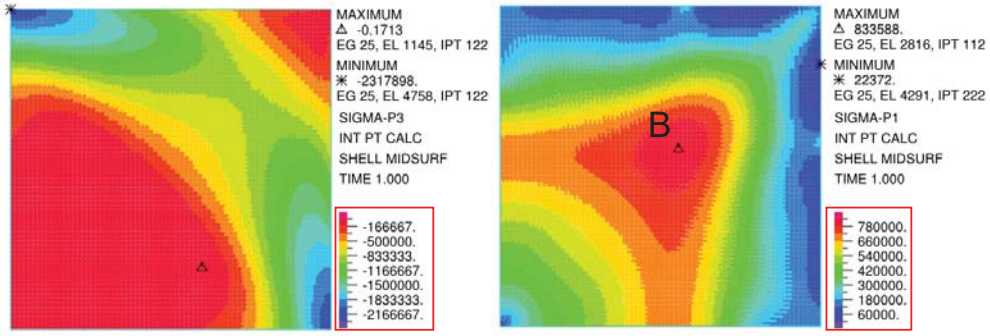

Figure 11.53 – LC5 (P3 left, P1 right) Midsurface [Pa]

The distribution of principal stresses is studied also through the thickness, on top and bottom surface (Figure 11.54 and Figure 11.55). The introduction of posts is changing the behavior of the structure in both compression and tension behavior.

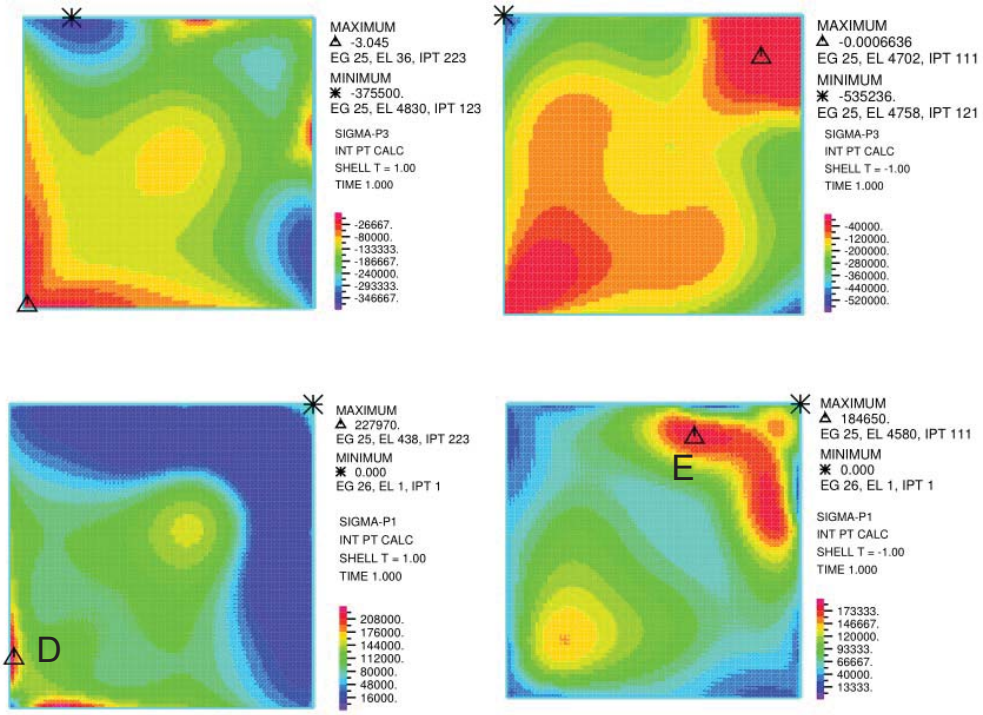

Figure 11.54 – LC4: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

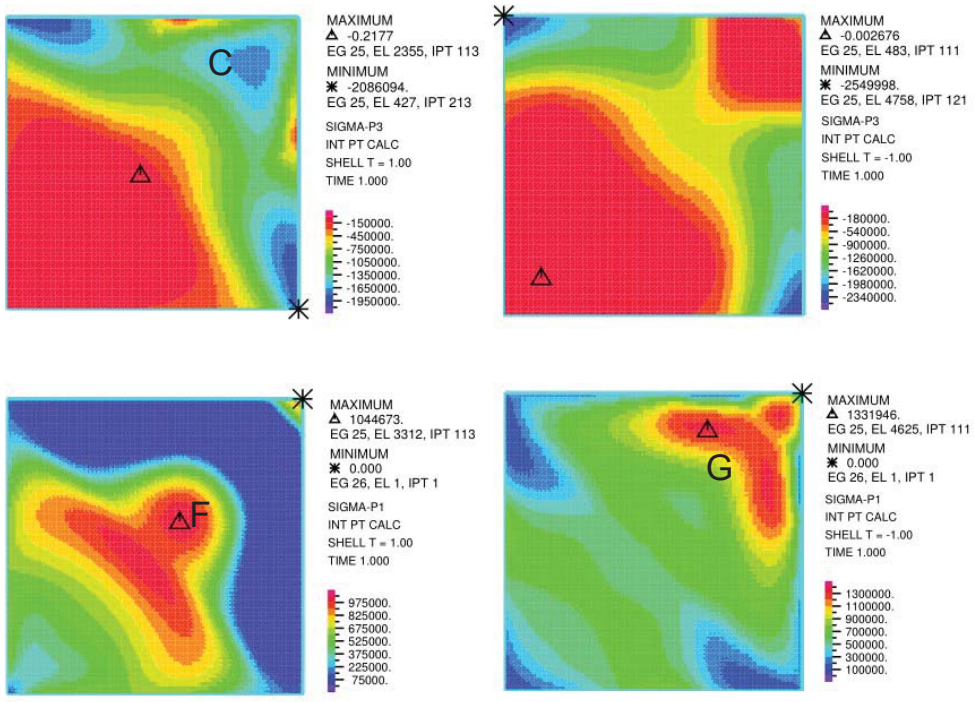

Figure 11.55 – LC5: Principal stresses (P3 above, P1 below) top and bottom surface (left, right)

Regarding the compression, the main difference, respect the previous cases, is that is not concentrated only in the supports but also in the corner between the tilted edges. This concentration is particularly relevant, due to the high intensity, in the fifth load case (indicated with C in Figure 11.55), since in this area the principal direction is at 45° and this means that the allowable stress needs to be divided by three in according to the APA (The Engineered Wood Association, 1997) recommendations. As already did in the previous cases the compression in these areas is called “Max 45P3” and they are compared with the related strength in the quantitative analysis.

In tension, the fourth load case induces to high principal stresses in two opposite areas: the first is on top surface in the horizontal edges, close to their shared corner (indicated with D in the Figure 11.54); the second is on the bottom surface close to the corner between the tilted edges (indicated by E in Figure 11.54). Due to the low intensity of stresses induced by this load case, only the maximum principal stress is considered in the quantitative comparison concerning the LC4.

Also the fifth load case induces to high tension in two different areas: on the top surface the tension is highly concentrated in the central area of the shell (F in the Figure 11.55), while on the bottom surface is more concentrated in the corner between the tilted edges (G in the Figure 11.55) as in the LC4. In LC5 the highest tension value is on the bottom surface but on the quantitative comparison is considered also the highest value in the top surface (F in Figure 11.55) as it has a high intensity.

Taking into account the qualitative considerations, Table 11.24 and Table 11.25 summarize the comparison between stresses and strength in according to the principal direction along which the stress is acting. The Figure 11.56 and Figure 11.57 show the location of the principal stresses compared with the strengths and the scheme of the principal directions of the shell.

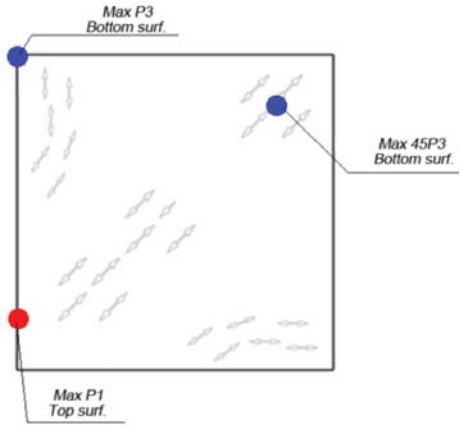

Figure 11.56 - Principal directions and location of maximum stresses LC4

Table 11.24 - Comparison stresses/strength LC4

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-0,54	-6,83	**0,08**
Max 45P3	**Fc/3**	**3P3/Fc**
-0,29	-2,28	**0,13**
Max P1	**Ft/6**	**6P1/Ft**
0,23	1,38	**0,16**

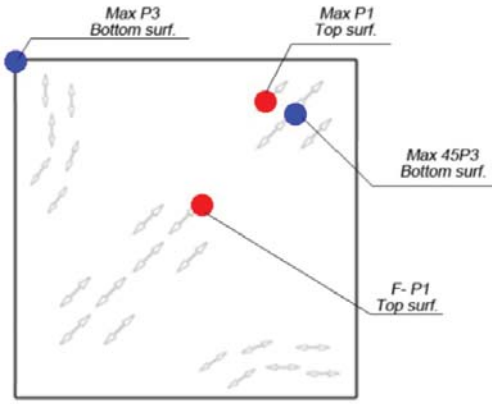

Figure 11.57 - Principal directions and location of maximum stresses LC5

Table 11.25 - Comparison stresses/strength LC5

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,26	-6,83	**0,37**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,80	-2,28	**0,79**
Max P1	**Ft/6**	**6P1/Ft**
1,33	1,38	**0,97**
F-P1	**Ft/6**	**6D/Ft**
1,05	1,38	**0,76**

From the quantitative comparison is possible to conclude that stresses that were considered as critical, due to their location and intensities, are lower than the strengths (compressive and tensile). The only case where the situation can be considered as critical is the maximum principal tension in the LC5, since the ratio stress/strength is 0,97.

The Figure 11.58 shows the vertical displacement of the diagonal that connects the corner between the horizontal edges with the opposite one. The graph confirms the high difference between the two load cases. The LC5 induces the highest displacement (approximately 1,9 [cm]) and is located at a distance of around 12 m from the corner.

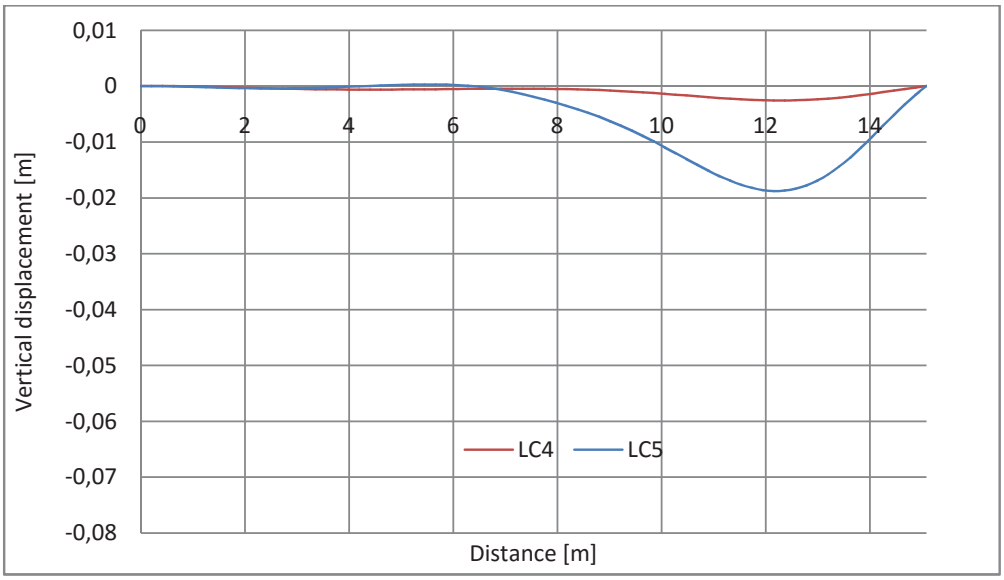

Figure 11.58 – Vertical displacement of the diagonal

11.3.4 Fourth Configuration – 4th

LC1-LC2-LC3

The Table 11.26 summarizes the maximum values of the principal stresses in the mid surface for the all the three load cases. It confirms what already noticed in all the previous cases analyzed. The maximum compression in the mid surface is reducing, about 50%, moving from LC1 to LC3. The tension is reducing from LC1 to LC2 but in the third load case is increasing of about 10% respect the LC1.

Table 11.26 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% difference between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC1	Max	-2,54	0,78	69	0	0
	Min	0	0			
LC2	Max	-1,21	0,57	53	-52	-26
	Min	0	0			
LC3	Max	-1,35	0,90	34	-47	15
	Min	0	0			

Comparing the results (maximum stresses in the mid surface) obtained in this case with the situation where the edges are clamped, the changes are not significant since the ratios between the stresses in the two cases are around the value 1 (Table 11.27).

Table 11.27 - Comparison of maximum stresses on mid surface between 3rd and 4th configurations

		3rd Configuration		4th Configuration			
		P3C [MPa]	P1C [MPa]	P3H [MPa]	P1H [MPa]	P3C/P3H	P1C/P1H
LC1	Max	-2,41	0,82	-2,54	0,78	**0,95**	**1,05**
	Min	0	0	0	0		
LC2	Max	-1,13	0,57	-1,21	0,57	**0,93**	**0,99**
	Min	0	0	0	0		
LC3	Max	-1,27	0,90	-1,35	0,90	**0,94**	**1,00**
	Min	0	0	0	0		

The maximum intensity of the compressive stresses is localized in the support between tilted and horizontal edges for the all three load cases. However, as it was happening in the third configuration, high values of compressive stresses can be found also in the central area of the shell (specially in LC3 – A in Figure 11.61) .

Concerning the stress P1, in the load cases two and three is localized in the corner between the horizontal edges, while in the first load case is localized in the center area of the shell. The band plots (Figure 11.59, Figure 11.60 and Figure 11.61) show the distribution of stresses in the mid surface.

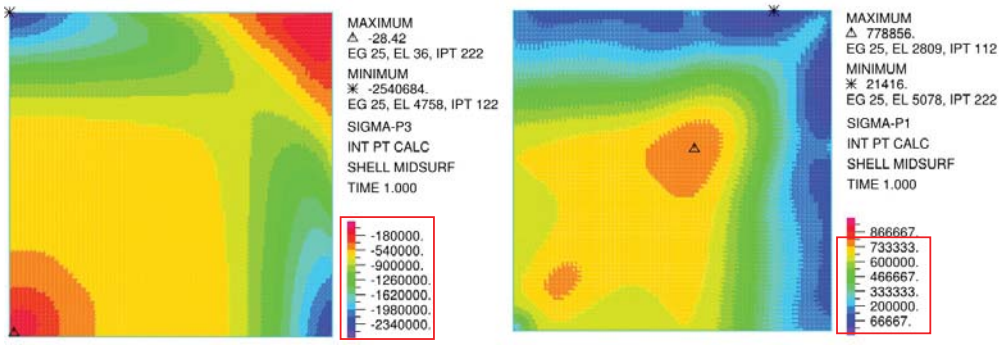

Figure 11.59 - LC1 (P3 left, P1 right) Midsurface [Pa]

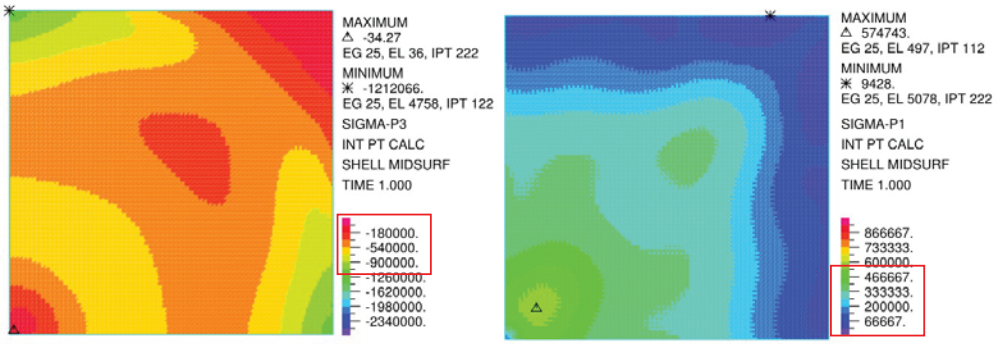

Figure 11.60 – LC2 (P3 left, P1 right) Midsurface [Pa]

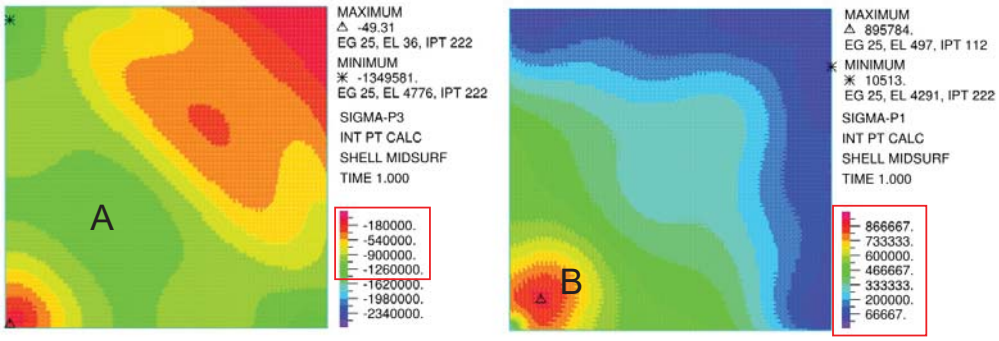

Figure 11.61 – LC3 (P3 left, P1 right) Midsurface [Pa]

The band plots show also that in the first load case the principal tensile stress is distributed along the central area, but shifting in the third load case it becomes much more concentrated in the corner of the shell (B in Figure 11.61). The compression, as in the previous case, is moving from the area between the tilted edges to the area between the horizontal ones.

The qualitative considerations done only in the mid surface are not enough for a deeply understanding of the structural behavior of the shell. The band plots of the principal stresses distribution are plotted also at the top and bottom surface (Figure 11.62, Figure 11.63 and Figure 11.64).

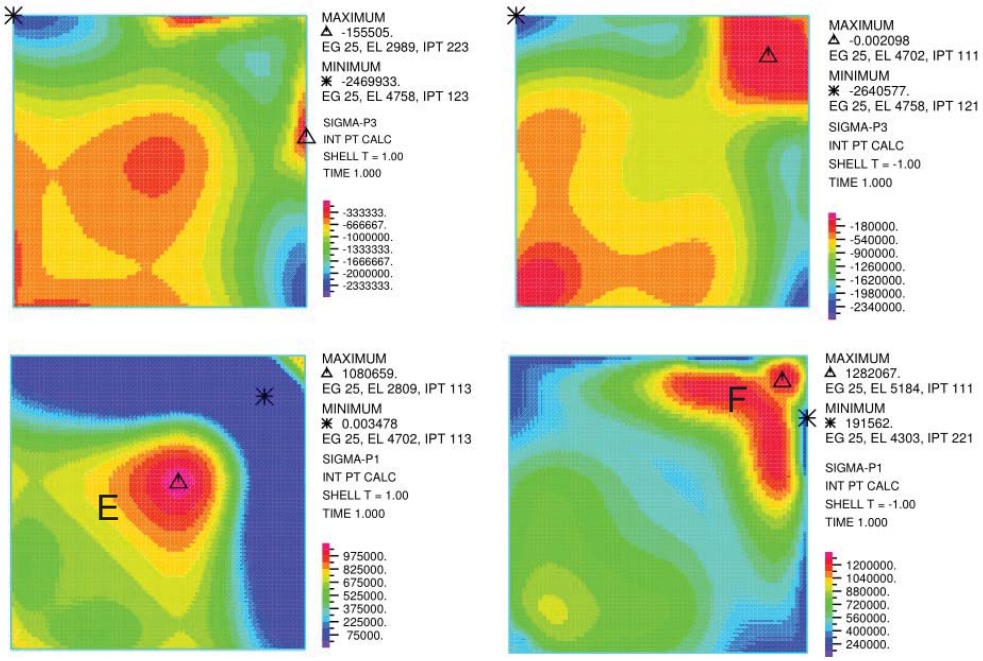

Figure 11.62 – LC1: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

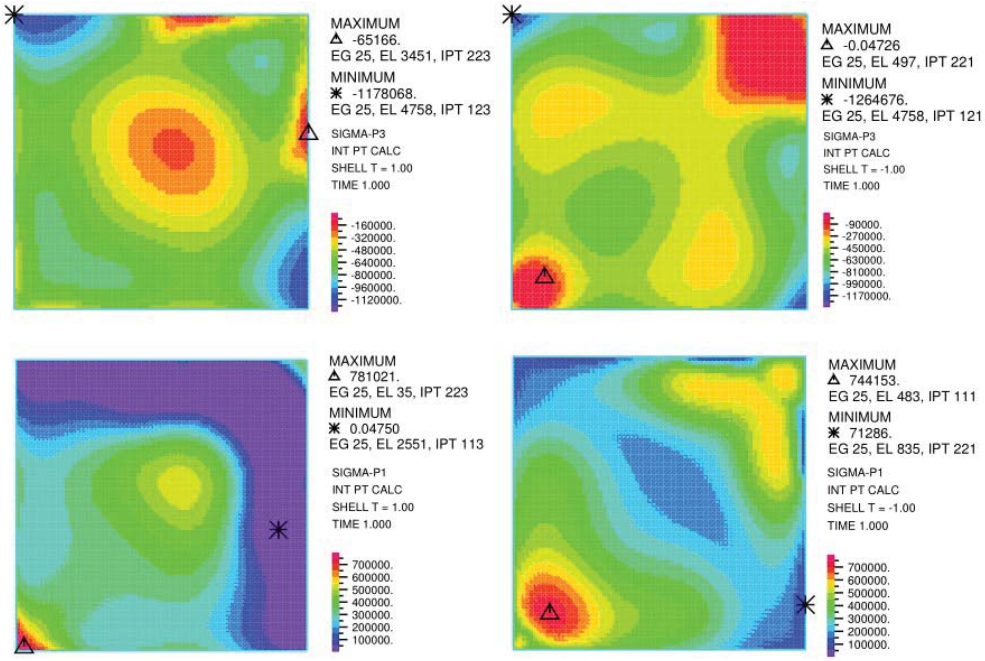

Figure 11.63 – LC2: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

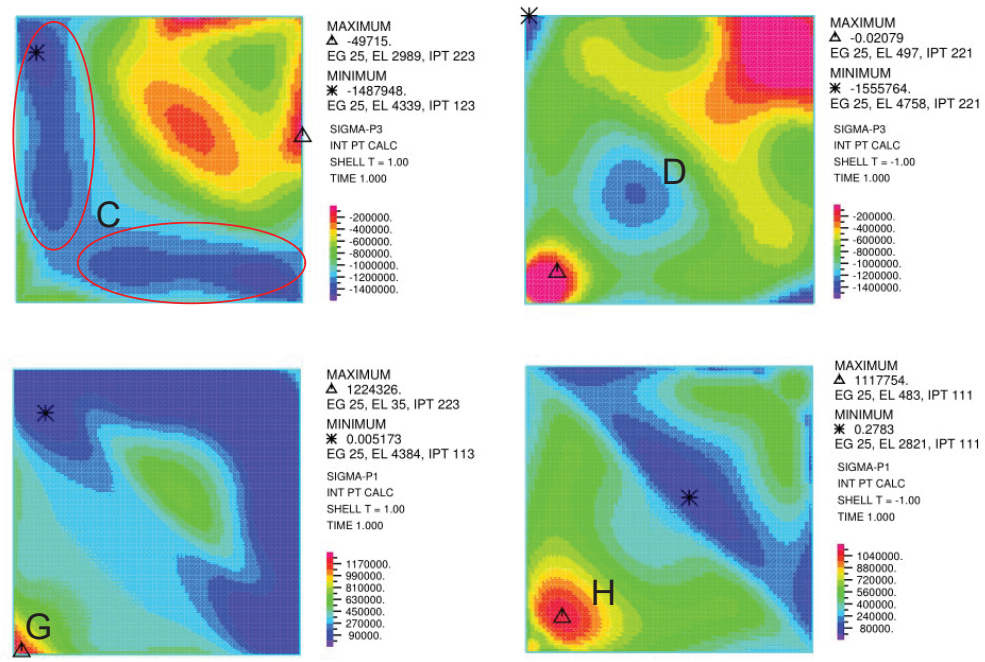

Figure 11.64 – LC3: Principal stresses (P3 above, P1 below) top and bottom surface (left, right) [Pa]

The plotting of the principal stresses through the thickness (top and bottom) shows that, regarding the maximum compression, in the first two load cases is concentrated in the supports between tilted and horizontal edges. In the third load case its maximum intensity on the top surface is more distributed in the areas parallel to the horizontal edges (C in Figure 11.64), while in the bottom surface is always localized in the supports. Moreover it is found a concentration also in the central area of the shell (D in Figure 11.64).

Concerning the tension, what already mention in the qualitative considerations of the results in the mid surface is also confirmed in the plotting through the thickness. The first load case has two areas of high concentration of stresses.

These two areas are the central part of the shell, in the top surface (E in Figure 11.62), and the corner between tilted edges, in the bottom surface (F in Figure 11.62). By increasing the load of the snow in the area between the horizontal edges, the tensile stresses increase, in a special way in the corner (G in Figure 11.64). The highest values is found in the top surface and concern the support between the horizontal edges.

In Figure 11.65, Figure 11.66 and Figure 11.67 are shown the values used in the quantitative comparison (Table 11.28, Table 11.29 and Table 11.30).

The quantitative comparison highlights that in the case where the posts are considered as structural elements and the horizontal edges as hinged, no load case represent a dangerous situation as all the maximum principal stresses induced are lower than the strengths. The only configuration that can be

considered as critic is the maximum principal tensile stress induced in the first load case, since the ratio stress/strength is 0,93.

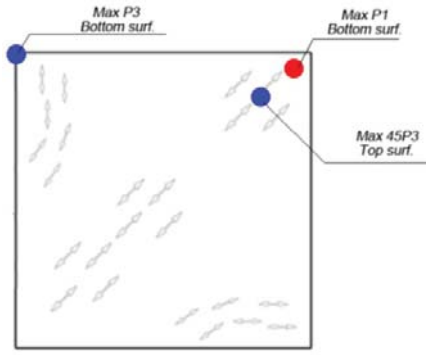

Figure 11.65 - Principal directions and location of maximum stresses LC1

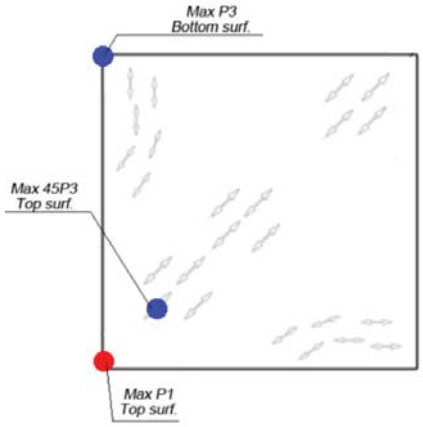

Figure 11.66 - Principal directions and location of maximum stresses LC2

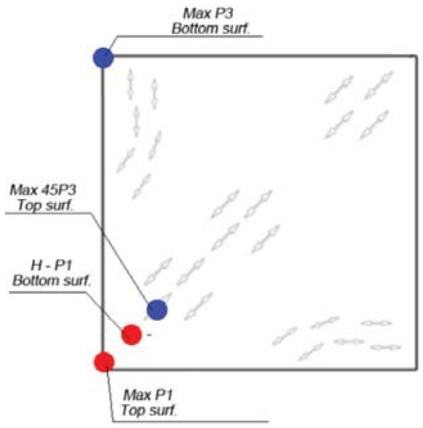

Figure 11.67 - Principal directions and location of maximum stresses LC3

Table 11.28 – Comparison stresses and strengths LC1

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,64	-6,83	**0,39**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,83	-2,28	**0,80**
Max P1	**Ft/6**	**6P1/Ft**
1,28	1,38	**0,93**

Table 11.29 – Comparison stresses and strengths LC2

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-1,26	-6,83	**0,19**
Max 45P3	**Fc/3**	**3P3/Fc**
-0,88	-2,28	**0,39**
Max P1	**Ft/6**	**6P1/Ft**
0,78	1,38	**0,57**

Table 11.30 – Comparison stresses and strengths LC3

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-1,56	-6,83	**0,23**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,27	-2,28	**0,56**
Max P1	**Ft/6**	**6P1/Ft**
1,22	1,38	**0,89**
H-P1	**Ft/6**	**6D/Ft**
1,11	1,38	**0,81**

The vertical displacement of the diagonal (from the corner of the horizontal edges to the opposite), Figure 11.68, highlights that the change from clamped to hinged edges is not affecting significantly the deformed shape in terms of maximum displacements.

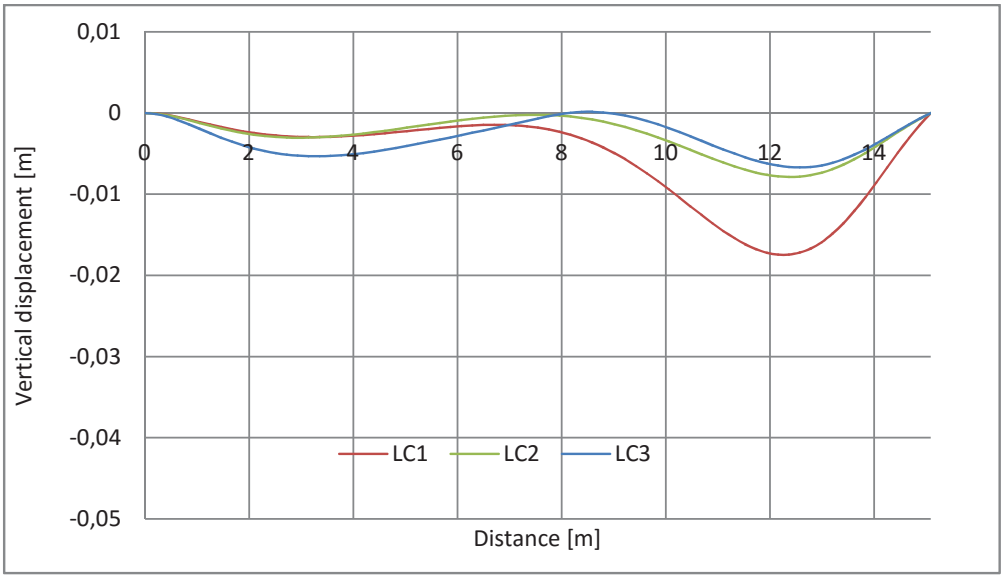

Figure 11.68 – Vertical displacement of the diagonal

LC4-LC5

The changing of the boundary conditions in the horizontal edges, from clamped to hinged, cause an increasing of the maximum principal compression stresses in the mid surface for both load cases. In tension, the stresses are getting higher but not in a significant way (Table 11.32). The Table 11.31 shows the maximum principal stresses in the mid surface for both cases, and it confirms that also in this configuration the intensity of the stresses induced by the fourth load case are relatively small compared to the fifth load case.

Table 11.31 - Maximum principal stresses on mid surface

				Difference Inside the Load case	Difference between Load cases	
		P3 [MPa]	P1 [MPa]	% difference between P1-P3 (in magnitude)	% difference P3 (in magnitude)	% differentce P1 (in magnitude)
LC4	Max	-0,50	0,12	76	0	0
	Min	0	0			
LC5	Max	-2,47	0,82	67	392	594
	Min	0	0			

Table 11.32 - Comparison of maximum stresses on mid surface between 3rd and 4th configurations

		3rd Configuration		4th Configuration			
		P3C [Pa]	P1C [Pa]	P3H [Pa]	P1H [Pa]	P3C/P3H	P1C/P1H
LC4	Max	-0,43	0,13	-0,50	0,12	**0,86**	**1,08**
	Min	0	0	0	0		
LC5	Max	-2,32	0,83	-2,47	0,82	**0,94**	**1,01**
	Min	0	0	0	0		

Observing the band plots of the principal stresses in the mid surface, and comparing them with the case with clamped edges, is possible to notice that there are not significant differences in terms of compression, while more differences can be found in tension. In the fourth load case the tension is not concentrated in the corner between the horizontal edges, as in the case of clamped boundaries, but is more uniformly distributed. In the LC5, the hinged boundaries concentrates more the mid surface stresses in the central area of the shell (indicated with A in Figure 11.70).

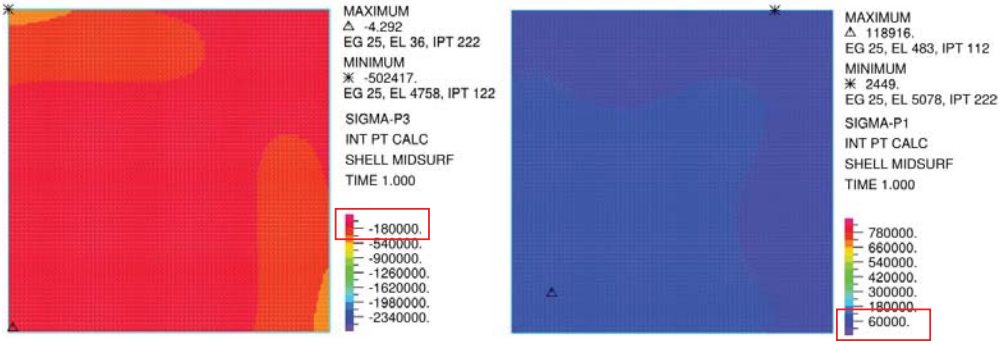

Figure 11.69 – LC4 (P3 left, P1 right) Midsurface [Pa]

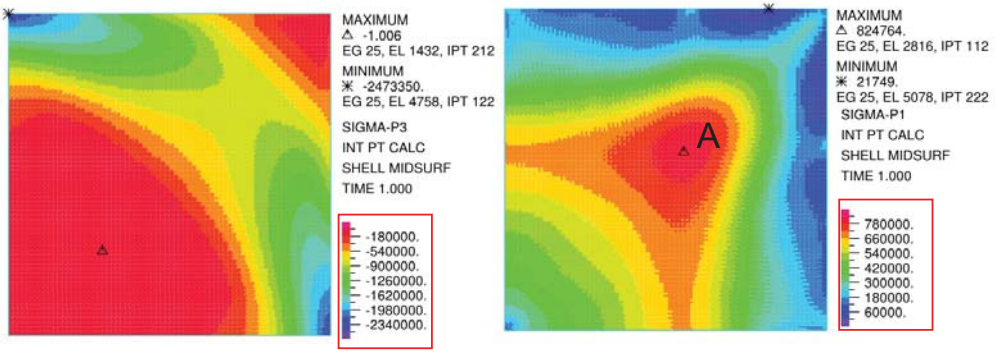

Figure 11.70 – LC5 (P3 left, P1 right) Midsurface [Pa]

The results obtained through the linear elastic analysis are evaluated also through the thickness (Figure 11.71 and Figure 11.72), as done in the previous cases. From the discussion of these last results is carried out that the behavior of the structure is more sensitive to the boundary conditions when the load is acting close to them. Indeed, in the fourth load case the main difference respect the case with clamped edges is in tension, since in this case it is more concentrated in the center of shell

(B in Figure 11.71) and in the support between the horizontal edges (indicated by C in Figure 11.71), while in the previous case was more concentrated in the in the connection with the edges.

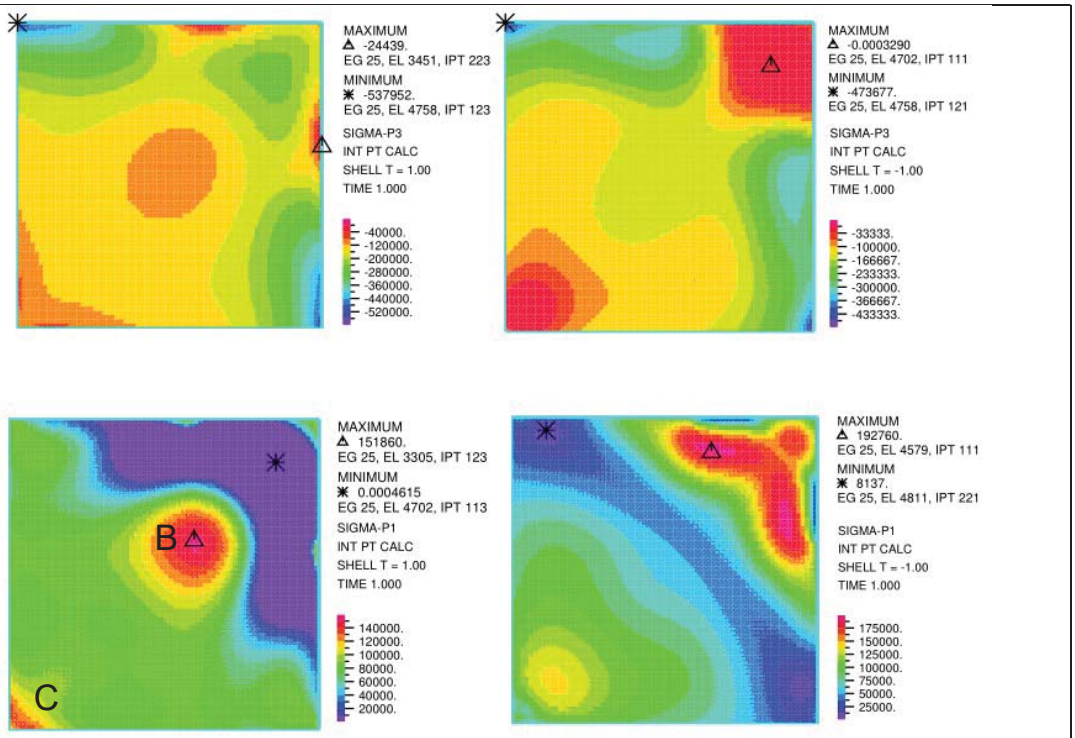

Figure 11.71 – LC4: Principal stresses (P3 above, P1 below) top and bottom surface (left, right)

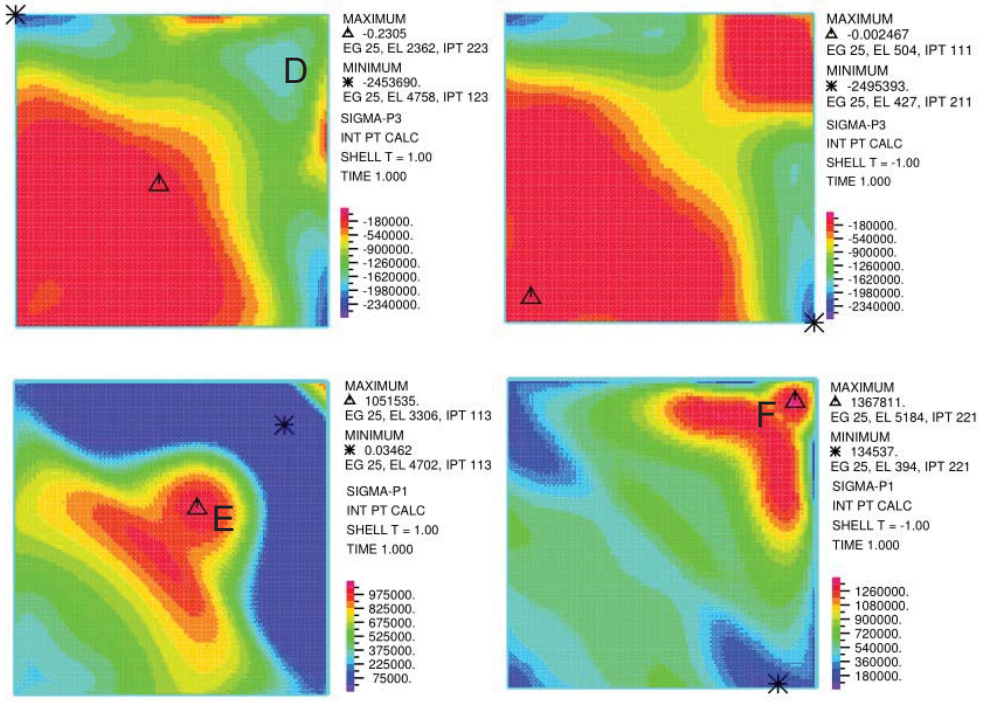

Figure 11.72 – LC5: Principal stresses (P3 above, P1 below) top and bottom surface (left, right)

In the quantitative comparison of the LC4 are taken only the maximum values, since this load case does not induce to high values of stresses. Concerning the fifth load case, the behavior of the structure is not deeply changing (in terms of intensity as already mentioned in Table 11.32 and in terms of distribution) from the clamped edges to the hinged edges.
The Figure 11.73 and Figure 11.74 show the stresses taken into account in the quantitative comparison and the directions of the principal stresses.

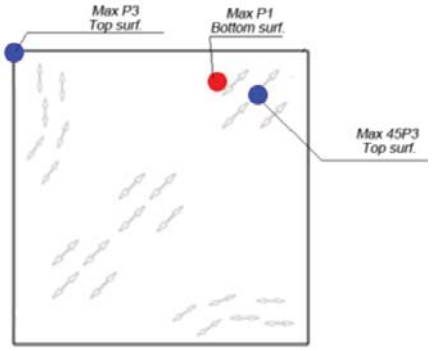

Figure 11.73 - Principal directions and location of maximum stresses LC4

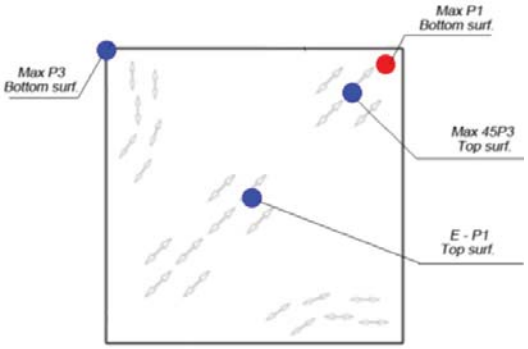

Figure 11.74 - Principal directions and location of maximum stresses LC5

Table 11.33 – Comparison stresses and strengths LC4

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-0,54	-6,83	**0,08**
Max 45P3	**Fc/3**	**3P3/Fc**
-0,28	-2,28	**0,12**
Max P1	**Ft/6**	**6P1/Ft**
0,19	1,38	**0,14**

Table 11.34 – Comparison stresses and strengths LC5

Point	Stress	P/S
[Mpa]	[Mpa]	[-]
Max P3	**Fc**	**P3/Fc**
-2,50	-6,83	**0,37**
Max 45P3	**Fc/3**	**3P3/Fc**
-1,80	-2,28	**0,79**
Max P1	**Ft/6**	**6P1/Ft**
1,37	1,38	**0,99**
E-P1	**Ft/6**	**6D/Ft**
1,05	1,38	**0,76**

From this comparison (Table 11.33 and Table 11.34) is carried out that the critic situation correspond to the fifth load case. The criticality is represented by a high tensile stress close to the support between the tilted edges (F in Figure 11.72). In these area the stress has almost the same value as the strength.
The vertical displacement of the diagonal is shown in Figure 11.75 and confirms the fact that the deformation is not significantly changing since the LC5 is acting far from the horizontal edges where the boundaries are changed.

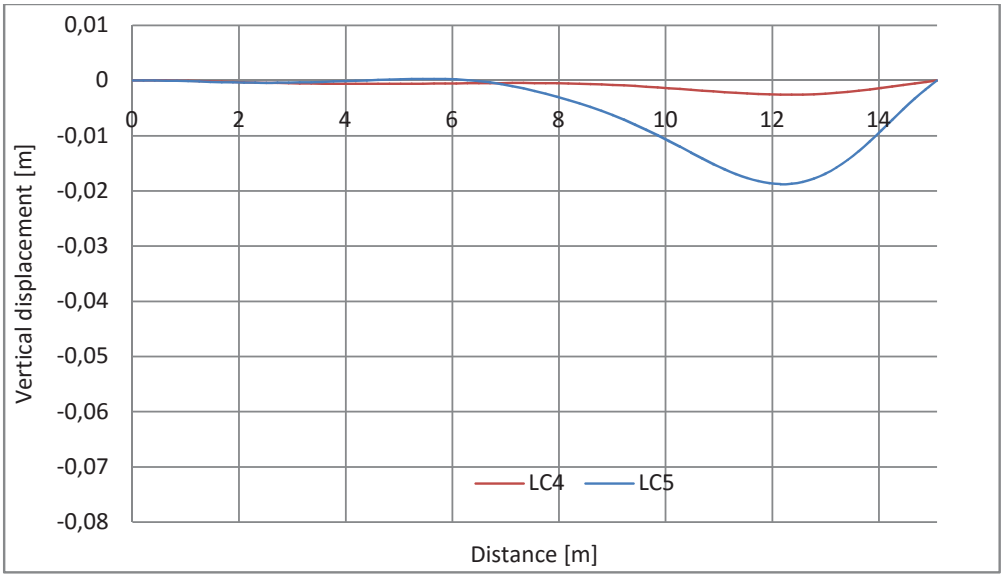

Figure 11.75 – Vertical displacement of the diagonal

11.3.5 Shear Through the Thickness

In according to the APA specifications (The Engineered Wood Association, 1997) for the grading and definition of the mechanical properties (Chapter 11) of the plywood, the shear resistance is 827 [kPa]. For all the load cases and configurations the shear through the thickness is computed and the band plots are shown in the Appendix3. The Table 11.35 summarizes illustrates the maximum values for every load case and configurations.

Table 11.35 - Maximum shear stresses

	LC (Load case)				
	1	2	3	4	5
	[kPa]	[kPa]	[kPa]	[kPa]	[kPa]
1st Configuration	937	497	816	193,00	930,00
2nd Configuration	1035	545	872	256,00	1058,00
3rd Configuration	766	491	811	119,00	764,00
4th Configuration	764	540	867	119,00	766,00

The comparison of these maximum values with the shear resistance ($F_v = 827[kPa]$) is shown in the Figure 11.76, where the red line represent the limit value of the strength.

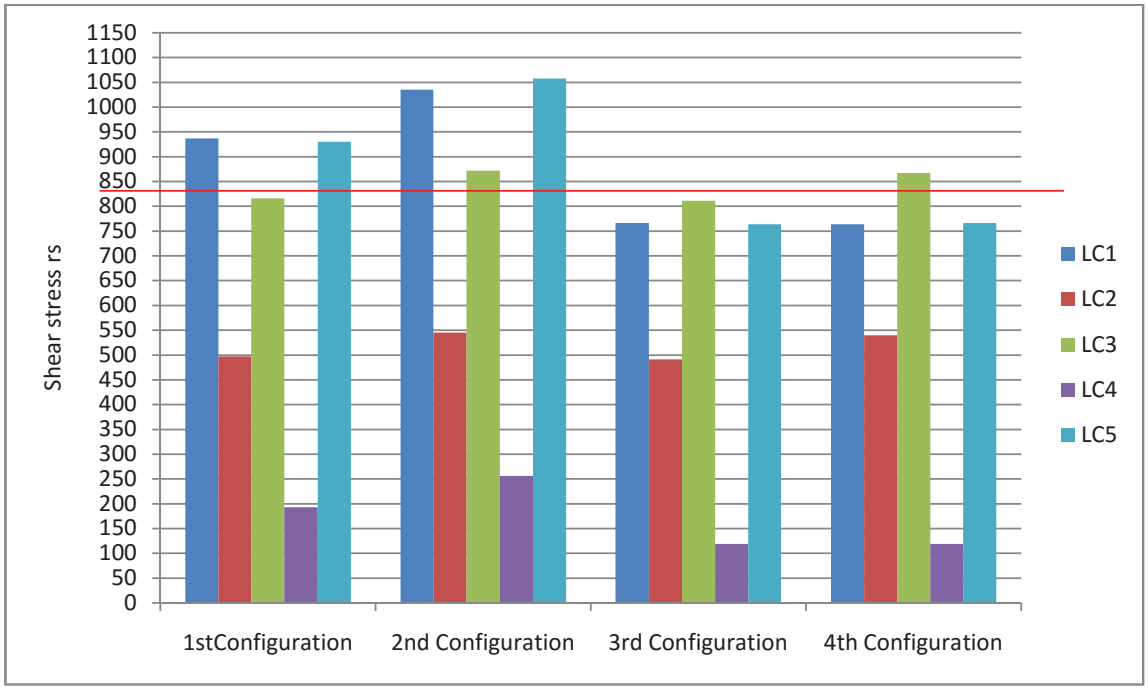

Figure 11.76 – Histogram: Max Shear Stress – Load Case - Configuration

Analyzing the Figure 11.76 it can be noticed that:

- The highest shear stresses occur in the first two configurations
- The shear strength of the plywood material is exceeded in first two configurations when LC1 and LC5 are applied
- LC3 shows small changes, in terms of maximum shear stress, between the all four configurations. The maximum shear stresses induced by this load case vary from 816 [kPa] to 872 [kPa]. In the second and fourth configurations the stresses induced are higher than the strength.
- The consideration of the horizontal edges as hinged lead to the increasing of the stresses, meanwhile with the addition of the posts the stresses decrease.

The band plots in the Appendix 3 highlight that the LC1 and LC5 present similar distribution of the shear stress. In the 1st Configuration their maximum is localized close to the corner between the tilted edges, while in the 2nd Configuration a concentration of stresses in this area still remains but the maximum value is located in the supports between horizontal and tilted edge.

The band plots of the LC3 present a similar distribution in all the configurations, confirming the small variation of the maximum shear stress between the different configurations, and the maximum value is close to the corner between the horizontal edge.

The Figure 11.36 summarize the situations considered as critical because the stresses are higher or close to the strength.

Table 11.36 - Critical (concerning shear through thickness) load cases

Configuration	Load Case	Stress/Strength	Localization	Surface	Reference
1st	LC1	**1,13**	Close to corner between tilted edges	Mid	Figure 16.1 – Appendix 3
	LC5	**1,12**	Close to corner between tilted edges	Mid	Figure 16.5 - Appendix 3
2nd	LC1	**1,25**	Support between tilted and horizontal edges	Mid	Figure 16.6 - Appendix 3
	LC3	**1,05**	Close to the corner between the horizontal edges	Mid	Figure 16.8 - Appendix 3
	LC5	**1,28**	Horizontal edges, close to their corner	Mid	Figure 16.10 - Appendix 3
4th	LC3	**1,05**	Close to corner between tilted edges	Mid	Figure 16.18 - Appendix 3

11.3.6 Axial Force in the Posts

The posts are considered only in the third and fourth configuration. Indeed for every load case and configuration the axial force in the posts is computed and shown in the Table 11.37. The post in the corner between the tilted edges is called “Corner” , meanwhile the other two “Lateral” (Figure 11.77).
The lateral posts are not differentiated because they are affected by the same stresses since the structure, loads and boundaries are symmetric. In the assessment of the posts two aspects are taken into account: the first is the material resistance and the second is the buckling. For this reason two critical axial forces are defined:

$$N_{cr\ material} = F_c A$$

$$N_{cr\ buckling} = \pi^2 \frac{E I_{min}}{{L_0}^2} \qquad (66)$$

where:

- Fc : is the compression strength
- A: area of the cross section
- I_{min}: minimum moment of inertia
- L_0: influence length of the post and since have been model as hinged L_0 is equal to L
- E: young modulus

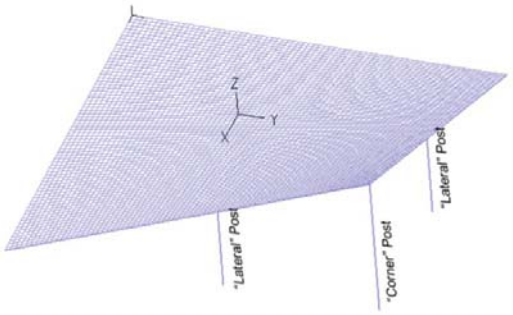

Figure 11.77 – “Corner” and “Lateral” Posts

The mechanical properties of the posts are defined in the Chapter 11 (Mechanical Characterization) in according with the grading provided by Professor David Biggs. Considering their geometry and their mechanical properties the two critical axial forces are computed for the lateral and corner posts and shown (Table 11.37). In the same table are shown also the maximum axial forces that every load case and configuration induce in the posts. Through this comparison is carried out that the posts do not represent an issue for any load case and configuration.

Table 11.37 - Comparison axial forces and axial resistance

		LC (load case)					Ncr	
		1	2	3	4	5	Material	Buckling
	Post	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]	[kN]
3rd Configuration	Lateral	10,43	5,57	5,134	2,76	10,91	**23,13**	**91,37**
	Corner	5,78	3,06	2,98	1,27	6,09	**34,70**	**44,75**
4th Configuration	Lateral	10,82	5,84	5,43	2,95	11,31	**23,13**	**91,37**
	Corner	5,83	3,10	3,07	1,27	6,10	**34,70**	**44,75**

11.4 Results Discussion

Maximum and Minimum Principal Stresses

The results in terms of principal stresses are discussed in the following firstly regarding the snow load and then wind load.

Snow load

The analysis of the results shown in the chapters above, pointed out that moving from clamped edges to hinged edges is reflected in an increasing of principal compressive stresses in the mid surface. However the compression in all configurations and load cases analyzed never showed a critic situation where the stresses are higher or close to the strengths. In tension, the maximum values on mid surface are similar between clamped and hinged edges, but the main difference is in the distribution of them, in particular in LC2 and LC3. Indeed, in these two load cases when the edges are clamped the tensile stresses are extremely localized and present high values in the connection between edges and shell layers. Moving to hinged edges the concentration of tensile stresses is directly in the support between the horizontal edges but is characterized by lower intensity than the clamped configurations. This behavior was found in all the four configurations analyzed. As an example is reported (Figure 11.78 and Figure 11.79) the comparison, in terms of principal tensile stresses P1 on top surface of the LC3, between 1st Configuration and 2nd Configuration.

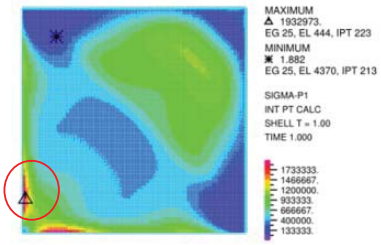

Figure 11.78 – 1st Configuration LC3- P1 Top

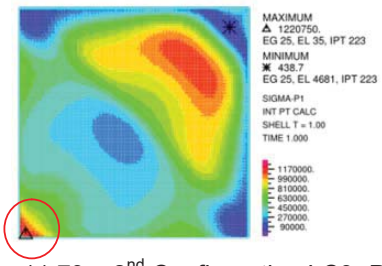

Figure 11.79 – 2nd Configuration LC3- P1 Top

The introduction of the posts as structural elements leads to a significant reduction of the compressive stresses but their distribution is changing. Without the post the stresses were more localized in the supports, while in configurations three and four, high compressive stresses are found also in the central area of the shell where the principal directions are at 45°. This has been analyzed, since in these areas the compressive strength need to be divided by three in according to the APA (The Engineered Wood Association, 1997) recommendations. The Figure 11.80 and Figure 11.81 show the distribution of P3 stresses on mid surface for LC1 in 1st and 3rd configuration.

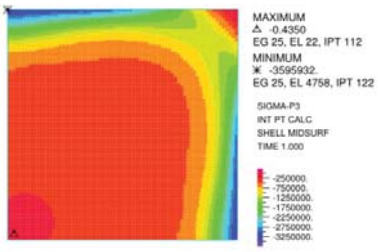

Figure 11.80 - 1st Configuration LC1- P3 Mid

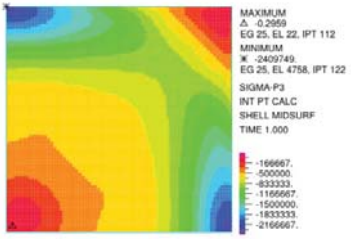

Figure 11.81 – 3rd Configuration LC3- P3 Mid

The considerations made about the tension behavior in the 1st and 2nd configurations are found also in the 3rd and 4th configurations.

The Table 11.38 presents for every configuration all the load cases considered as critical or dangerous since the ratio stress/strength is close to 1 or higher.

Analyzing the table is possible to say that the first configuration leads to critic situations for LC1 and LC3. Considering edges as hinged (2nd configuration) the LC3 does not induce anymore to any critic situation but the issue of LC1 still remains. Summarizing the dangerousness of the LC1 in the first configuration is reduced by introducing the posts as structural elements (3rd and 4th configurations). Regarding the LC3, the high stresses induced in the first configuration disappear when the horizontal edges are considered as hinged (2nd and 4th configurations).

Table 11.38 – Critical (in terms of principal stresses) snow load cases for every configuration

Configuration	Load Case	Stress/Strength	Localization	Surface	Reference
1st	LC1 - Max P1	**1,4**	Close to corner between tilted edges	Top	Figure 11.9
	LC3 - Max P1	**1,4**	Horizontal edges, close to their corner	Top	Figure 11.11
2nd	LC1 - Max P1	**1,5**	Close to corner between tilted edges	Top	Figure 11.28
3rd	LC1 - Max P1	**0,98**	Horizontal edges, close to their corner	Top	Figure 11.45
	LC3 - Max P1	**1,4**	Horizontal edges, close to their corner	Top	Figure 11.47
4th	LC1 - Max P1	**0,93**	Close to corner between tilted edges	Bottom	Figure 11.62

Wind load

The fourth load case that considers a negative pressure of the wind load is not enough to have an uplifting of the roof, since the dead load has a higher intensity. As already mentioned, this load case was studied because wind and dead load have different direction so the final pressure will act in the

surface differently in any point (Figure 11.82). However, the intensity of this load case is small compared with the fifth load case and it never leads to critic situation in all the configurations.

Critic situations are shown only in regarding to the fifth load case and mainly in the two first configurations, where the posts are not considered. This is mainly due to the fact that LC5 is acting in the area of the tilted edges, where (in 1st and 2nd configurations) there are no vertical supports.

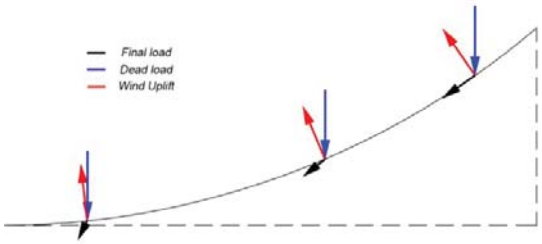

Figure 11.82 - Scheme of the wind uplift LC4

The boundaries conditions at the horizontal edges do not affect significantly the behavior of the structure under this load case. Only in the first configuration a critic situation with high tensile concentration of stresses in the horizontal edges is found (stress/strength = 0.94). In Table 11.39 are shown the critical load case for every configuration.

In the first two configurations the structure shows almost the same critical issues, highlighting that the boundaries at the horizontal edge do not affect the global behavior under the LC5, since the load is acting far from those boundaries. The addition of the posts as structural elements improves significantly the behavior of the structure. Indeed in the LC5 of the third configuration the maximum stress is close to the strength but not higher. Moreover in the 4th Configuration the structure does not show any critic situation for both load LC4 and LC5.

Table 11.39 – Critical (in terms of principal stresses) snow load cases for every configuration

Configuration	Load Case	Stress/Strength	Localization	Surface	Reference
1st	LC5 - Max P1	1,4	Close to corner between tilted edges	Top	Figure 11.19
	LC5 - P1 - E	0,94	Horizontal edges	Bottom	Figure 11.19
2nd	LC5 - Max P1	1,48	Close to corner between tilted edges	Top	Figure 11.38
3rd	LC5 - Max P1	0,97	Close to corner between tilted edges	Top	Figure 11.55

Displacements of the Diagonal

The vertical displacement of the diagonal that connect the corner between the horizontal edges with the opposite corner showed that is more affected by the presence of the posts than the boundaries at the horizontal edges. The influence of the post in the vertical displacement is clearly shown in the Figure 11.83 that present the displacement of the diagonal under the dead load in all four configurations.

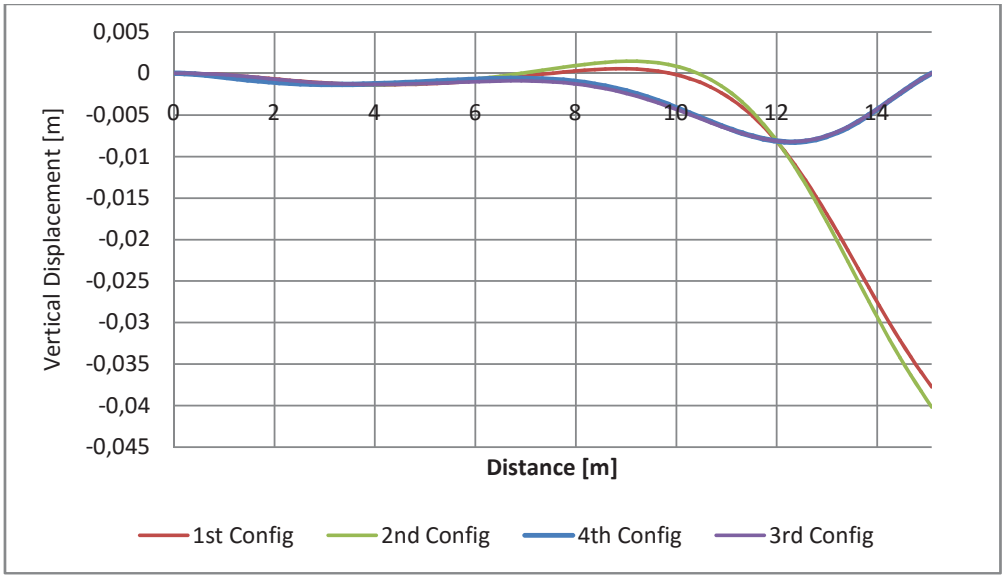

Figure 11.83 - Vertical displacement of the diagonal under dead load - 4 configuration

Shear Through the Thickness τ_{st}

The results obtained in terms of shear through the thickness showed that the most critical situations are found in the 1st and 2nd configurations. The vulnerabilities are due to the LC1 and LC5. The introduction of the posts improves the structural behavior of the shell in terms of stresses, since in the 3rd and 4th configurations the LC1 and LC5 do not induce to any critical situations. The only load case that is not influenced by the changing of the boundary conditions at the horizontal edges or the introduction of the posts is the LC3, since its maximum values are in all the configurations close to the limit value of the stress.

Axial Forces in the Posts

The linear elastic analysis performed for the different configurations and load cases have shown that, in terms of axial forces on the posts, there are no limit situations where the strength is reached or exceeded.

12. CONCLUSIONS

The numerical analysis carried out in this work has as a background an important process of knowledge of hyperbolic shallow shells' theory. The first step consisted of comparison between the simplified design rules (West Coast Lumbermen's Association, 1964) and the FE model; this comparison showed a 2% difference between the results (in terms of reactions, shear stress and compression along the edges) and therefore confirms the accuracy of the simplified design rules. However, the limits of those design rules are represented by the geometry conditions of the structure. Indeed they are developed for leveled hyppar structures. When a structure is tilted, as in the case of Nakashima Arts Buildings, the normal stresses increase significantly therefore making the assumptions of the simplified rules no longer valid. The second step was related with the verification of the FE model; the numeric model was verified since the analytical solution, developed through the theory of shallow shells (Blaauwendraad and Hoefakker, 2014), and the numerical solution differ in terms of shear stresses by a maximum of 15%. Furthermore in bending behavior, both solutions presented similar distribution of moments and influence lengths.

Based on the numerical analyses carried out for different boundary conditions and load cases, the posts of the Nakashima Arts Building do not suffer buckling instability. The main issues of the structure concern the shear through the thickness and the tensile behavior, since in mostly all configurations a critic situation has been found.

Through the results obtained it was found that the most vulnerable situation for the roof structure occurred in the configuration where the horizontal edges are considered as hinged and the contribution of the posts is neglected. In this configuration the vulnerabilities concern both, shear through the thickness and tensile stresses and are induced mainly by the LC1, LC3 and LC5.

In terms of shear stresses through the thickness, considering the structure as clamped or hinged does not influence significantly the structural behavior. The situation improves only when the posts are introduced as structural elements in the 3rd and 4th configurations. However, this improvement does not affect the LC3 which remains a critical load case in all the four configurations.

Regarding the principal tensile stresses, considering the edges as clamped or hinged produces a larger effect on the behavior of the structure under the LC3. This is mainly due to the fact that LC3 is acting in the area close to the boundary conditions. The addition of the posts improves the shell's structural behavior for LC1 and LC5.

In reference to the snow load, its uniform distribution all over the shell induces the highest values of principal tensile stresses. The most vulnerable region of this load case is the area close to the corner between the tilted edges, with exception of the 3rd configuration where the vulnerability is located along the horizontal edges close to the corner. Moreover, LC3 (half of the snow load swept onto half area of the shell) also represents a critical situation for the structure since in the 1st and 2nd configurations the tensile stresses exceed the strength. The vulnerability shown in this load case is

located along the horizontal edges close to their shared corner. This is considered to be particularly dangerous because it is highly concentrated and concern the connection with the edges.

The wind load represents a critical load case for the roof structure only when it is acting downward in half of the area of the shell (LC5). In the 1st configuration, LC5 is inducing vulnerabilities in two areas: close to the corner between the tilted edges and in the horizontal edges. Considering the horizontal edges as hinged, the vulnerability is reduced only to the corner between the tilted edges. Introducing the posts as structural elements the vulnerability is reduced and in the fourth configuration LC5 does not induce any critical situations. The uniform uplift (LC4) is not leading to vulnerabilities since is not intense enough to unbalance the dead load. The results obtained through the analyses of various boundaries and load cases are suitable to be used for three different purposes:

- Planning the ordinary maintenance: from the numerical analysis was observed that the uniform distribution of the snow induce vulnerabilities in all the configurations. It is therefore suggested to keep the structure free from the snow load. Moreover, if the real behavior of the structure is close to the 4th configuration, the snow distribution as LC3 does not induce vulnerabilities in terms of principal tensile stresses, while in terms of shear through the thickness the maximum stress is similar to the shear strength. This underlines that is necessary to investigate the real behavior of the structure. Through the results of this investigation it will be possible to define with more accuracy the weakness of the structure under a specific load distribution.

- Improving of the investigation plan: the vulnerabilities for every configuration and load case are localized mainly in two specific areas, in the corner between the tilted edges and along the horizontal edges. Is suggested to investigate these areas in order to check if there is any damage that could confirm the results of the numerical analysis. Moreover, an investigation on the connection between the posts and the tilted edges is needed, since the structural behavior is deeply changing when considering them as structural elements.

- Calibration of the model: Mr. Cesar Bargues Ballester has already performed a campaign of measurements on the underside of the roof structure subjected only to dead load and creep. In order to calibrate the model for further analysis, it is suggested to perform similar campaign during the wintertime. In this way it will be possible to have the deflections of the structure under the snow load. Through this “natural” load test it will be possible to check the real behavior of the structure. This process will also allow the calibration of the numerical model. Moreover, through the snow deflections it will be possible also to check the effectiveness of the posts.

The work carried out in this thesis could be a starting point for further numerical analysis where the plywood is modeled as an orthotropic material in order to better describe its real structural behavior. This analysis would allow for the safety assessment of the structure under the most critical load case and configuration. Through this consideration it will be then possible to evaluate if structural strengthening is needed.

13. REFERENCES

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14. APPENDIX1: PLAN AND CROSS SECTION OF NAKASHIMA ARTS BUILDING

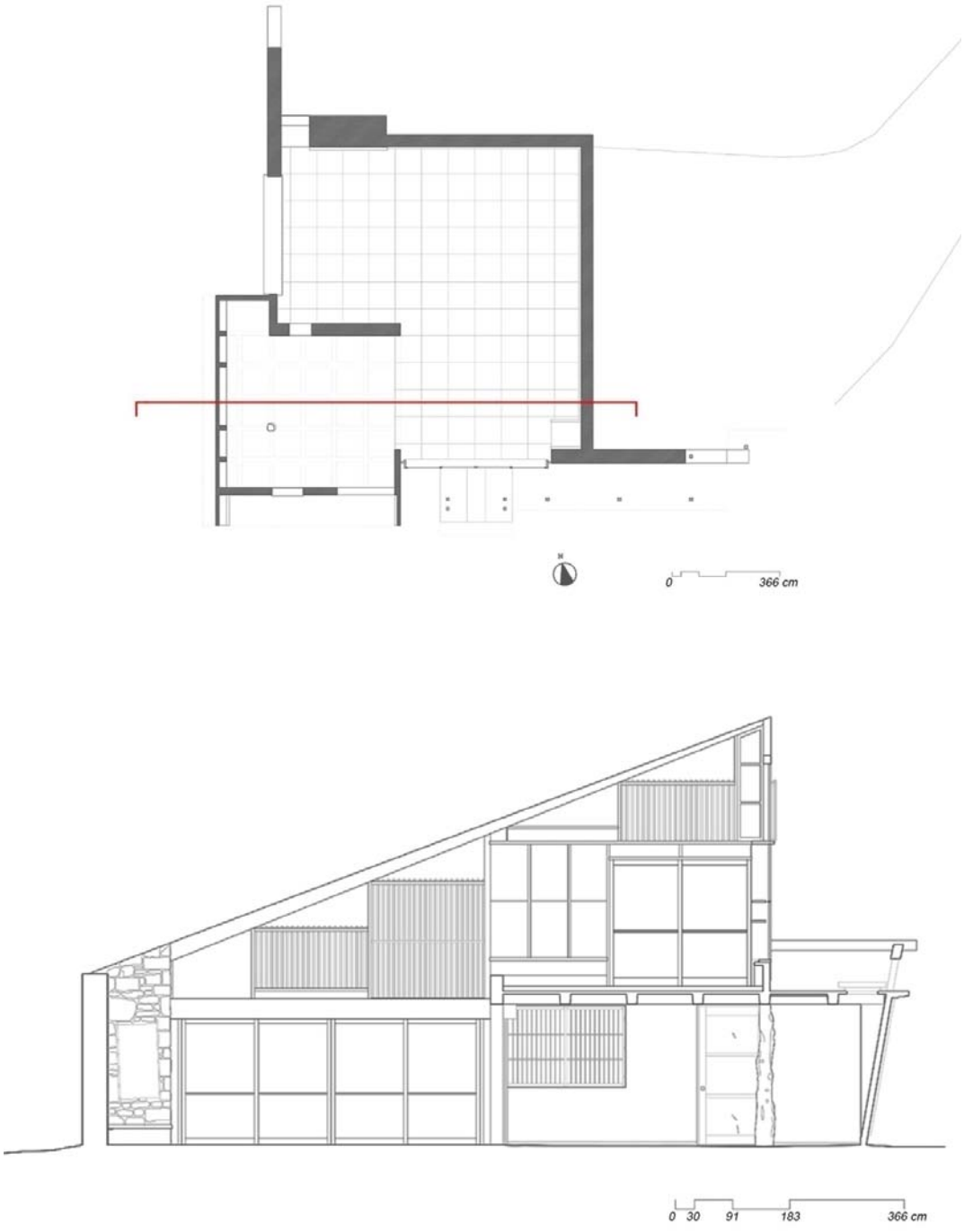

Figure 14.1 - Plan (above) and cross section (below) of Nakashima Arts Building

15. APPENDIX 2: DISCRETIZATION OF THE EDGE BEAMS AND CALCULATION OF THE MOMENTS OF INERTIA

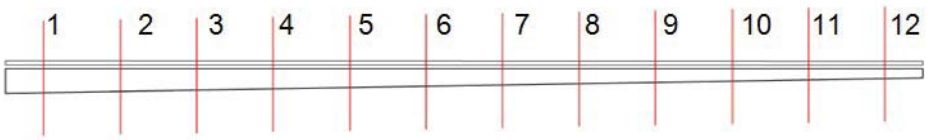

Figure 15.1 - Discretization of the Beam

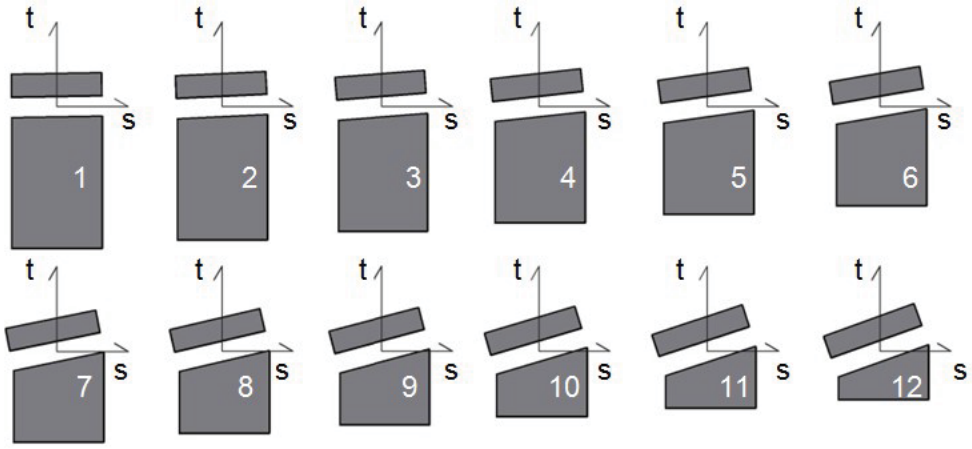

Figure 15.2 Cross Sections for the computation of the moments of inertia I_s, I_t, I_{ts}

Table 15.1 - Moments of inertia and product of inertia of the cross sections considered

	I_t	I_s	I_{ts}
Section	[cm^4]	[cm^4]	[cm^4]
1	222612	24208	456
2	185228	22920	1016
3	152312	21520	1424
4	123624	20192	1744
5	98896	18872	1936
6	77804	17760	2064
7	60024	16448	1936
8	45280	15328	1904
9	33388	14080	1728
10	23896	12912	1544
11	16664	11696	1240
12	11288	10576	984

16. APPENDIX 3: BAND PLOTS OF THE SHEAR THROUGH THE THICKNESS

The band plots shown in the following are computed at the mid-surface of the shell and the unit of the shear stress is [Pa].

1st Configuration

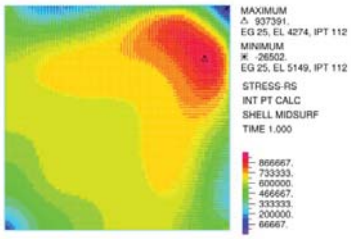

Figure 16.1 - LC1

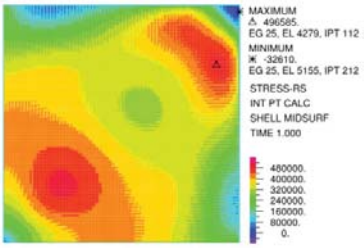

Figure 16.2 – LC2

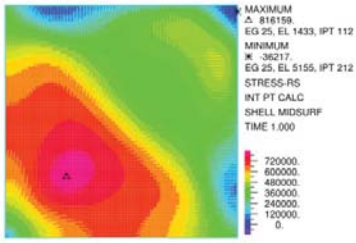

Figure 16.3 – LC3

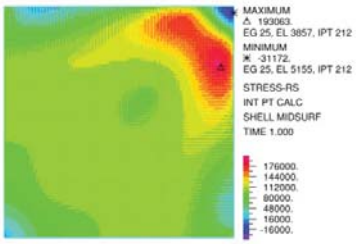

Figure 16.4 – LC4

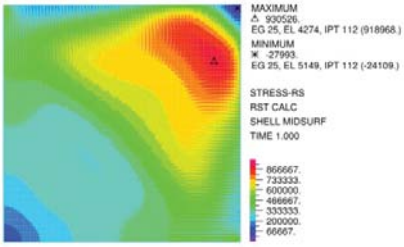

Figure 16.5 – LC5

2nd Configuration

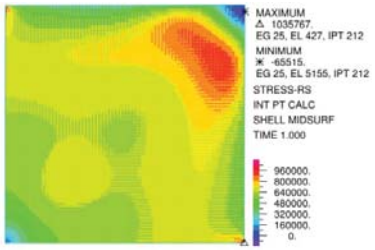

Figure 16.6 - LC1

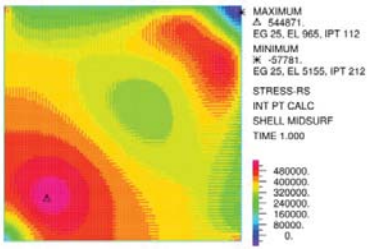

Figure 16.7 – LC2

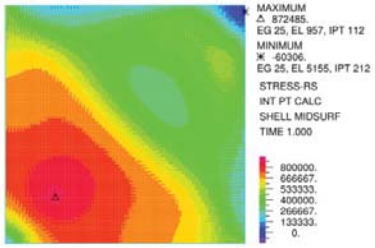

Figure 16.8 – LC3

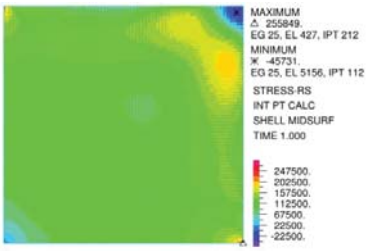

Figure 16.9 – LC4

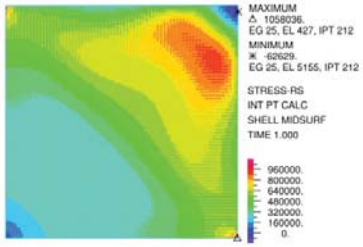

Figure 16.10 – LC5

3rd Configuration

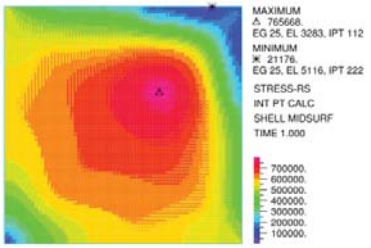

Figure 16.11 - LC1

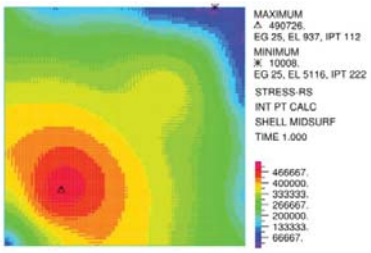

Figure 16.12 – LC2

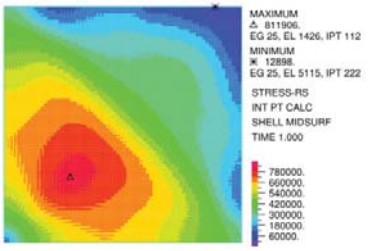

Figure 16.13 – LC3

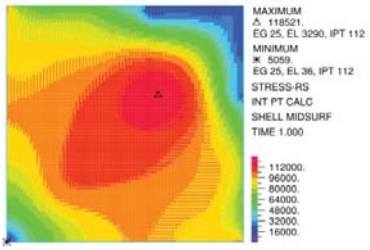

Figure 16.14 – LC4

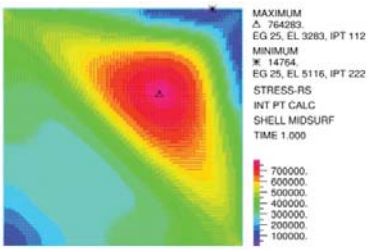

Figure 16.15 – LC5

4th Configuration

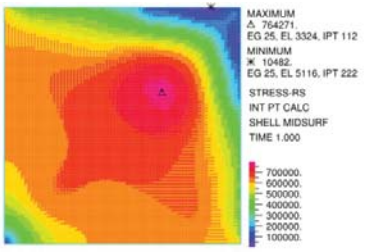

Figure 16.16 - LC1

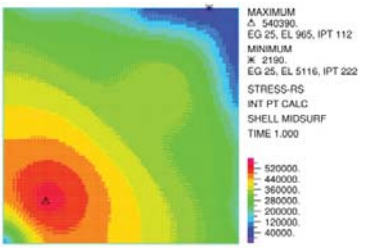

Figure 16.17 – LC2

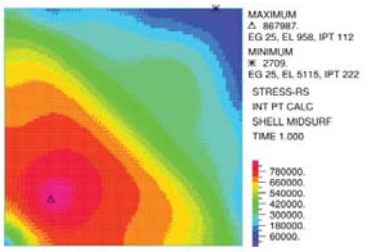

Figure 16.18 – LC3

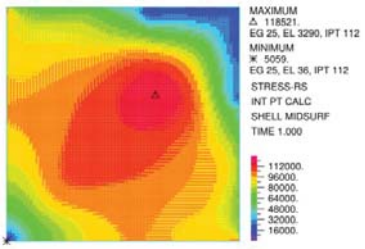

Figure 16.19 – LC4

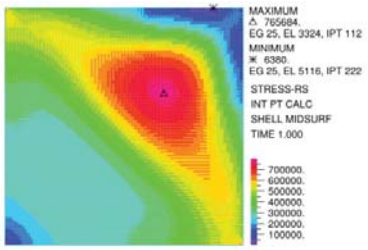

Figure 16.20 – LC5

Appendix B

Investigating the Preservation Needs of Objects within the
George Nakashima Arts Building.
Leah Bright,
Winterthur/University of Delaware Program in Art Conservation, 2016

Investigating the Preservation Needs of Objects within the George Nakashima Arts Building

A Research Project Carried Out to Fulfill the Preventive Minor
Winterthur, University of Delaware Program in Art Conservation

Leah A. Bright, WUDPAC Class 2017
May 13, 2016



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   c. Specific condition issues noted
   d. Analysis of Temperature, Relative Humidity, and Light Data from March 2016

III. **Suggestions to Mitigate Risks**:
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   b. RH/Temp
   c. Other suggestions

IV. **Appendix**:
   a. Winterthur light guidelines
   b. All data logger graphs

Investigating the Preservation Needs of Objects within the George Nakashima Arts Building

I. Project Background, Goals, & Process

George Nakashima (1905-1990) was an American woodworker and architect considered the father of the American craft movement and well known for his elegant conoid chairs and large slab tables that embrace the natural beauty of wood. Nakashima also founded the George Nakashima Institute for Peace to promote global peace through the crafting of peace altars for each continent. The nineteen buildings on Nakashima's estate near New Hope, Pennsylvania still function as home and workshop and the complex was listed as a National Historic Landmark in 2013.

One notable building on the estate is known as the Arts Building, which Nakashima designed in 1964-1967 to serve as a gallery for the artwork of his friend Ben Shahn (1898-1965), but sadly Shahn passed away in 1965 before construction was complete. The unique hyperbolic paraboloid roof of the building is of special interest to historic preservationists, and the building still holds many objects and works associated with Shahn, and a mosaic Shahn designed is installed on the exterior of the building. Today, the Arts Building serves as a museum and an example of Nakashima's skill as an architect and is the home of the Foundation for Peace. It is used for events and houses furniture, furniture prototypes, drawings, and archival materials in addition to the objects and works associated with Ben Shahn (Historic Structures Report, 2013).

In 2014 after the completion of a Historic Structures Report for the Arts Building, the Nakashima Foundation for Peace, George Nakashima Woodworker SA, Inc., and the School of Design at the University of Pennsylvania signed a five-year memorandum of understanding to promote George Nakashima "through the study and preservation of the property" (Historic Structures Report, 2013). A complex and interdisciplinary team has been formed to contribute to the project and ensure the future preservation of the building. In 2015, the Getty Conservation Institute awarded a "Keeping It Modern" grant to the University of Pennsylvania to prepare a Conservation Management Plan for the Arts Building and Cloister, to which the project outlined in this report will contribute. To date, a full set of measured drawings and photo-documentation has been completed, a large collection of archival material has been organized in a database, and a comprehensive report about the life and work of George Nakashima has been compiled for the project.

As part of the preservation of the physical structure of the Arts Building, Michael C. Henry, Adjunct Professor of Architecture at the University of Pennsylvania, is consulting with the primary team concerning the building envelope and environmental management. The following report will serve as a conservation perspective that outlines the vulnerabilities and condition risks of the objects within the collection housed in the Arts Building, which will be integrated into the Conservation Management Plan.

In October 2015, the author of this report accompanied Henry and a group of students in his Building Diagnostics and Monitoring course on a visit to the Arts Building. The students were charted with assessing the hygrothermal performance of the building and the condition of the roof deck, and the author completed a basic assessment of the movable contents of the space and noted any preservation vulnerabilities or risks in regards to relative humidity, temperature, and light. In March 2016, a second visit to the Arts Building involved further installing four loggers to monitor the temperature, relative humidity, and light levels, as well as further investigations into the contexts of the collection, their locations within the building, and any risks and vulnerabilities. This

second visit also involved taking light levels with and without screens and curtains, and consulting with Mira Nakashima about the collection background and use of the building.

II. Project findings: Materials, Risks, and Data Analysis

General characteristics of the Arts Building

Initial analysis of the space involved identifying general materials present in the collection and inherent characteristics of the building itself that could present a risk to the objects within. The large windows and sliding doors on the south and west walls allow unattenuated daylight to enter the space, which is damaging to all organic materials and especially to textiles and works on paper. Interior soji screens over the windows near the front door on the lower level seemed to reduce light levels significantly. Fluctuations in relative humidity and temperature also seemed to present a moderate risk to the collection, as much of it is comprised of furniture, wooden, and composite objects. It was also noted that the some of the small baskets and other wooden/organic objects within the window-shelving unit on the mezzanine display tide lines and water damage, an apparent effect of condensation forming on the interior windows.

Contents of the collection

The collections within the Arts Building consist primarily of furniture and wooden objects and other organic materials, along with works on paper, metal objects and sculptures, and a small number of textiles (figs. 1-2). Figures 3 and 4 illustrate the general placement of objects within the space, and Table 1 summarizes the contents of the Art Building and briefly outlines the primary risks associated with each category. Time constraints limited the study of the objects in the Arts Building to a general overview and brief investigation into particularly sensitive objects. Table 1 and other discussion of objects in the space are not an inventory or exhaustive list. just represent a general sense of the general contents.



Fig. 1. The upstairs mezzanine with many chairs, a table, and myriad objects on a window-shelving unit



Fig. 2. A representation of the mix of materials in the Arts Building, furniture and other wooden objects, framed works on paper, and metal sculpture



Fig. 3. Diagram of the ground floor of the Arts Building

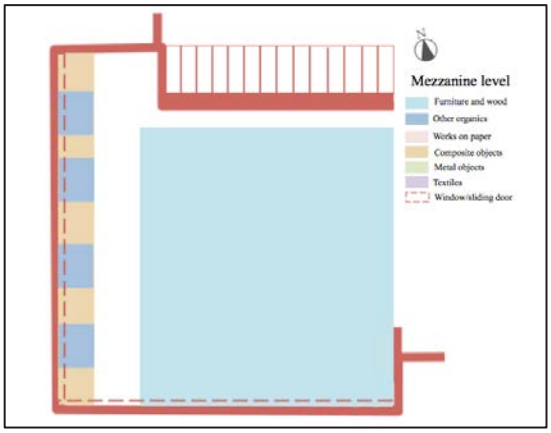


Fig. 4. Diagram of the mezzanine level of the Arts Building

Table 1. Summary of General Categories of Objects in the Arts Building and their Light, RH/Temp Risks

Category of material	Risks	Ideal conditions
 Wood/furniture	Slight sensitivity to fluctuations in RH, can cause warping, cracking Slight sensitivity to light and UV	Most pieces of furniture in the Arts Building have likely been "proofed" or experienced fluctuations They are a medium to low vulnerability to humidity fluctuations: 150 lux 11.24 mW/m^2
 Textiles	Sensitive to light and UV	100 lux 7.7 mW/m^2

 Metals (bronze, iron, brass etc.)	Sensitive to high humidity, not light sensitive	Ideally RH should be kept between 35% and 55%
 Small composite/paper objects	Light sensitive High RH, temperature could cause warping of components	150 lux 11.24 mW/m^2
 Drawings, prints, other works on paper	Light sensitive The sensitivity of the many works on paper in the Arts Center depends on their framing, works with UV-filtering glazing will be much less sensitive than un-framed works (like the scroll shown at left)	50-200 lux 3.75- 15 mW/m^2
 Other composites like clocks, musical instruments	Sensitive to RH fluctuations Slightly to moderately sensitive to light In addition to the wooden furniture, objects comprised of wood in combination with other materials like the mandolin and piano are more sensitive to RH fluctuations because the different materials respond differently to humidity.	Least dramatic fluctuations as possible 100-150 lux 7.7- 1.25 mW/m^2

 Other organics like basketry, leather	Sensitive to light, insect and water damage Some organic materials will fade with light exposure, while other will darken	50-200 lux 3.75- 15 mW/m^2
 Other inorganics like ceramics, glass	Not light sensitive or sensitive to RH or T (unless very extreme) Vulnerable to physical forces, dropping, earthquakes etc.	Because of their lack of sensitivity to light, ceramics and glass objects could be considered as replacement for some of the more sensitive objects in the window shelving

Specific condition issues noted

While most objects seem to be in good condition, a few objects stood out as either unstable or particularly at risk due to their composition or condition:

1. *Lacquer box in SE corner* (fig. 5)
   This lacquer box is currently in very good condition, but Asian lacquer objects are especially sensitive to light damage, at Winterthur they are considered moderately sensitive and are kept at 100 lux. Although the exterior of the box remains in good condition, there is already a marked difference between the interior and exterior, illustrating that light damage has already occurred, and will continue.



Fig. 5. The lacquer box sitting on another wooden box in the south eastern corner, vulnerable to light damage

2. *Ed Fields rug from 1959* (fig. 6)
   There are a few notable textiles in the Arts Building, including an original 1959 Ed Fields rug near the fireplace and a small wall hanging on the mezzanine. Textiles are especially vulnerable to light fading, as ultra-violet and visible light can fade dyes and embrittle fibers. Without knowing exactly the composition of the dyes and fibers, it is difficult to establish lifespan, but in museum settings textiles are generally displayed in short rotations to limit light exposure. The Canadian Conservation Institute suggests three-month rotations for sensitive objects (CCI 2013). The Fields rug was recently stabilized and put on display in

the Arts Building. It is a special example of an original Fields rug that relates to Fields and George Nakashima design collaborations that have only recently been reproduced (Wallis 2015). The rug is currently in beautiful and stable condition, with rich navy blue and bright yellow. The small wall-hanging at the top of the stairs in front of a mezzanine window (fig. 7) exemplifies light damage well, as the side facing the window is a faded light mustard, while the original deep olive green in visible on the opposite side. It is possible though, that with many years of exposure, the fading on the window side has plateaued, and will not worsen significantly. The other side though, is still vulnerable to ambient light, if not as direct as the other side.



Fig. 6. Original Ed Fielding rug near the fireplace



Fig. 7. Hanging textile at the top of the stairs, which is already markedly differently colored on each side

3. *Harry Bertoia sculptures (one spherical (fig. 8) and one "Sonambient" (fig. 9))*
These two sculptures are particularly important pieces and as metals, are particularly sensitive to high relative humidity. Green corrosion is visible at the tips of the spherical sculpture, which is likely active and serves as evidence of episodes of high relative humidity. There is also visible dust on the other Bertoia sculpture, which can promote corrosion by holding moisture on a metal surface (ASHRAE 2003, 21.2). It would be beneficial to monitor these two sculptures for any further changes in condition.

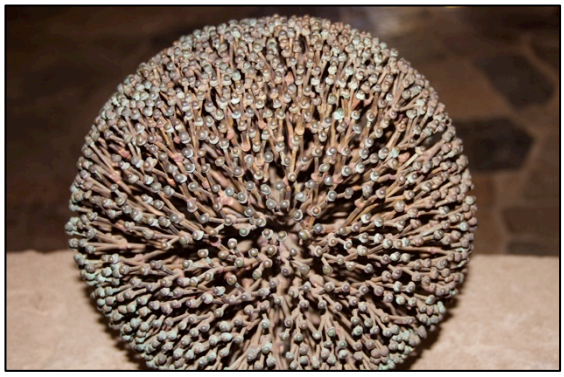


Fig. 8. A spherical Harry Bertoia sculpture with green-white corrosion at ends of nodules

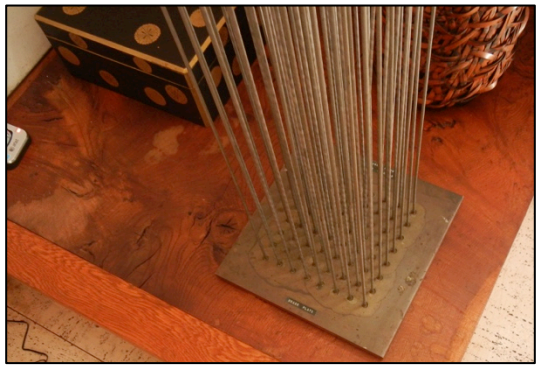
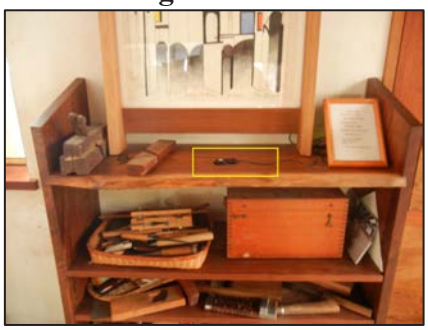


Fig. 9. Second Harry Bertoia sculpture with visible dust accumulation

Analysis of Temperature, Relative Humidity, and Light Data from March 2016

Data was recorded for approximately one month, from March 2, 2016, through early April (loggers deinstalled approximately April 6, 2016 (exact date unsure at this time). Although only one month of environmental data only provides a small window of information about the entire year, this data can help provide insight into relationships between different areas of the building, and we can speculate about other seasonal trends. Summer months will likely be warmer and more humid, while winter months will likely be cooler and drier. It is also possible the winter and summer months will display less fluctuations, as March is a transitional spring month with generally wider more frequent changes in temperature. It will be valuable to continue monitoring the space to gauge these changes.

Figs. 10-15. Location of Data Loggers in Place During the Month of March



Logger H. Near front door on bottom floor, light sensing only (no RH/T)



Logger I. Light sensor draped over central drawing, RH/T sensor wedged near bottom edge by heater



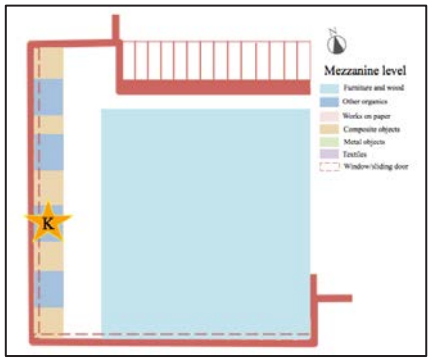
Map of the bottom floor showing the locations of loggers I, H, and L



Logger K. Both sensors on the top shelf third column from the left.



Logger L. Both sensors near center of fireplace mantle



Map of the mezzaninie showing the location of logger K

Temperature

As summarized in Table 3, there are no major differences between the highs, lows, and averages of the three loggers. The lows were all about 44 °F, and the averages are all in the mid 60s. The only major outlier was the high temperature recorded in the mezzanine, which was 95.72 degrees. This may be due to a stack effect, heat from the sun penetrating through the surrounding windows, or the proximity of a baseboard heater. It was noted during both visits that it felt quite

warm on the mezzanine, so these results were not surprising. Comparing the temperature graphs for all three loggers shows that there were dramatic daily fluctuations in temperature on the mezzanine, while the smallest fluctuations were recorded on the fireplace mantle. This may be due to the buffering effects of the stone mantle. The large, dramatic fluctuations in the mezzanine are likely due to exterior air infiltrating the surrounding windows, making the space more sensitive to exterior fluctuations. The fluctuations recorded on the frame were in between those of the mezzanine and fireplace. Overall the same broad patterns are visible, with larger fluctuations occurring over about 3-6 days.

Table 2. High, low and average temperature logged from March 2016 (degrees Fahrenheit)

Location	High	Low	Average
Frame (I)	76.64	44.60	63.29
Fireplace (L)	77.00	44.96	63.12
Mezzanine (K)	95.72	44.06	66.00
Overall Average	83.12	44.54	64.14

Relative Humidity

Relative humidity recorded by the three loggers displays similar patterns as temperature. There is a strong inverse relationship overall between RH and temperature, strongest on the mezzanine. The highs in humidity are with 2% of each other, and both the frame and fireplace shared a low of 23%, while the low on the mezzanine was 14%, which relates to the abnormal high in temperature. The overall average relative humidity was 49.17%. All loggers recorded similar fluctuations as temperature, with the mezzanine recording the most dramatic, the fireplace the smallest, and the frame between the two. The most dramatic overall fluctuations are visible the last few days of March, when there is a 40% change in humidity over 2-3 days.

Table 3. High, low, and average relative humidity logged March 2016 (% RH)

Location	High	Low	Average
Frame (I)	66.00	23.00	44.44
Fireplace (L)	64.00	23.00	43.32
Mezzanine (K)	64.00	14.00	39.98
Overall Average	69.00	27.32	49.17

Light

Light levels recorded by three of the four loggers were extremely high, while the logger near the front door was relatively much lower, and recorded no UV. This is due to the soji screens that cover the window and three skylights. Generally, for a partially controlled environment light levels are recommended to be 200-lux visible light and 15mW/m^2 UV (Michalski 1997, 2). For

comparison, Winterthur suggests 200 lux for its least light sensitive objects (see Table 6 in the appendix for Winterthur's guidelines). The majority of the light recorded at the Arts Center is related to daylight, so there is very little to no light exposure after sundown, which is a perk of day-lighting.

Table 4 shows the highs, lows, averages, sum, and extrapolated annual sum for all four loggers. At the front door, the average visible light reading was 7.54 lux, which is quite low. The average at the fireplace logger is the next lowest, with an average of 207.71 lux, the average recorded at the frame was 271.56, and at the mezzanine was a massive 1,135 lux. Seasonal changes in sun's position would likely influence the light recorded by the loggers at other points in the year, but to gain insight into light levels overall, each sum was divided by 35 then multiplied by 365 to estimate a annual lux hour total. All except the front door logger totaled huge lux hours, much over the ideal 730,000-lux hours if 200 lux was maintained all year.

Interestingly, looking at the graphs recorded by the loggers, the light levels in the mezzanine are very high and then drop off dramatically after March 12th (see appendix). This is a phenomena witnessed at Winterthur as well, and is likely related to seasonal positions of the sun (Peirce 2016).

Table 4. Light logged March 2016 (ultra-violet in mW/m^2, visible light in lux)
A maximum **200**-lux **is recommended**, with **15 mW/m^2 UV**, for a total of **730,000-lux hours annually**

Location	High		Low		Average		Sum (for ~35 days)		Sum (1 year est.)
	UV	Vis	UV	Vis	UV	Vis	UV	Vis	Vis
Front door (H)	0.00	201.3	0.00	0.00	0.00	7.54	0.00	7,215.5	71,179
Frame (I)	2,140	45,480.0	0.00	0.00	16	271.56	15,085	259,810	2,562,990
Fireplace (L)	680	15,740.0	0.00	0.00	9	207.71	8,972	198,770	1,960,839
Mezzanine (K)	3,520	33,630.0	0.00	0.00	191	1,135.4	183,100	1,088,800	10,740,865
Overall Average	370	23,762.83	0.00	0.00	54	405.55	51,789	388,648.88	3,833,969

During the second site visit, light levels were recorded in three places throughout the building with and without soji screens, and in one place, with and without curtains. Table 5 summarizes these findings, which show that both screens and curtain drastically reduce light infiltration, which is also demonstrated by the low light levels near the front door.

Table 5. Testing light levels with and without screens in three places:
Taken about 1:15pm on 3/2/2016, a clear, sunny day
A maximum **200**-lux **is recommended**, with **15 mW/m^2 UV**

Location	Ultra Violet Light (mW/m^2)			Visible Light (lux)		
	Without screen	With screen	Difference	Without Screen	With screen	Difference
Front sliding door in direct sun, partially diffused by trees outside	8,100-11,000	190-220	~9,345	17,000-23,000	1000-1300	~8,850

Back window by fireplace in indirect sun	2274	258	2,016	990	319	671
Upstairs sliding door in direct sun	17,000	930-960	~16,055	34,000	3,850	30,150
Upstairs sliding door in direct sun with curtains pulled instead of soji screens	17,000	500-480	~16,510	34,000	1230-1250	~32,760

III. Suggestions to mitigate risks to objects

Light

There are many ways to mitigate daylight, from simple to complex. It would be beneficial to pull all curtains as much as possible, which as indicated by Table 5, is a very effective light mitigation step. The soji screens are also effective means to diffuse light, so installing the screens present in the mezzanine would be very helpful. The manufacture of more screens may also be an option, which could even be temporarily installed. Soji screen in the window shelving may also protect the objects from damage from condensation.

In addition to these physical light barriers, the installation of light-filtering window films in highly suggested. There are many films currently on the market with a range of protection. Some filter only ultra-violet light, while some also filter some visible light. Some can change the color of light slightly, so it is important to consider aesthetic choices as well (Boye et al. 2010, 14).

Mitigating light damage will go a long way in lengthening the lives of the objects in the Arts Building. If some of these options are not possible to reduce light exposure, it is also suggested to rotate light sensitive objects, or even move them permanently. It is possible that some objects from the window shelving could be moved down near the front door, and some of the least light sensitive objects from the door area (like ceramics, glass, and wood-working tools) could be moved to the mezzanine.

Relative Humidity and Temperature

Wooden artifacts and furniture

Original George Nakashima furniture comprises a large quantity of the objects within the Arts Building. There are also many large slabs of raw wood and other small wooden objects like baskets and textile printing blocks. Furniture and wooden objects are especially sensitive to fluctuations in relative humidity (RH), and expansion and contraction can cause warping and cracking (Camuffo et al. 2014, 27). An important concept for this space though, is the idea of proofed RH, which Stefan Michalski explains as "The largest RH or T fluctuation to which the object has been exposed in the past or, alternatively, just the lower and highest RH and T of the past" (Michalski 2007, 11). For the furniture and wooden objects in the collection to remain stable in this environment, relative humidity extremes should be kept within those already experienced by the object. It is assumed that any modifications to the HVAC system would only tighten the control and fluctuations; and the furniture and wooden objects in the Building have likely already experienced any future fluctuations caused by the exterior climate.

Humidity sensitive objects: metals

Although fluctuations may not pose a major threat to the wooden artifacts in the collection, metal objects like the Harry Bertoia sculptures and other small metal artifacts are sensitive to high levels of relative humidity. 35%-55% is generally suggested to prevent corrosion on metal objects (Logan and Selwyn 2007).

Other suggestions to promote the preservation of the collection:

Housekeeping:

Establish a general housekeeping plan that includes regular dusting of collection objects to prevent dust accumulation, which can hold moisture on the surface of an object, attract pests, abrade surfaces, and be visually disruptive. Although the space appeared very clean and tidy, it would be beneficial to ensure a housekeeping plan is undertaken to ensure floors are clean of any food, dirt, or debris from outside to discourage pest activity.

Pest management:

Three potted plants were noted on the second visit; raw wood for the fireplace, and crumbs of food could all harbor or attract pests, which could then damage textiles, paper, and other organic materials. The pragmatic useful nature of the Arts Building means eliminating these activities would be impractical, but it would be beneficial to enact a pest monitoring protocol with a few pest traps strategically placed and checked every month or two to prevent any infestation that could detrimentally damage the collection.

Dissociation:

It would be beneficial to establish an inventory of the objects in the Arts Building, especially the many small objects on the mezzanine window shelving, most of which seem to have been separated from their labels. An inventory could facilitate easier evaluation of the objects, their condition, and location within the Building. An email conversation with Pan Sergey of the James A. Michener Museum revealed that an inventory previously thought completed of all the objects in the Building actually only contains archival materials donated to the Museum: "The only inventory I created is of paper materials (correspondence, photographs, publicity materials, and a few original drawings) which were contained in flat files and vertical file cabinets in the Arts Building, or boxes in the Cloister Room, and transferred to the Michener archives" (Sergey 2016).

Archival documents within the flat file:

A further investigation into the temperature and humidity within the flat file cabinet could be beneficial, as it is situated over a heated floor, which has unknown effects on heat and moisture buildup within the cabinet.

Ben Shahn Mosaic on exterior of Building:

The mosaic on the West exterior wall of the Arts Building appears to be in good condition, while only a basic visual assessment was performed during the two site visits. The slight outward slope has ensured water does not settle on the mosaic, which would have eroded the tesserae and substrate over time. There are various lost tesserae, and an area of dark grime and biogrowth at the middle of the bottom edge of the mosaic, where water has dripped off the roof and splashed on a large square stone and onto the mosaic. The removal of this stone would remediate this issue. It would also to be valuable to monitor more closely for the continued loss of tesserae to ensure no water is infiltrating behind and compromising the substrate.



Fig. 16. An overall view of the Ben Shahn mosaic on the exterior of the Arts Building



Fig. 17. A lost tessera over a screw



Fig. 18. An area of lost tesserae



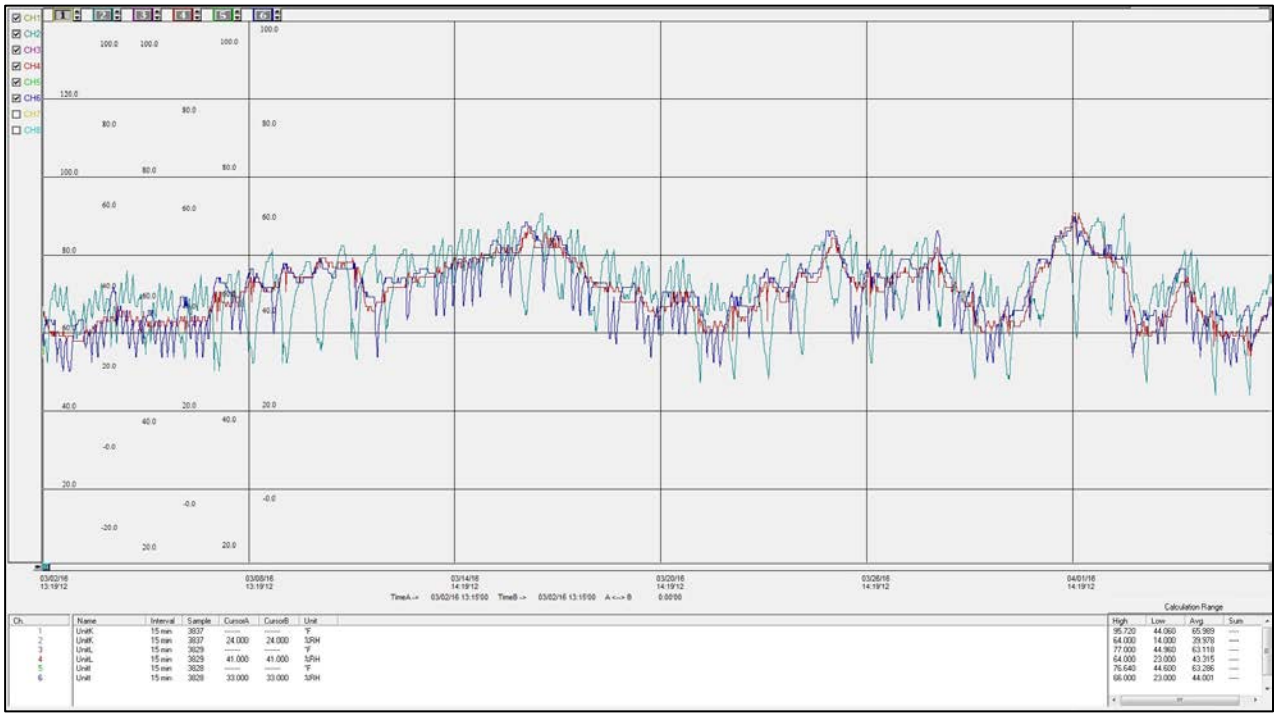
Fig. 19. Area of biological growth where water drips and splashes off of a stone onto the mosaic, promoting mold and other bio growth

IV. Appendix:

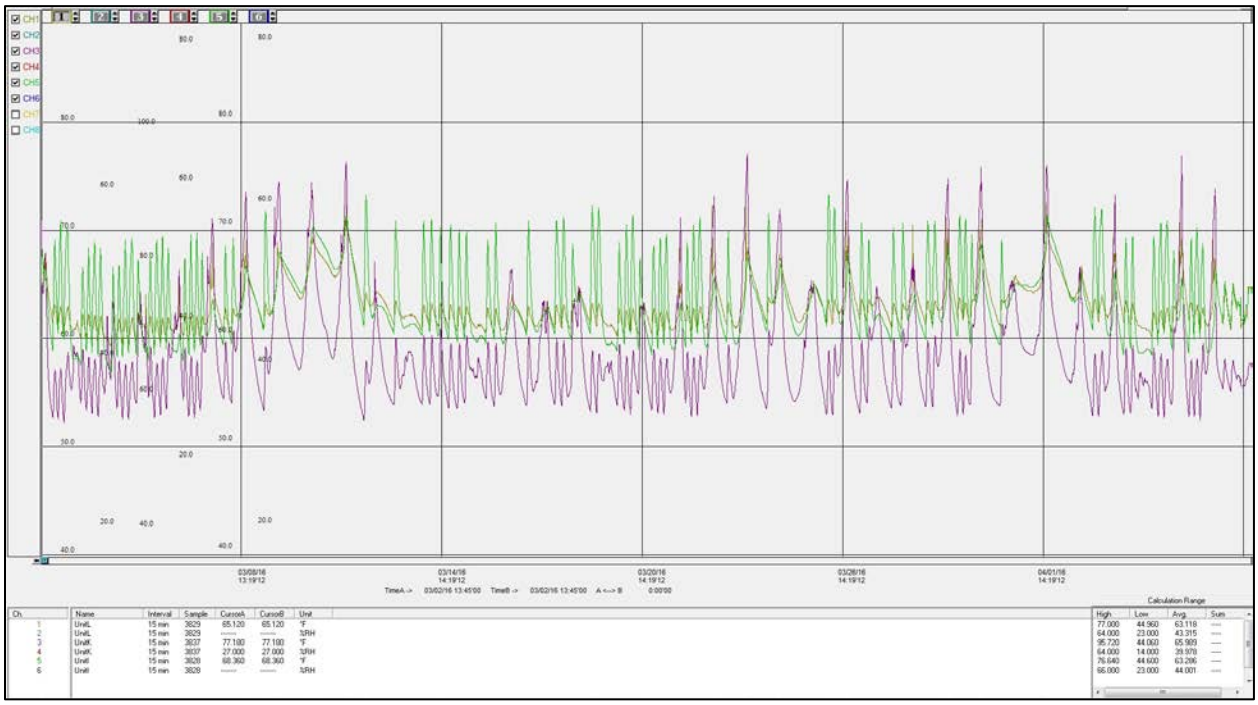
Table 6. Recommended Light Levels at Winterthur

Sensitivity	Visible Light (Lux)	Lux hours annually	UV (mW/m^2)
Sensitive: Other textiles and paper; sensitive organic materials and pigments/media	50 lux	180,000 lux hours *(50 lux x 10 hours x 365 days)*	3.75 mW/m^2
Moderately sensitive: Asian lacquer; other organic materials.	100 lux	365,000 lux hours *(100 lux x 10 hours x 365 days)*	7.5 mW/m^2
Slightly sensitive: Paintings (oil, egg tempera, acrylics), furniture, objects with painted surfaces	150 lux	545,000 lux hours *(150 lux x 10 hours x 365 days)*	11.25 mW/m^2
Least sensitive: metals, stone, glass, enamels, ceramics	200 lux	730,000 lux hours *(200 lux x 10 hours x 365 days)*	15 mW/m^2

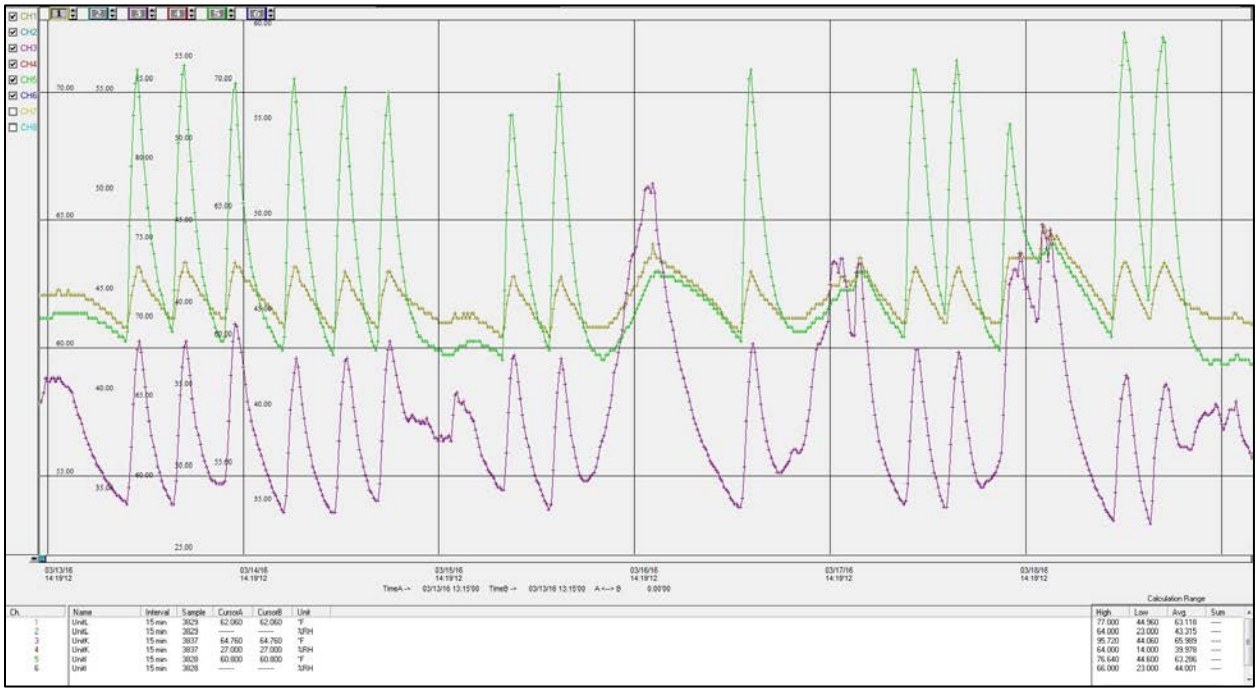
Temperature and Relative Humidity Data



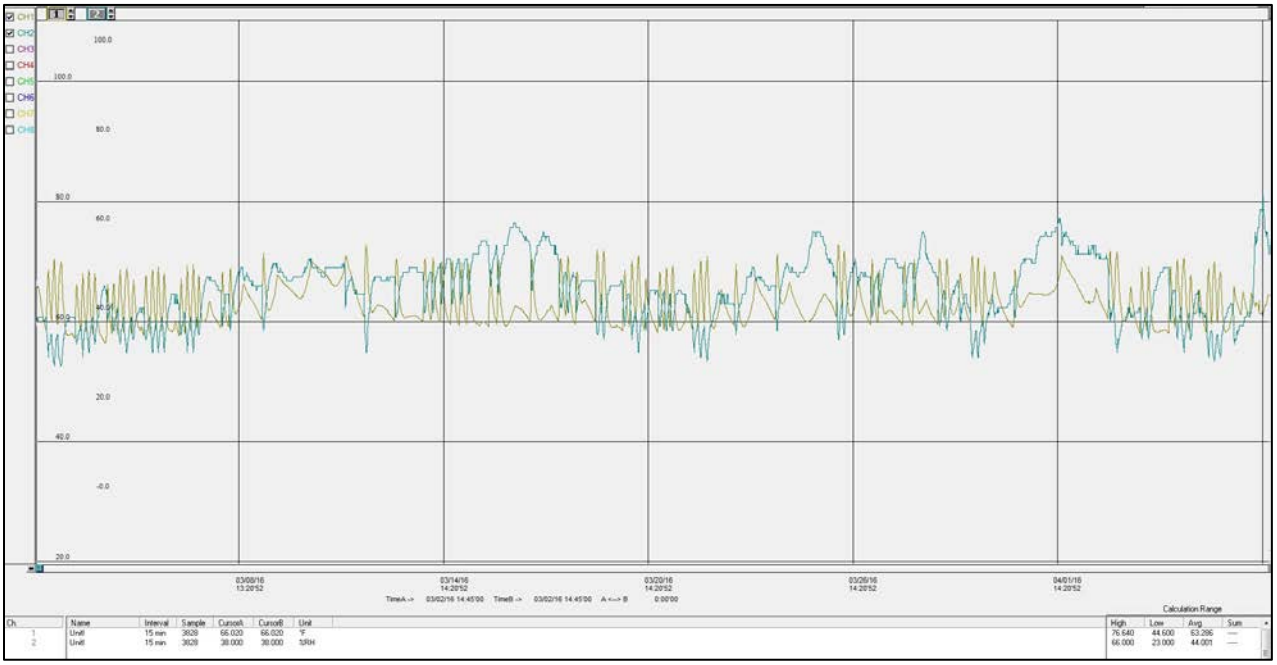
Relative humidity during the month of March for all three RH-recording loggers: the mezzanine (K), fireplace (L), and frame (I). Shows the tightness of fluctuations on the fireplace (in red) relative to the large fluctuations on the mezzanine (in teal). The severity of fluctuations near the frame (in purple) are somewhere between the other two. The overall average relative humidity was 43%.



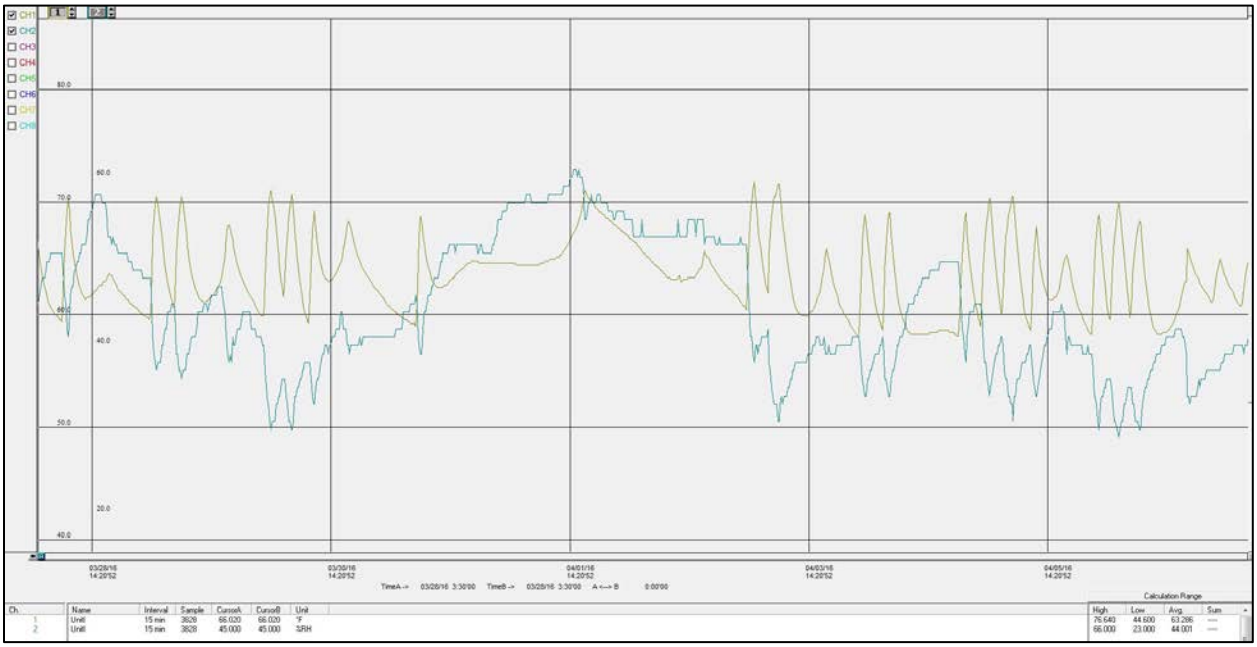
Temperature during the month of March for all three RH-logging loggers.



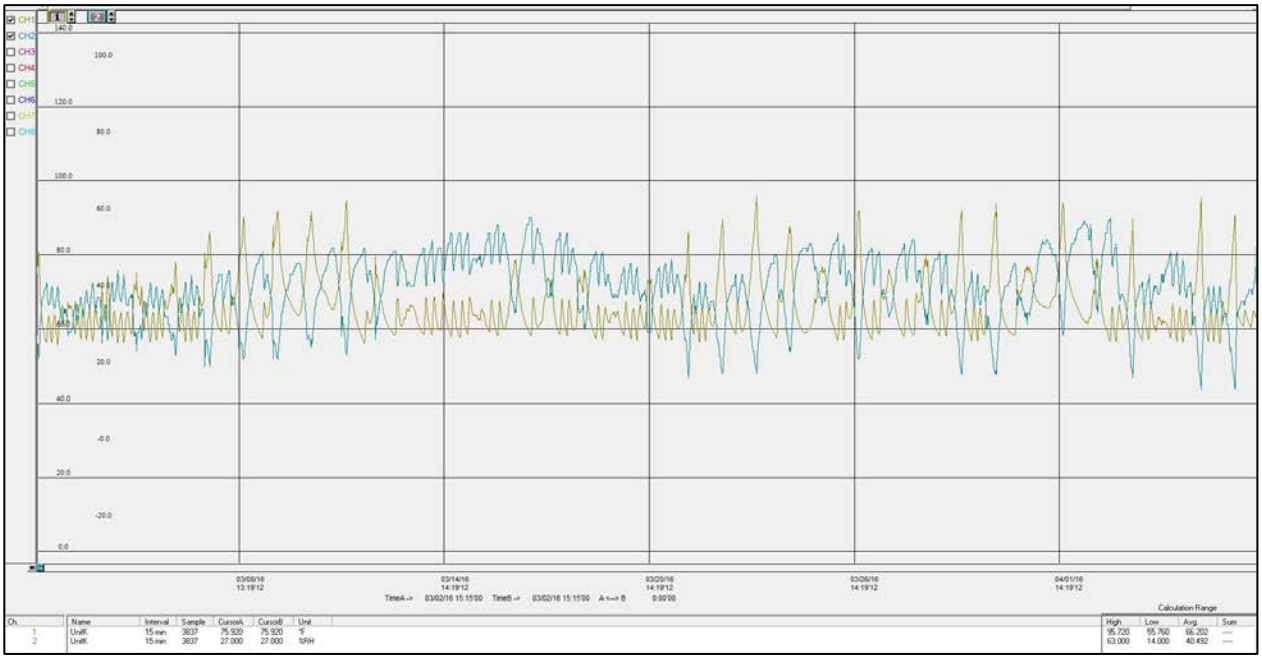
This graph shows approximately six days of temperature data from 3/13-3/18 for all three of the temperature-recording loggers. The logger at the center frame (green) was overall higher in temperature than the other two locations, but the mezzanine (purple) recorded the highest single temperatures and had the largest fluctuations overall while recording generally lower temperatures. The large peak recorded on the mezzanine between 3/15 and 3/16 may be related to the heat being turned on. The logger on the fireplace mantle (yellow) recorded the smallest fluctuations overall.



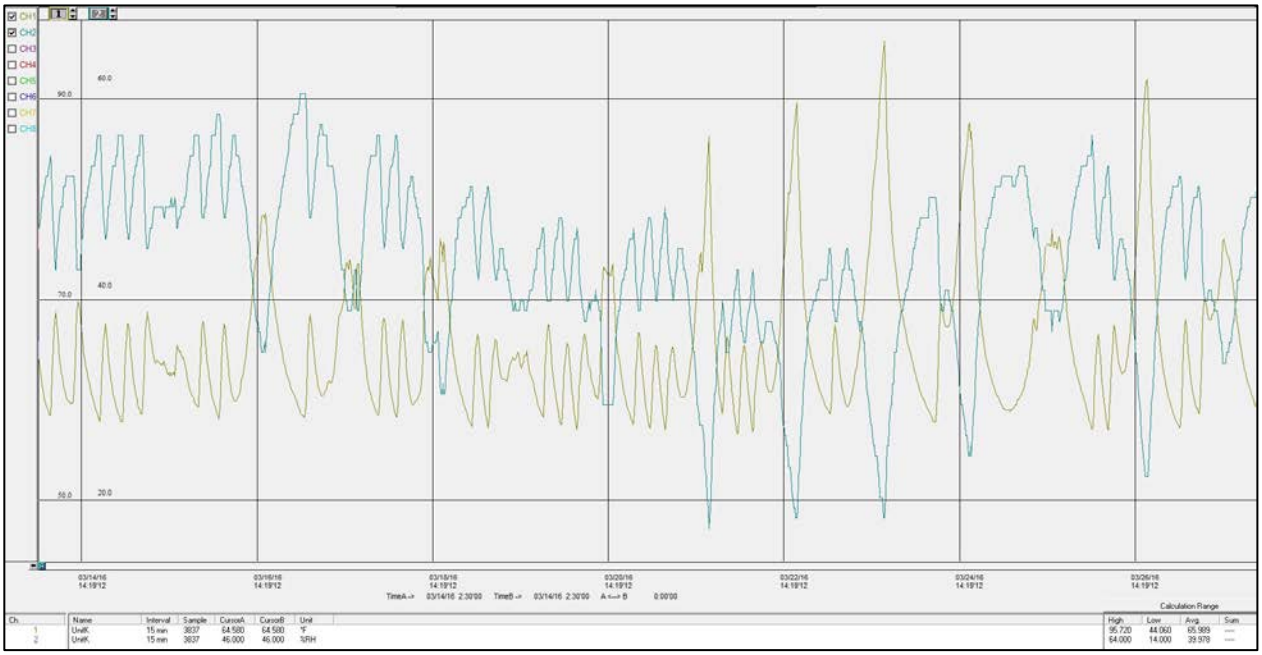
Overall temp and RH for the frame logger (I). (RH blue, temp yellow).



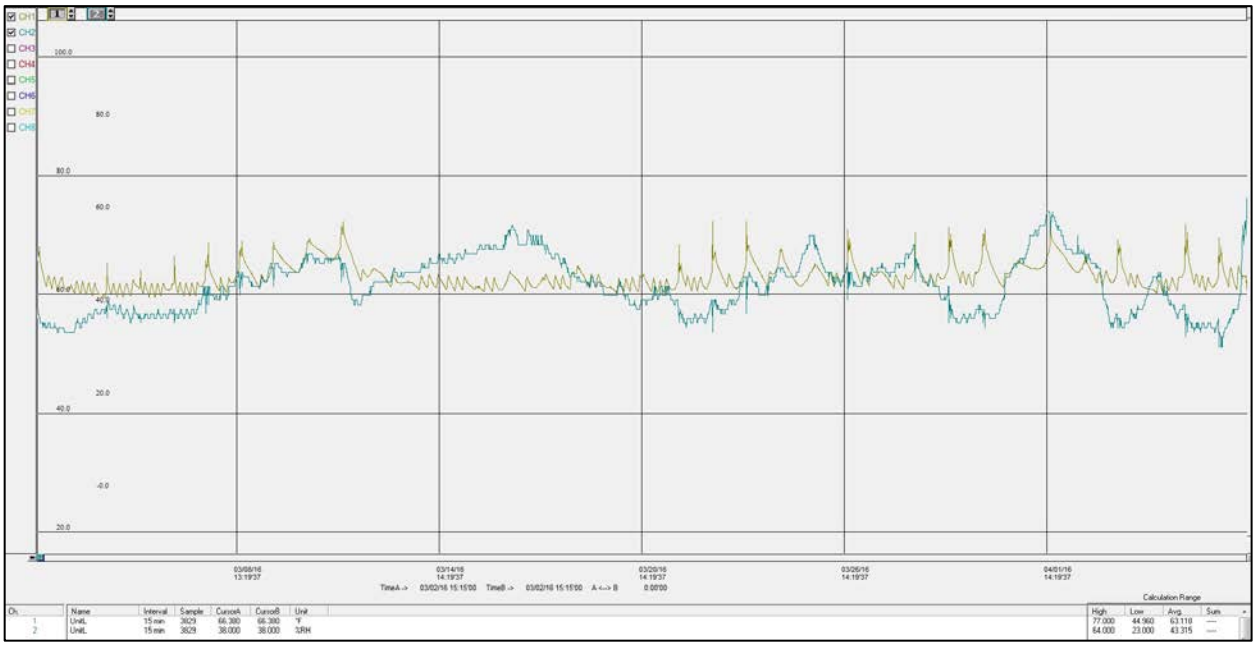
Detail temp and RH for the frame logger (I) from about 3/28-4/7, when one of the largest fluctuations in RH occurred. (RH blue, temp yellow).



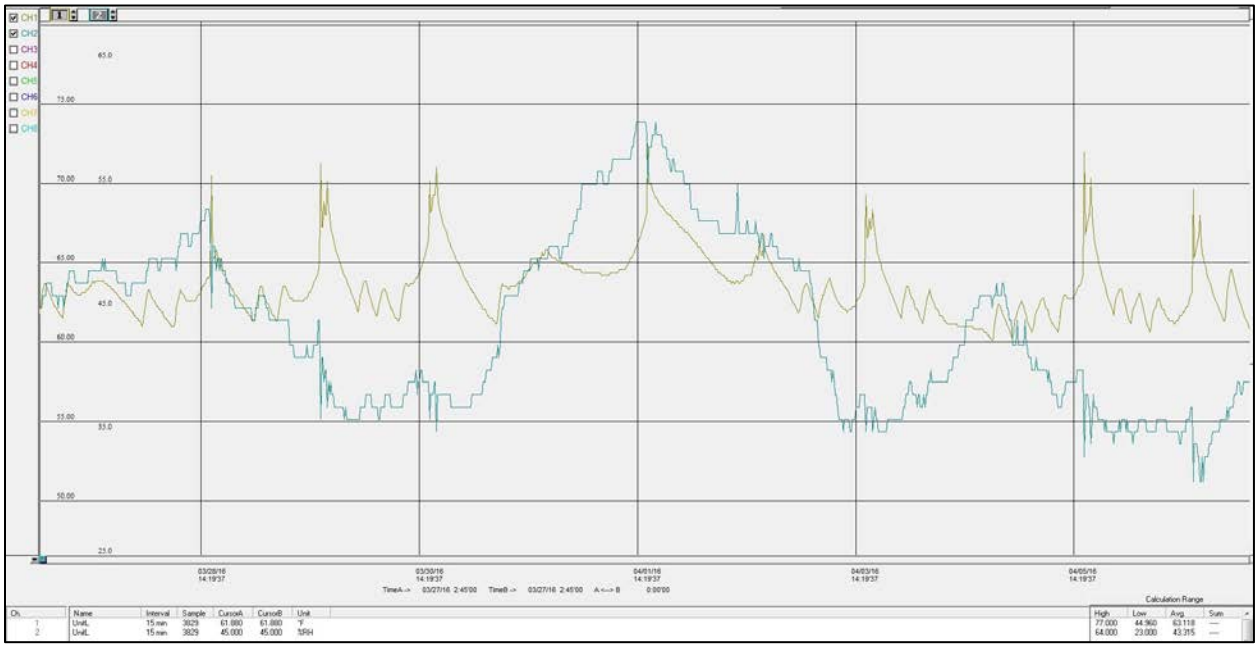
Overall temp and RH data from the mezzanine logger (K) (temp yellow, blue RH).



Detail of temp and RH data from the mezzanine logger (K) from about 3/14/-3/26 (temp yellow, blue RH), showing the strong inverse relationship between RH and temp, and the sharp daily fluctuations.

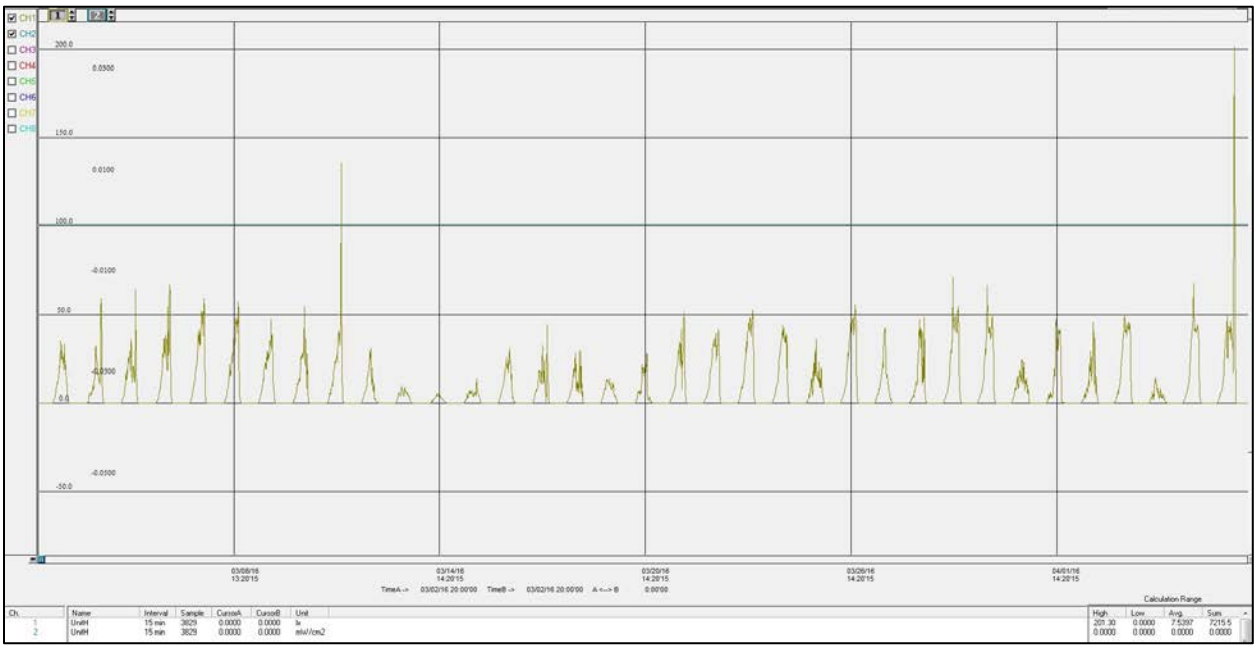


Overall temp and RH data from the fireplace logger (L) (temp yellow, blue RH), showing relatively shallow fluctuations.

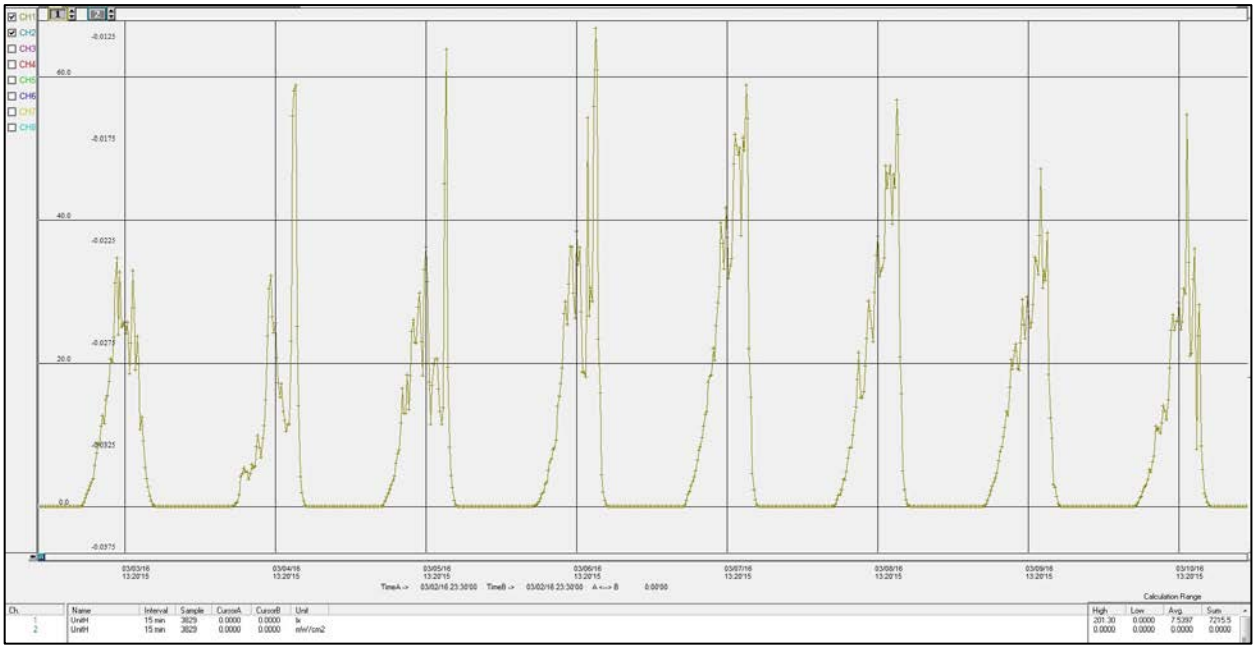


Detail temp and RH data from the fireplace logger (L) from about 3/27- 4/5 (temp yellow, blue RH).

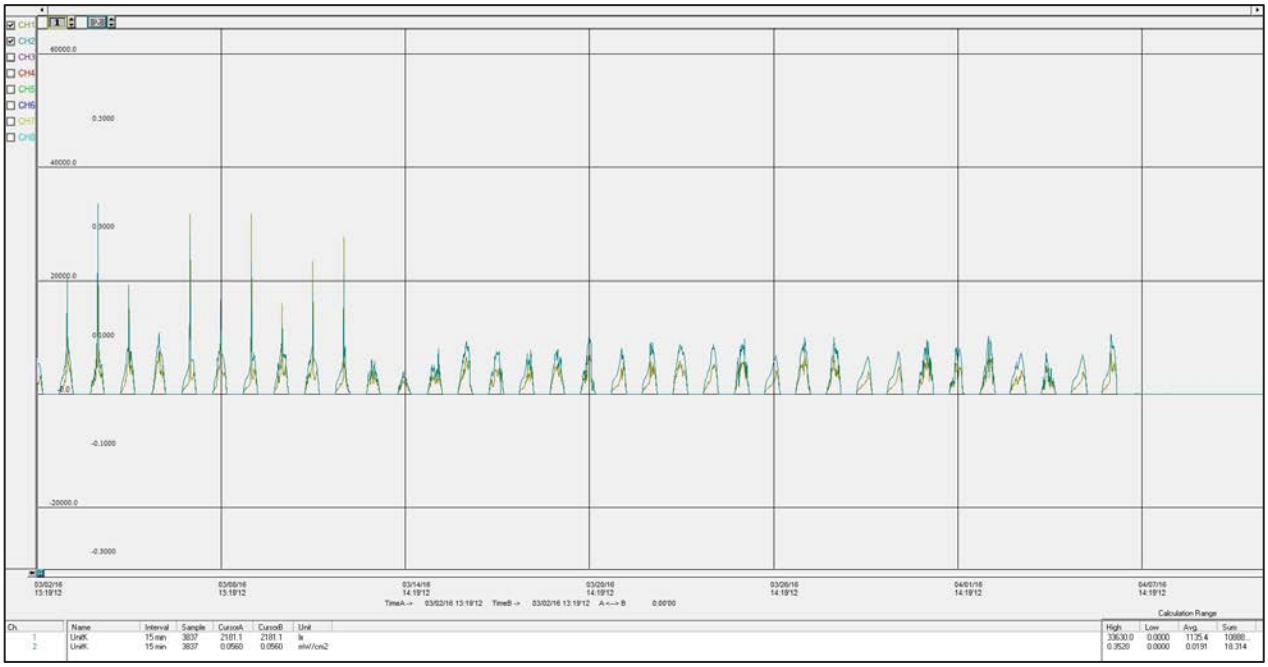
Light Data



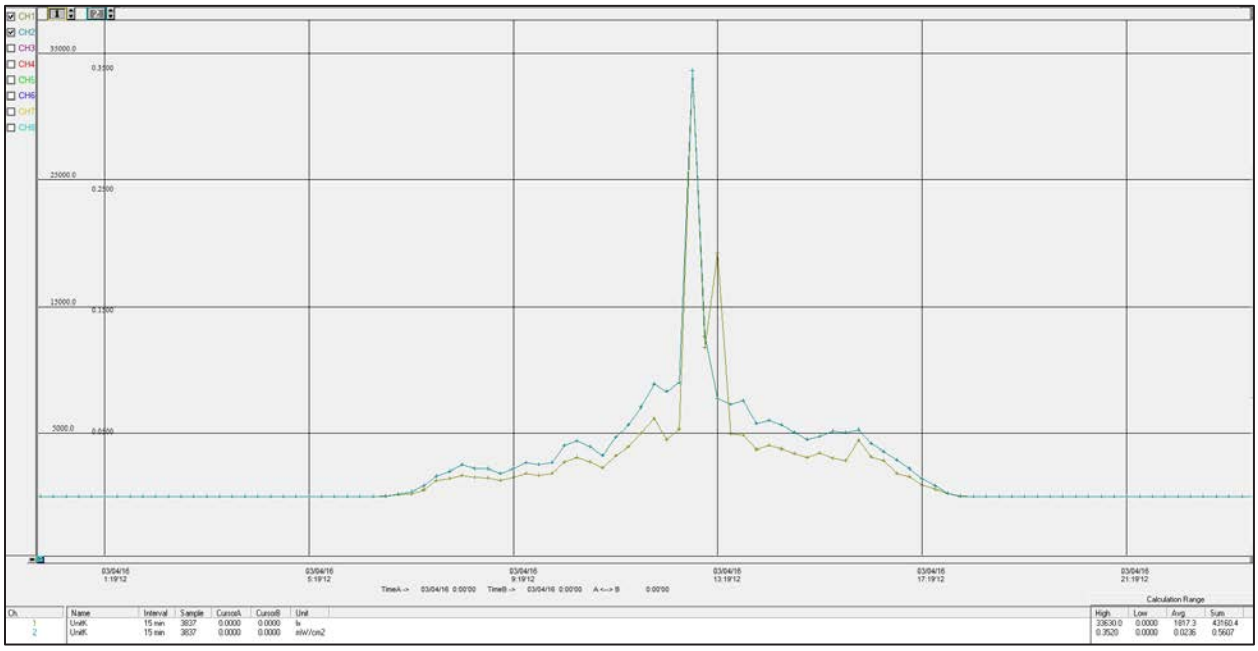
Overall light data from the door logger (H) showing that there is no ultra-violet radiation detected in this area.



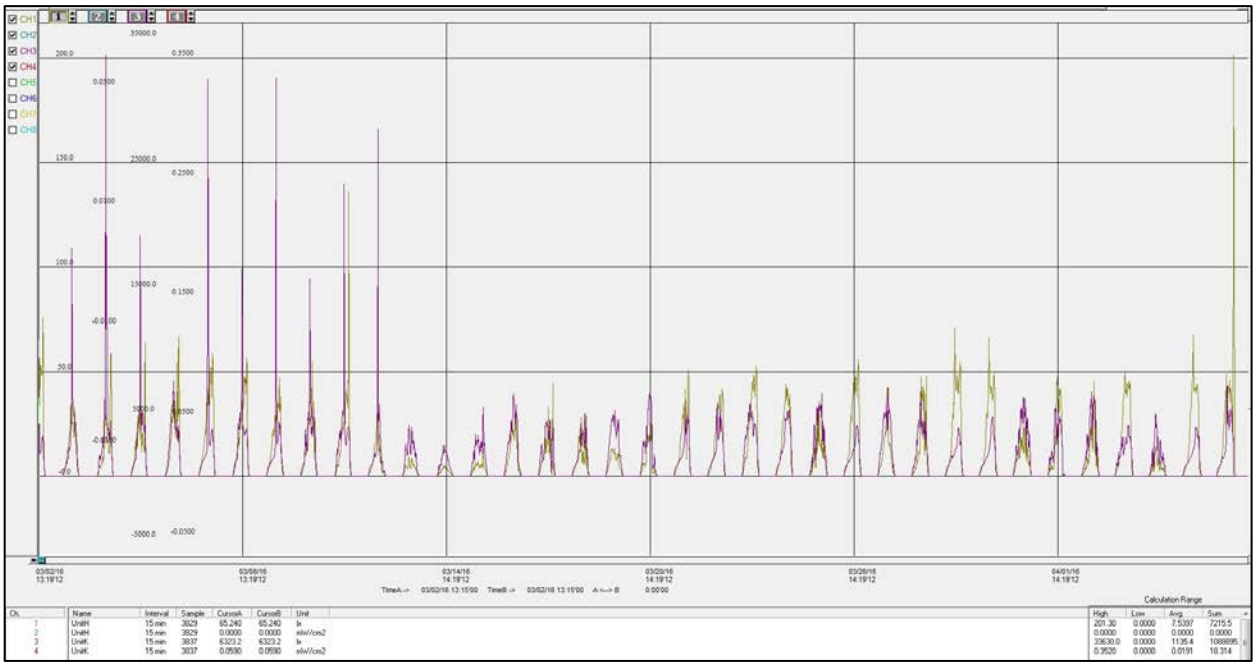
Detail of light data from the door logger (H) from about 3/2-3/10, showing a slight late-afternoon peak in visible light.



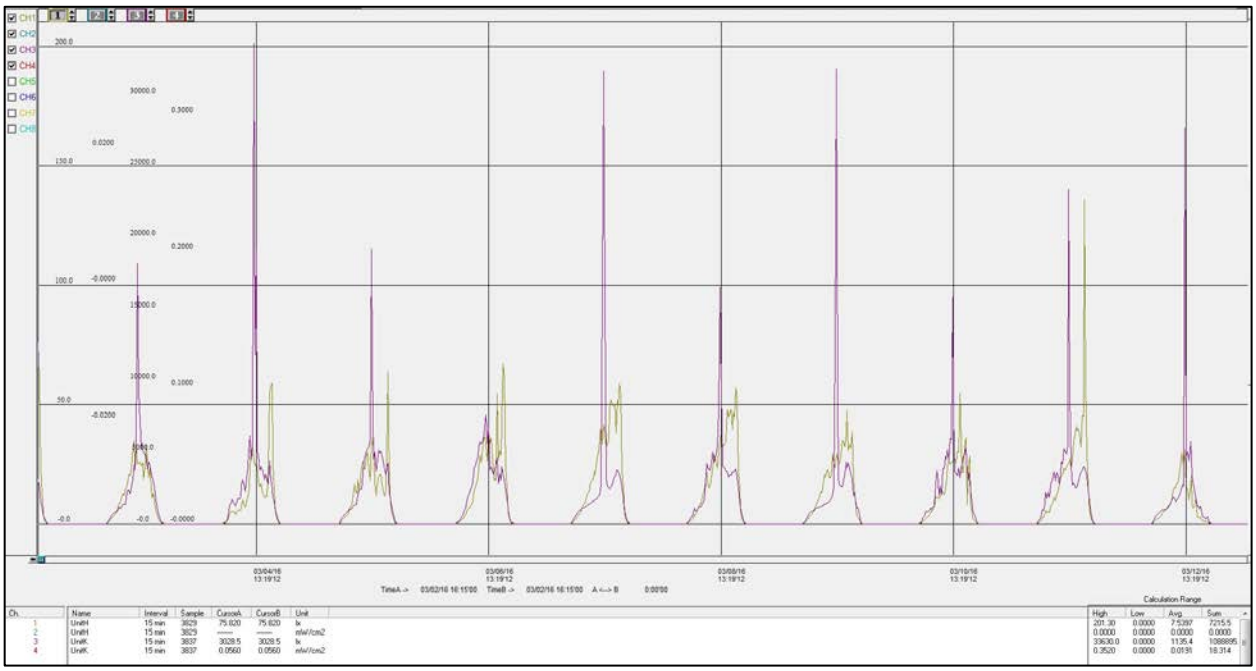
Overall light data from the mezzanine logger (K), showing the interesting drop-off of high peaks after approximately 3/12 that is likely due to a seasonal shift.



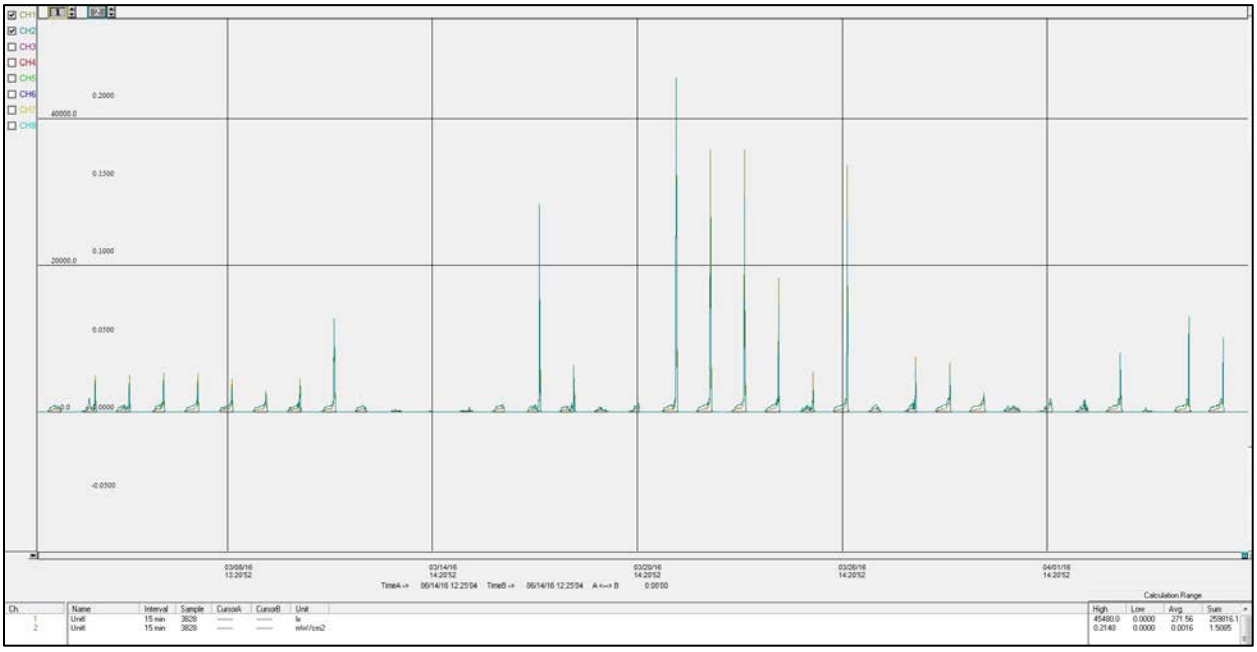
Detail of light data from the mezzanine logger (K), showing all day of 3/4, showing a peak around noon.



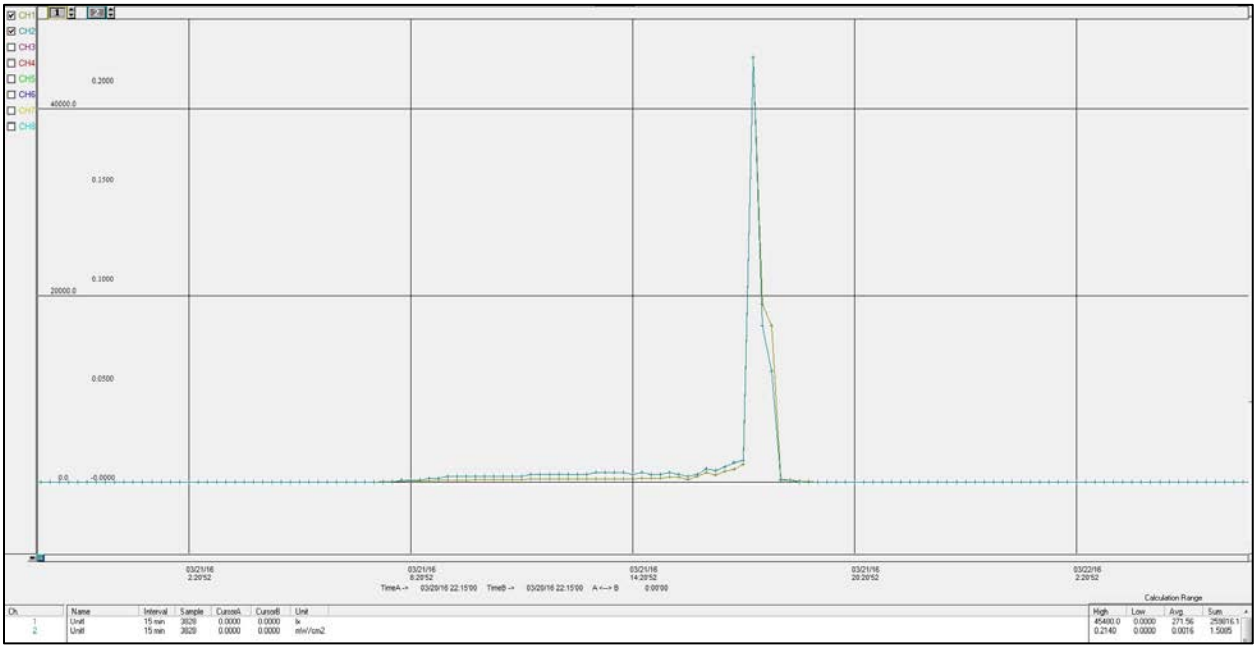
Overall visible light data overlaid from the door (yellow) and mezzanine (purple) loggers.



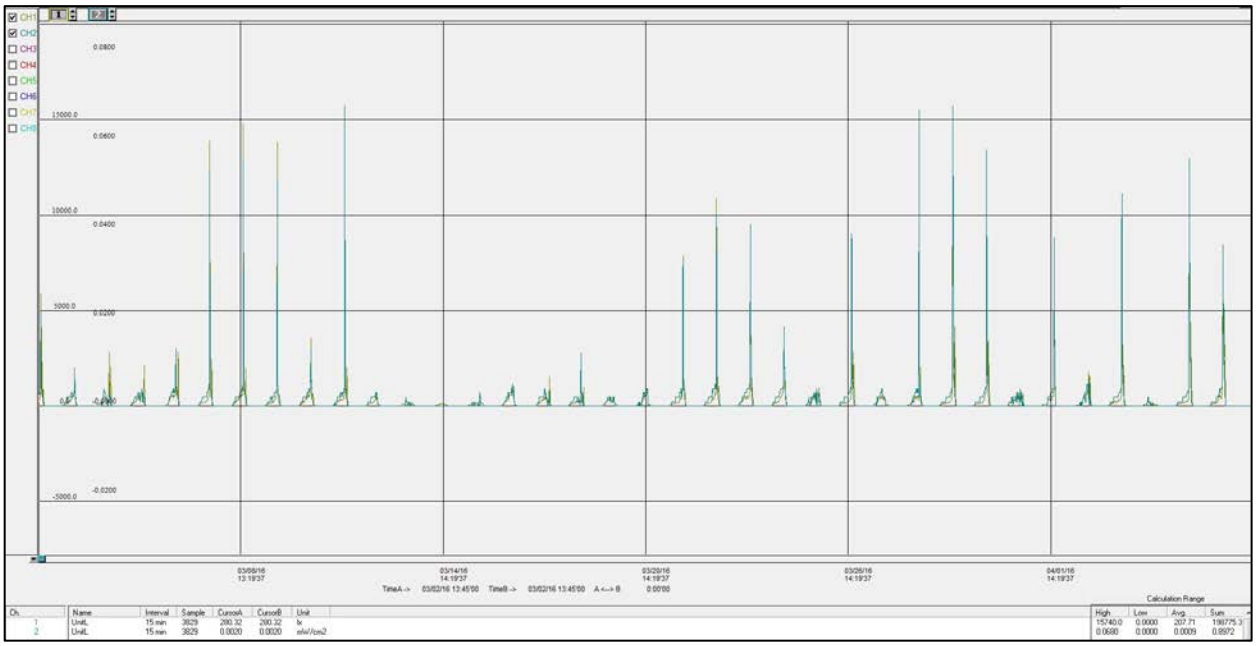
Detail of visible light data overlaid from the door (yellow) and mezzanine (purple) loggers from about 3/2 to 3/12.



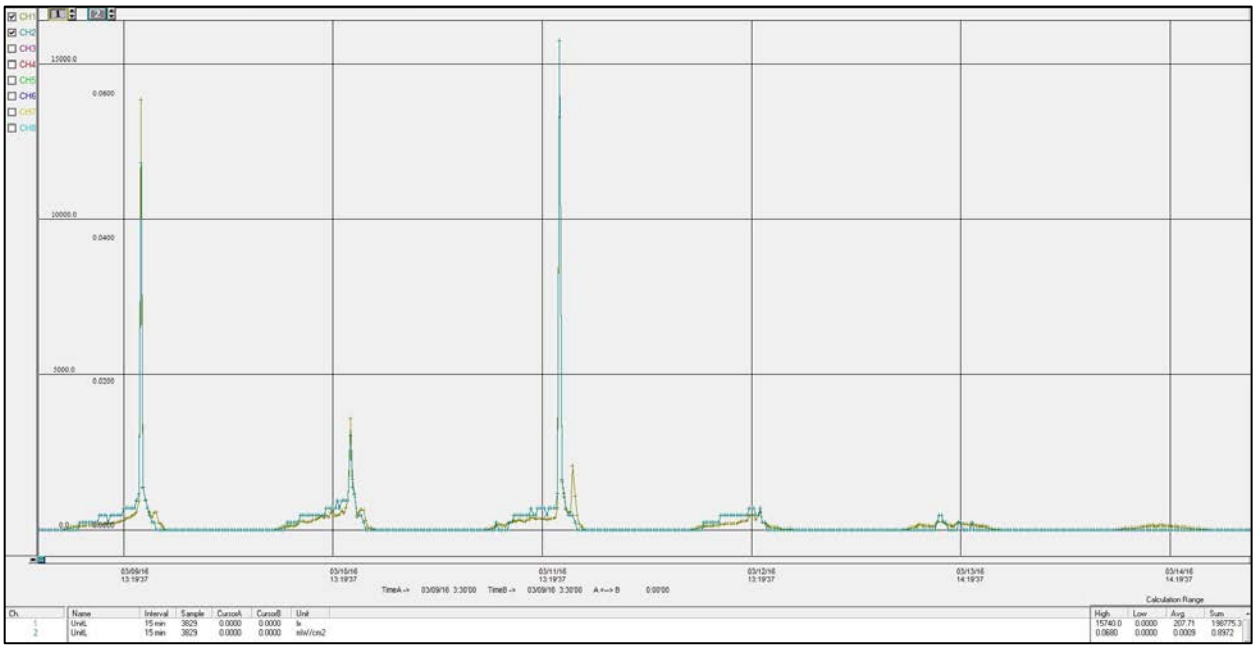
Overall visible and UV light data from the frame logger (I), showing some large peaks mid-month on 3/21-3/24 and 3/26. 3/21 was snowy, while 3/22-3/24 and 3/26 were clear and sunny.



One-day of visible and UV light data from the frame logger (I) on 3/21, the peak is about 5pm.



Overall visible and UV light data from the fireplace logger (L).



Detail of visible and UV light data from the fireplace logger (L).

Partially Annotated Bibliography

General Environmental Control of Cultural Heritage Collections

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2003. *Chapter 21: Museums and Libraries, ASHRAE Handbook*. Atlanta, GA: American Society of Heating, Refrigerating and Air Conditioning Engineers.

- The ASHRAE Chapter 21 concerning cultural heritage collections is a useful basic reading for all preventive conservators and anyone involved in collections management, and is a concise review of basic preventive concepts. It is a good resource for anyone that works in a collaborative environment with building managers and engineers as it uses concise and clear language that is easy to understand. It outlines major agents of deterioration that relate to the building engineering, their general effects on cultural heritage objects.

Bickersteth, J. 2014. "Environmental conditions for safeguarding collections: What should our set points be?" *Studies in Conservation.* 59 (4): 218-224.

Henry, M. 2001. Materials in museum buildings and collections: Technical note. http://extranet.getty.edu/gci/teaching/downloads/MaterialsInMuseums.TN.pdf

Huijbregts, Z, M. Martens, J. van Schijndel, and H. Schellen. 2015. The use of computer simulation models to evaluate the risks of damage to objects exposed to varying indoor climate conditions in the past, present, and future. *Climate for collections: standards and uncertainties*. London, United Kingdom: 375-387.

- This article is complex and dense, but explains well the potential of modeling climate conditions within a historic structure as well as modeling heat and moisture induced strain of a specific object, in this case a wooden cabinet from 1690-1710 within Amerongen Castle, a 17th century castle in the Netherlands. The research looks to pinpoint the appropriate limits of RH and temperature fluctuations for the cabinet and to gauge the potential damage caused by a newly installed heating system in the castle. The authors distill the overwhelming computer calculations involved in modeling into manageable explanations that make the process seem doable for other institutions. They provide graphs that compare gathered climate data with computer modeling to demonstrate the accuracy of the process. This is a great resource for anyone interested in the effects of RH on collections and the great potential of computer modeling in museums and historic houses.

Mecklenburg, M. F., and C. S. Tumosa. 1999. Temperature and relative humidity effects on the mechanical and chemical stability of collections. *ASHRAE Journal* 41(4): 77-83.

Michalski, S. 1994. Relative humidity and temperature guidelines: What's happening? *Canadian Conservation Institute Newsletter,* No 14: 6-10.

Michalski, Stefan. 1996. "Quantified Risk Reduction in the Humidity Dilemma". *APT Bulletin.* 27 (3): 25-29.

- This is a brief yet pithy article that outlines issues and mechanics of humidity fluctuations and the effects on building envelope and wooden artifacts. Michalski discusses seasonal wall condensation and the importance of understanding geographical climate differences. He also explains the influence of stack effect and the building skin. Briefly discussed as well are the risks associated with humidity fluctuations on wooden artifacts and furniture. He provides a summary chart that outlines objects of low to high vulnerability based on joinery techniques and construction, as well as discusses the influence of reaction time and stress relaxation. This article is in no way comprehensive, but is a good starting point for anyone considering the effects of relative humidity fluctuations on building and wooden artifacts.

Thickett, D, L. Cséfalvayová, and M. Strlič. 2011. Smart conservation: targeting controlled environments to improve sustainability. *ICOM-CC 16th triennial conference.* Lisbon, Portugal: 19-23.

Environmental Control of Historic Buildings

Camuffo, D., and G. Sturaro. 2002. Church heating: A challenge looking for solutions. *Research for Protection, Conservation and Enhancement of Cultural Heritage: Opportunities for European Enterprises*. Luxembourg: European Commission: 128–36. <ftp://ftp.cordis.europa.eu/pub/eesd/docs/ka4_protection_conservation_enhancement.pdf>

Kerschner, R.L. 2008. Providing safe and practical environments for cultural property in historic buildings… and beyond. *Getty Conservation Institute: Contribution to the Experts' Roundtable on Sustainable Climate Management Strategies.* Tenerife, Spain. http://www.ischool.utexas.edu/kilgarlin/gaga/proceedings.html

Michalski, S. 1998. Climate control priorities and solutions for collections in historic buildings. *Historic Preservation Forum* 12(4): 8-14.

Thickett, D., L. N. Luxford, and P. Lankester. 2012. Environmental management challenges and strategies in historic houses. *The artifact, its context and their narrative: Multidisciplinary conservation in historic house museums.* The Joint Conference of ICOM-DEMHIST and three ICOM-CC Working Groups. Los Angeles: the Getty Research Institute.

- This is a brief overview of challenges historic houses face in regards to preventive conservation and particularly environmental control and management. It discusses some unique solutions to these challenges enacted by historic houses in the United Kingdom. The article focuses on relative humidity and temperature, light, and acoustic emissions. It presents case studies complete with graphs and figures that illustrate the issues that can arise when conservators have to balance the needs of old and historic buildings and composite collections.

Winterthur Preventive Team. 2014. Updated Environmental Guidelines Handout. Winterthur Museum and Country Estate, Winterthur, DE.

Risk Assessment and Management

McCubbin, M, A. Cannon, C. Carter, D. Henry, H. Privett, N. Ladas, D. Leggett, R. Leveson, M. Raberts, L. Stedman, and R. Waller. Improving risk assessment methods in a complex setting: Museum Victoria's collection risk assessment. *ICOM Committee for Conservation preprints.* 17th Triennial Meeting*,* Melbourne. Paris: ICOM. 15-19.

Michalski, S. 1996. Environmental guidelines: Defining norms for large and varied collections. Paper presented at the workshop *Preservation of collections: assessment, evaluation, and mitigation strategies,* Norfolk, Virginia. Washington DC: AIC. 28-33.

Michalski, S. 2007. The ideal climate, risk management, the AHRAE chapter, proofed fluctuations, and toward a full risk management. Contribution to the Experts' Roundtable on Sustainable Climate Management Strategies. Getty Conservation Institute.

- In this paper Michalski discusses the past, present, and future of the ASHRAE chapter 21 about environmental management in museums and how it can be used by conservators and museum professionals to develop a risk management approach to climate control. Michalski focuses on the development of and characteristics of the AA, A, B, C, and D ratings established in the newest ASHRAE chapter and how these rating can be used to evaluate collection risks, instead of establishing an "ideal." He also discusses the idea of proofed RH, its benefits, as well as some complications like fatigue and stress. This is a valuable introduction to risk management in conversational language that is easy to understand.

Michalski, S. 2015. "Tools for assessing needs and impacts". *Studies in Conservation.* 60 (S2): S2-23-S2-31.

Staniforth, S. Conservation heating to slow conservation: A tale of the appropriate rather than the ideal. *Getty Conservation Institute: Contribution to the Experts' Roundtable on Sustainable Climate Management Strategies.* Tenerife, Spain.

- This article was written for members of IIC and discusses philosophically the present state of environmental management in museums in a historical context. The article is a valuable reality check for anyone invested in preventive conservation, it looks to predict what the future of environmental management will look like, and is particularly focused on a global perspective that considers climate change and sustainability. Staniforth also discusses leadership and the need for conservators and preservation-minded individuals to gain leadership skills that will help them achieve higher positions in cultural

institutions. This article is a manifesto that outlines what the conservation field needs to achieve in the next 35 years.

Preventive Conservation of Specific Materials

Canadian Conservation Institute Textile Lab. 2013. Textiles and the environment. Canadian Conservation Institute (CCI) Notes 13/1. Minister of Public Works and Government Services, Canada. < http://canada.pch.gc.ca/eng/1439925170741>

Camuffo, D.; C. Bertolin, A. Bonazzi, F. Campana, and C. Merlo. 2014. "Past, present and future effects of climate change on a wooden inlay bookcase cabinet: A new methodology inspired by the novel European Standard EN 15757:2010". *Journal of Cultural Heritage.* 15 (1): 26-35.

- This article explores ways to reconstruct the past climactic experience of objects, which would provide information used to establish best conditions. The article uses one particularly vulnerable object, a 1477 wooden inlay bookcase to illustrate these methods. The authors discuss how historic climate data, or "proxy data" is compiled. This is an interesting article that looks to more accurately establish a protocol for quantifying the idea of proofed RH or temperature. The methodology is interesting but not efficient or especially relevant to the preventive workings of most museums as it is time consuming, mathematically cumbersome, and requires detailed knowledge of an objects provenance. The article does however, represent a valuable case study of an object with such a well-known provenance, and it exemplifies proofed RH, and how conservation treatment can "reset" proofing.

Logan, J, and L. Selwyn. 2007. The storage of metals. Canadian Conservation Institute (CCI) Notes 9/2. Minister of Public Works and Government Services, Canada. <http://canada.pch.gc.ca/eng/1439925170350>

Lighting

Boye, C., F. Preusser, and T. Schaeffer. 2010. UV-blocking window films for use in museums--revisited. *Newsletter (Western Association for Art Conservation)* 32, no. 1, pp. 13-18.

- This article clearly and concisely explains the complexity that is choosing a UV-blocking window film. Like a scientific paper it discusses how different films were tested for UV transmittance as well as color change. It is possible that the films tested for this study are no longer available or perform differently now that this 2010 article is six years old. It is still a useful resource and introduction to the world of UV films, and would be an ideal place to start for anyone starting to look to purchase films. Unfortunately this article does not consider price, which would be a major consideration for most institutions. It also does not address aging properties, another key characteristic of window films. They highlight some unacceptable films, which is key information to have when considering which to purchase.

Michalski, S. 1997. The lighting decision. *Fabric of an Exhibition, Preprints of Textile Symposium 97*. Ottawa: Canadian Conservation Institute: pp. 97-104.

- This is a key reading about the tension and balance between visibility of objects and light damage. Michalski discusses the need for conservators to broaden their lighting benchmarks for museum and for them to adopt a more complex case-specific outlook. The article contains a useful and simple chart that explains basic steps for museums/historic houses where either total control of lighting is possible or if partial lighting control is possible. The article also explains details about human vision, and how we see differently based on factors like age and the style of lighting. Another table provides lightfastness ratings of natural dyes on wool, cotton, and silk. This would be valuable if one knew the dye components of a textile. While not completely useful to the everyday employee, this article is a valuable source for anyone invested in preventive conservation.

Himmelstein, P., and B. Appelbaum. 2000. An overview of light and lighting in historic structures that house collections. *APT Bulletin.* 31(1): 13-15.

- This article outlines basic ideas for mitigating light in historic houses. It is indeed an overview and only a few pages long, yet lays the foundation for understanding the complexities of collection care in a historic structure. It discusses the tension between visibility and preservation, and the potential for the use of lighting as an interpretive element. The authors primarily focus on fixture lighting but also briefly discuss daylight. While likely too basic for most conservation professionals, this is a good starting place and explains lighting issues well.

Tétreault J., and C. Anuzet. 2015. Ultraviolet Filters - Canadian Conservation Institute (CCI) Notes 2/1. <http://canada.pch.gc.ca/eng/1439925170062>

Other Sources

Sergey, P. 2015. Email communication concerning inventory of Nakashima archives at the James Michener Museum. Archivist and Volunteer Manager, James A. Michener Museum, Doylestown, PA.

Bing, S., J. Herrick, and A. Yates Krain. 2003. Conservation and treatment reports for six Nakashima drawings on paper. The Conservation Center for Art & Historic Artifacts (CCAHA). Philadelphia, PA.

Keeping it Modern: 2015 Grant Awardees. The Getty Foundation. http://www.getty.edu/foundation/initiatives/current/keeping_it_modern/grants_awarded_2015.html

National Historic Landmark Nomination Form: George Nakashima Woodworker Complex.

www.nps.gov/nhl/news/LC/.../Nakashima.pdf

Peirce, L. 2016. Personal communication about data analysis. Winterthur Museum, Gardens, and Library. Winterthur, DE.

Wallis, S. 2015. New carpets honor Nakashima's designs. *Architectural Digest*, April 30, 2015. Published by Condé Nast. <http://www.architecturaldigest.com/story/edward-fields-george-nakashima-carpets-article>

Appendix C

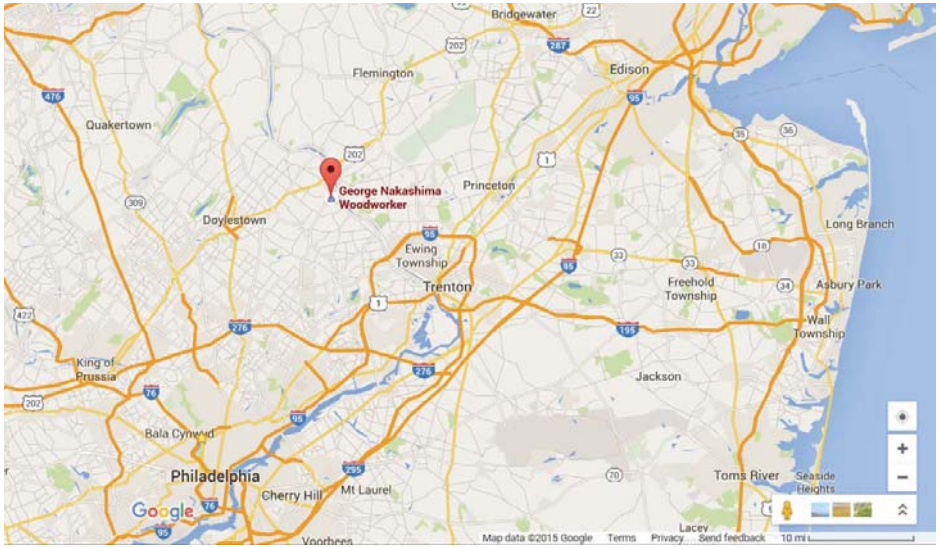
Nakashima Art Studio Daylighting Study.
Shin-Yi Kwan and Janki A. Vyas,
Master of Environmental Building Design (MEBD),
School of Design, University of Pennsylvania, 2016



LOCATION + BACKGROUND

General Background

George Nakashima (1905-1990), the internationally-renowned architect, furniture designer and woodworker, first moved to New Hope, Pennsylvania with his family in 1943. They moved from Idaho where they were interned at Camp Minidoka for two years after the Japanese attacked Pearl Harbor. Shortly after the war ended in 1946, Nakashima bartered three acres of land along Aquatong Road in Solebury Township in exchange for carpentry work. Between 1946 and 1954, the three-acre site consisted of two buildings, the Nakashima House and Workshop. As Nakashima's furniture business gained notoriety, the site grew into twenty-one buildings spread across a 12.2-acre tract, known today as the George Nakashima Woodworker Complex. In 2008, the Nakashima Woodworker Complex was added to the National Register of Historic Places. The instrumental role Nakashima played in constructing nineteen of the complex's buildings led to their "contributing" status. In 2013, the Nakashima Woodworker Complex was designated a **National Historic Landmark**. This proposal is focused on the International-style Arts Building, which was completed in 1967 to exhibit the artwork of Nakashima's friend, Ben Shahn, one of the nineteen contributing buildings.



WEATHER FILE	USA_NJ_Trenton-Mercer.County.AP.724095_TMY3
SITE ADDRESS	1847 Aquetong Rd, New Hope, PA 18938
LATITUDE + LONGITUDE	40.339348, -74.954851



The Arts Building

The Arts Building has footprint of roughly 36 by 40 feet and measures 23 feet in height at its tallest point. It is a single story structure with a loft in the southwest corner; oriented to the south to maximize solar gain in the winter, while deciduous trees around the building provide shade in the summer.

The north and east walls are composed of concrete masonry units (CMU) parged with a cementitious stucco on the exterior. The CMU walls are insulated with Styrofoam boards adhered to the interior face, covered with lath, and finished with Structolite plaster. The south and west walls consist primarily of fixed, custom-sized, single- and double-pane glazing set in site-fabricated cypress wood framing. Protruding from and receding into the southwest corner of the main space is a cast-in-place, reinforced concrete bay one-story in height with a slab roof used as an exterior porch and interior mezzanine.

The south wall is pierced at grade by two door openings. The western-most opening is in the poured concrete bay that enters into the vestibule; the opening is filled with a site-made, wood panel door. The second opening consists of a glazed, sliding-double door located at the center of the south wall that enters directly into the main gallery space. The glazed west wall is penetrated at grade by the sliding sashes of the one-story-tall tripartite window. The operable glazing from mezzanine consists of sliding door in the south wall providing access to the porch and stacked, three-light casement windows at the corner peak of the south and west walls.

The hyperbolic paraboloid roof, which is the buildings most distinguishing feature, covers the main gallery space of the Arts Building. The roof is constructed of three layers of 5/8" plywood that extends over the CMU and glazed walls creating an eave of approximately 2 feet. The inside face of the roof is left exposed with the long seams between plywood sheets running east to west and concealed with wooden ribs. For strength, the middle layer of plywood was laid perpendicular to the bottom and top layers with the long seam running north to south.



1 MAIN SPACE SOUTHWEST CORNER



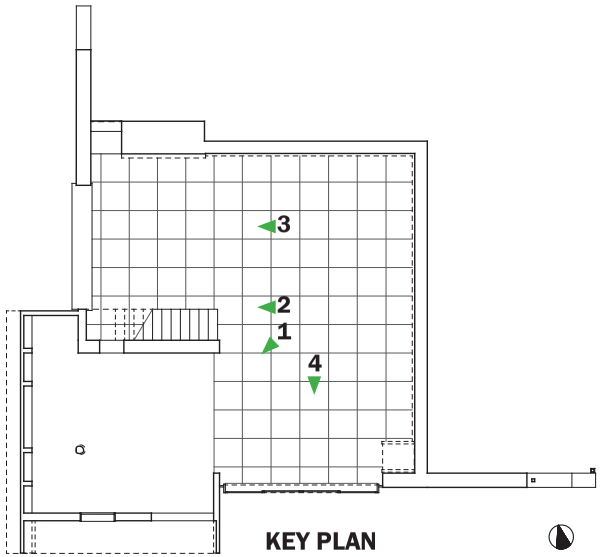
2 MAIN SPACE WEST @ STAIR



3 MAIN SPACE WEST

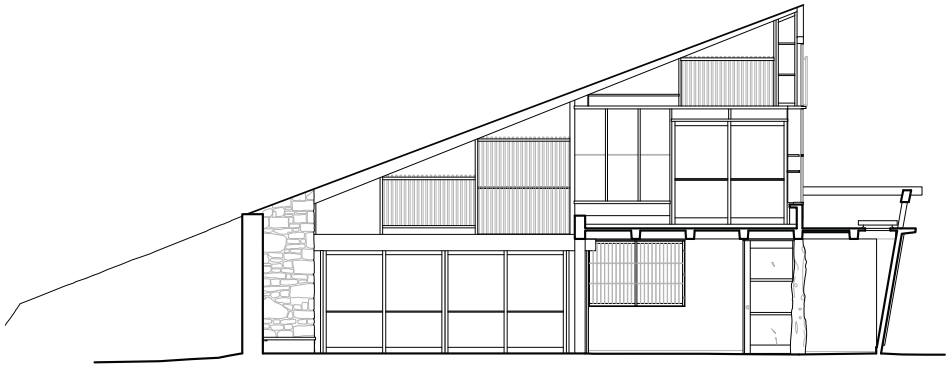


4 MAIN SPACE SOUTH

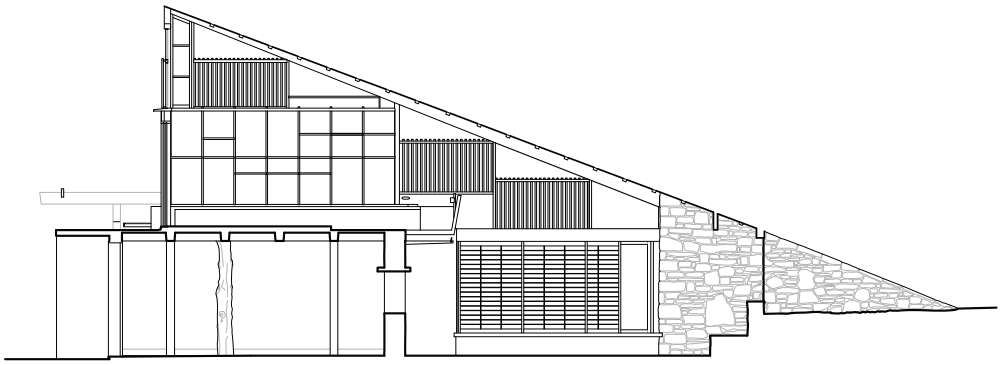


NAKASHIMA ART STUDIO

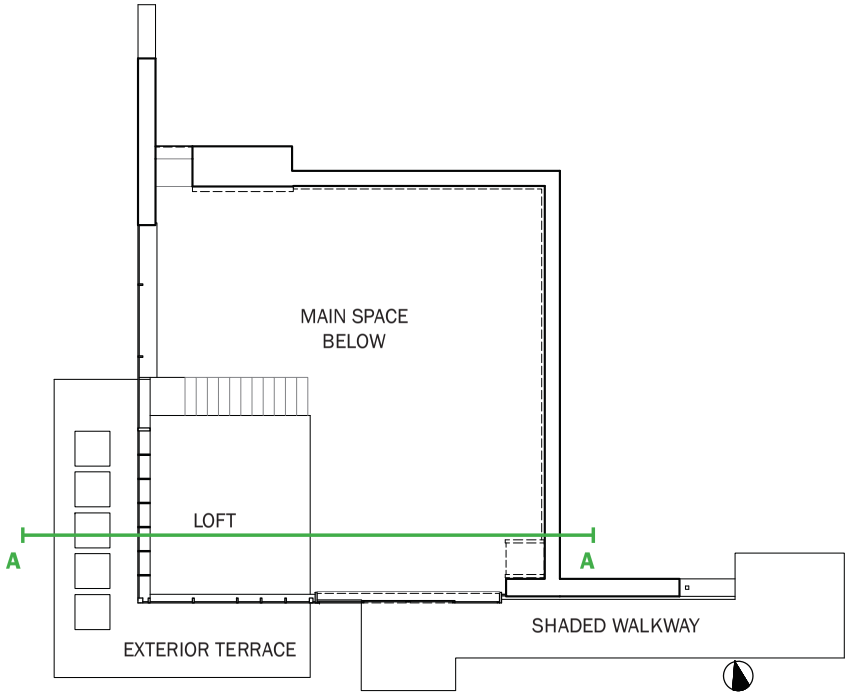
ARCHITECTURE



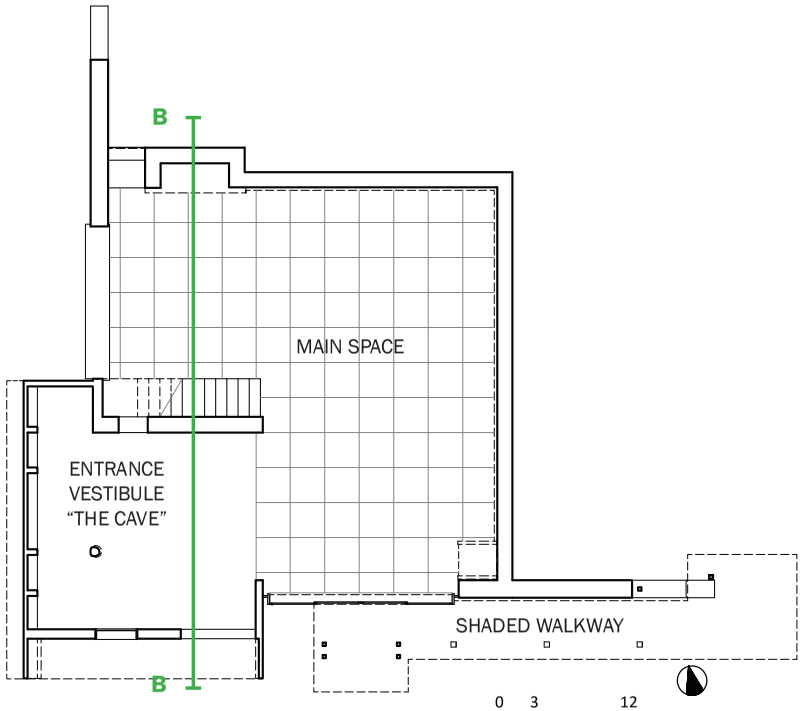
SECTION A-A



SECTION B-B



LOFT PLAN



GROUND FLOOR PLAN



METRICS FOR DAYLIGHTING MUSEUM BUILDINGS AND OBJECTS

TABLE 3.1
Recommended Total Exposure Limits in Terms of Illuminance Hours Per Year to Limit Light Damage to Susceptible Museum and Art Gallery Artifacts

Note: All ultraviolet radiation (400 nm and below) should be eliminated.

Types of Materials	Maximum Illuminance (Neither value should be exceeded)	Lux-Hours/Yr
Highly susceptible displayed materials: textiles, cotton, natural fibers, furs, silk, writing inks, paper documents, lace, fugitive dyes, watercolors, wool, some minerals.	50 lux	50,000
	Note: Approximately (50 lux) × (8 hours per day) × (125 days per year). Different levels (higher or lower) and/or different periods of display (4 hours for 250 days) may be appropriate, depending upon material. If in doubt, consult a conservator.	
Moderately susceptible displayed materials: textiles with stable dyes, oil paintings, wood finishes, leather, some plastics.	200 lux	480,000
	Note: Approximately (200 lux) × (8 hours per day) × (300 days per year). Lower levels may be appropriate, depending upon material. If in doubt, consult a conservator.	
Least susceptible displayed materials: metal, stone, glass, ceramic, most minerals.	Dependent upon exhibition situation.	

IESNA Museum and Art Gallery Lighting: A Recommended Practice, p.14.



METRICS FOR DAYLIGHTING NON-MUSEUM BUILDINGS AND PEOPLE

Daylight Autonomy (DA) & Useful Daylight Illumination (UDI)

A measure of the percentage of occupied hours a point in a space receives a required illuminance threshold. This metric does not establish a range of lighting levels, only tells you how often one illuminance value is met. Thus, it is not a good measure of overlit spaces. To account for overlit spaces a variation of DA, Useful Daylight Illuminance, which establishes three thresholds, how often the illuminance on a point is below 100 lux, between 100 and 2,500 and over 2,500. UDI considers values above 2,500 lux to be in the glare or thermal discomfort.

Spatial Daylight Autonomy (sDA)

A measure of how much of a space receives sufficient daylight. Results of an sDA simulation identify the percentage of floor area that receives at least 300 lux for at least 50% of the annual occupied hours.

Annual Sun Exposure (ASE)

A measure of how much of a space receives too much direct sunlight, which can cause visual discomfort (glare) or increase cooling loads. ASE measures the percentage of floor area that receives at least 1000 lux for at least 250 occupied hours per year.*

Both ASE and sDA are typically used together because sDA has no upper limit on illuminance levels, allowing spaces with too much direct sunlight to appear as well performing. By assigning a higher threshold, ASE provides the balance and indicates areas with potential lighting problems.

** For the purposes of this assignment, the occupancy schedule is adjusted to reflect annual daylit hours, since objects displayed in the building have a 24/7 occupancy.*

CAVE MATERIALITY + OBJECT INVENTORY



LEATHER SUITCASE (25-100 LUX)



CERAMIC BOWL (500-2000 LUX)



1 "THE CAVE" SOUTH



2 "THE CAVE" WEST

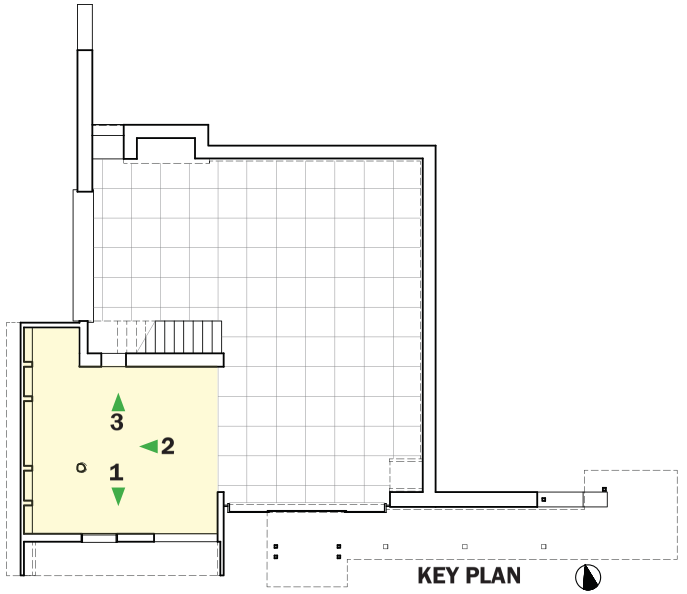


3 "THE CAVE" NORTH

OBJECT INVENTORY IN SPACE	
RECOMMENDED LIGHT LEVELS	QTY OF OBJECTS MEETING CRITERIA
25-100 LUX	21
100-400 LUX	2
500-2000 LUX	1

MATERIALS





MAIN SPACE MATERIALITY + OBJECT INVENTORY



WOOD LUTE (25-100 LUX)



METAL HELMET (500-2000 LUX)



1 MAIN SPACE NORTHEAST CORNER



2 MAIN SPACE EAST

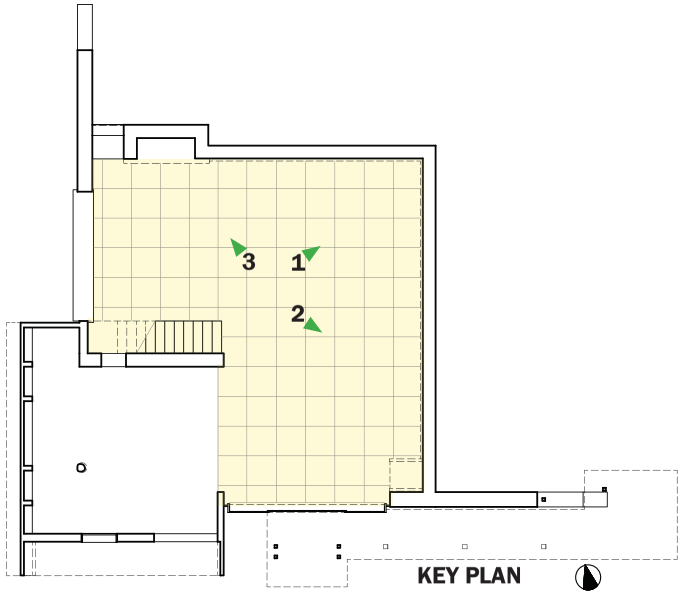


3 MAIN SPACE NORTHWEST CORNER

OBJECT INVENTORY IN SPACE	
RECOMMENDED LIGHT LEVELS	QTY OF OBJECTS MEETING CRITERIA
25-100 LUX	7
100-400 LUX	5
500-2000 LUX	13

MATERIALS





LOFT MATERIALITY + OBJECT INVENTORY



WOOD CRAVINGS (100-400 LUX)



1 LOFT WEST



2 LOFT SOUTH



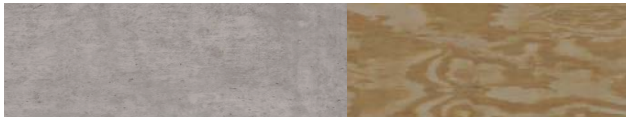
PAPER DOLLS (25-100 LUX)

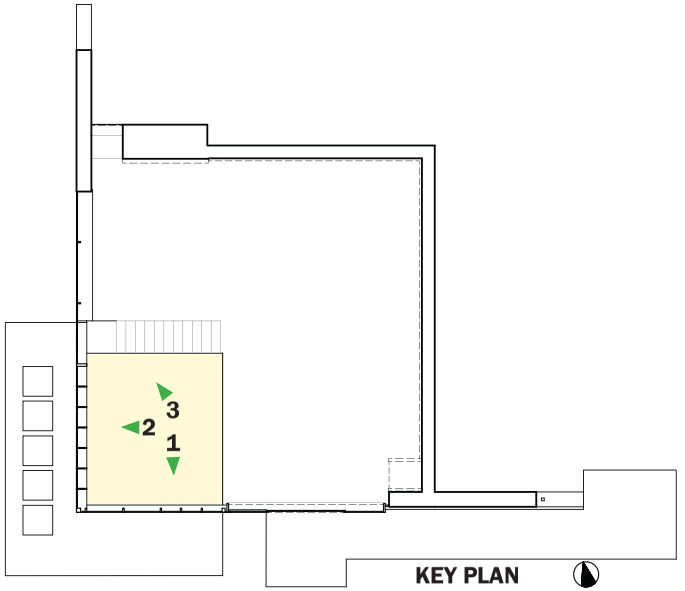


3 LOFT NORTHWEST CORNER

OBJECT INVENTORY IN SPACE	
RECOMMENDED LIGHT LEVELS	QTY OF OBJECTS MEETING CRITERIA
25-100 LUX	11
100-400 LUX	8
500-2000 LUX	21

MATERIALS





SIMULATION MODEL INPUTS + SETUP

DAYLIGHT SIMULATION PARAMETERS

SIMULATION TOOL: DIVA

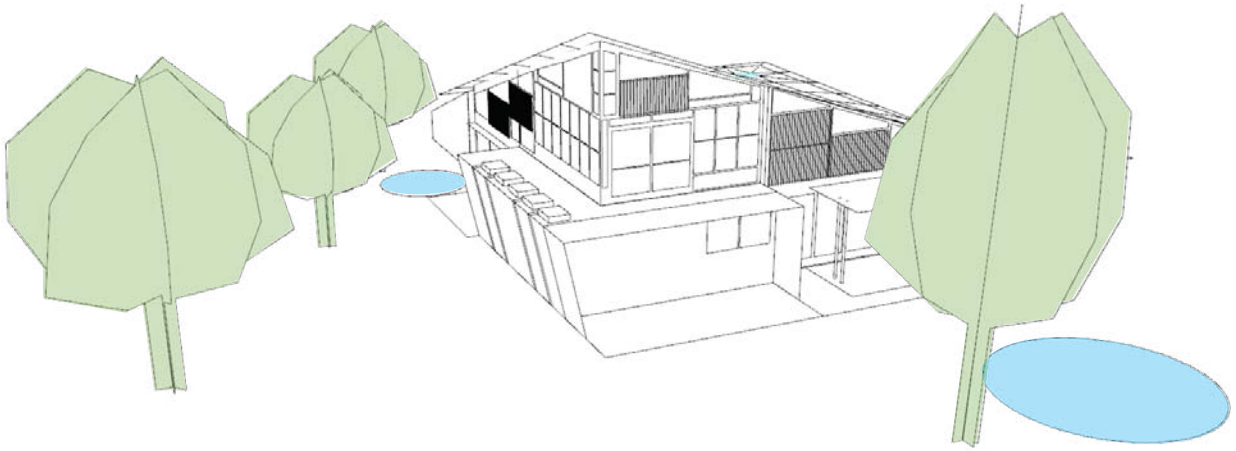
SIMULATION GRID: FLOOR: 2'-6" AFF @ 1'-6" ON CENTER
WALLS: 0'-1" OFF WALL @ 1'-6" ON CENTER

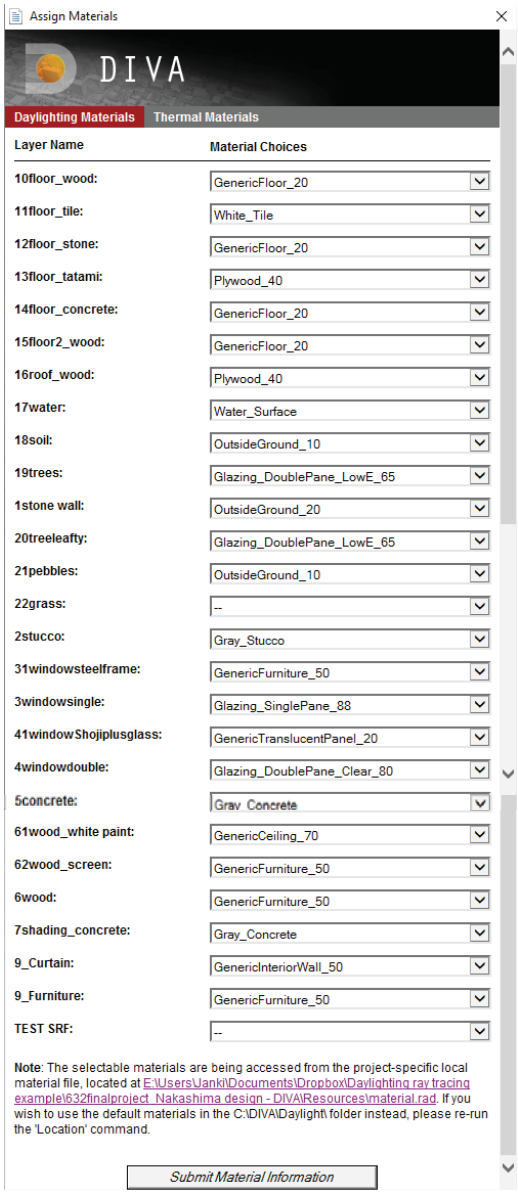
POINT- IN-TIME ILLUMINANCE: CLEAR SKY WITH SUN (CIE CLEAR)

RADIANCE PARAMETERS

- Ambient Bounces 3
- Ambient Divisions 1000
- Ambient Sampling 20
- Ambient Resolution 300
- Ambient Accuracy 0.1

CLIMATE BASED DA / SDA : SAME RADIANCE PARAMETERS AS ABOVE + ASSUME OCCUPANT CAN ADJUST FOR GLARE

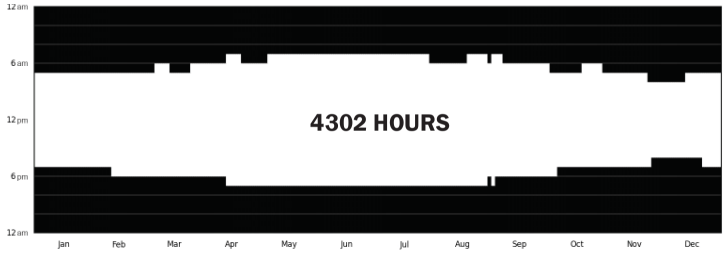


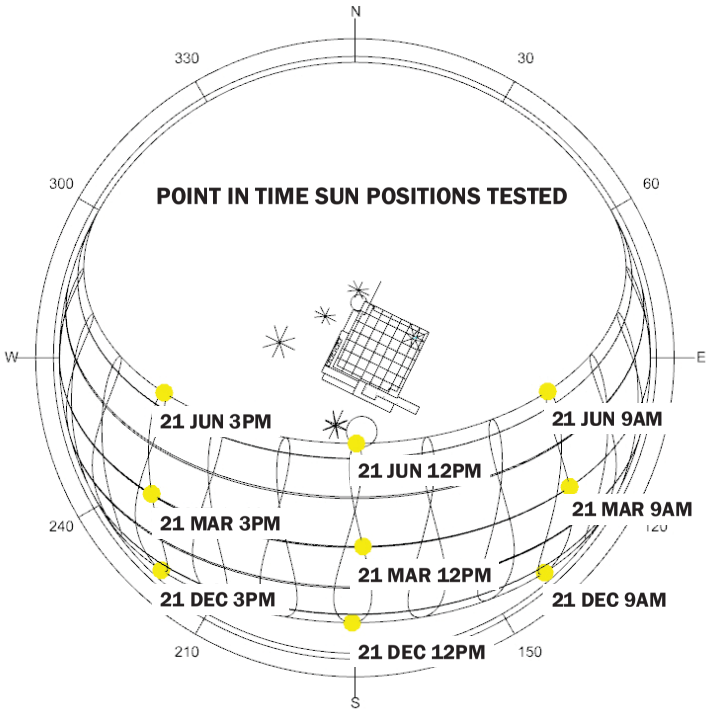


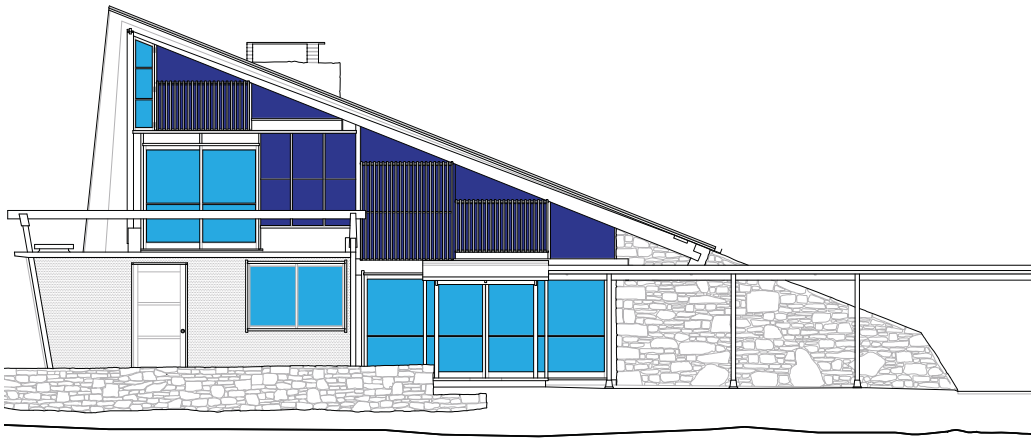
NAKASHIMA ART STUDIO

SIMULATION MODEL INPUTS + SETUP

MODIFIED OCCUPIED HOURS SCHEDULE CORRESPONDING WITH DAYLIGHT HOURS [DOES NOT CONSIDER DAYLIGHT SAVINGS]





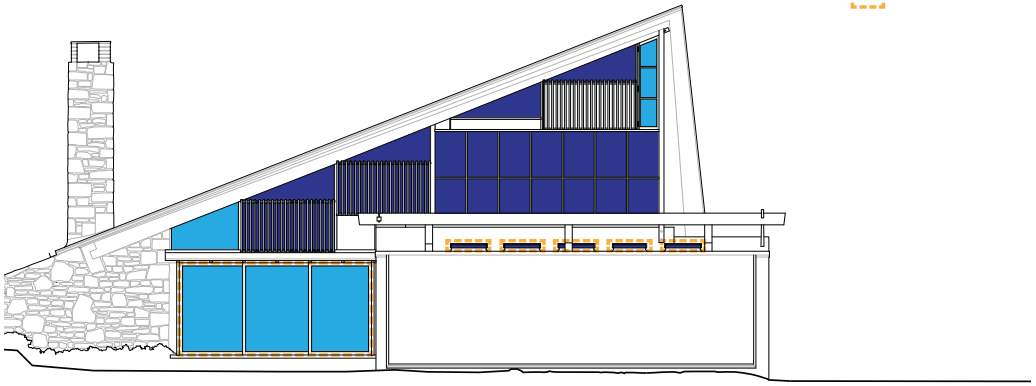


SOUTH facade

DOUBLE PANE

SINGLE PANE

SHOJI SCREEN



WEST facade

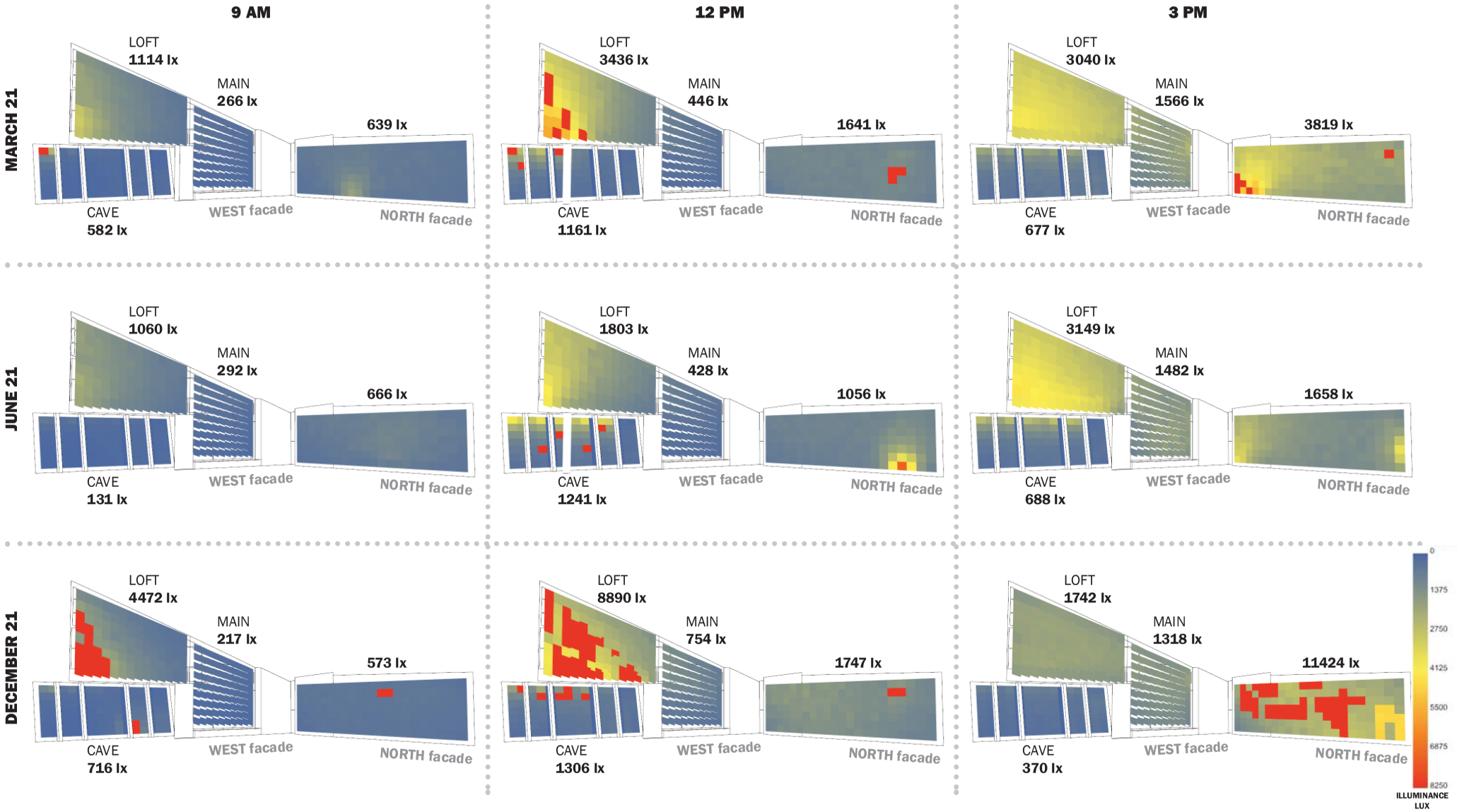
0 3 12

1 6

NAKASHIMA ART STUDIO

baseline_DAYLIGHTING FOR OBJECTS_north + west facade

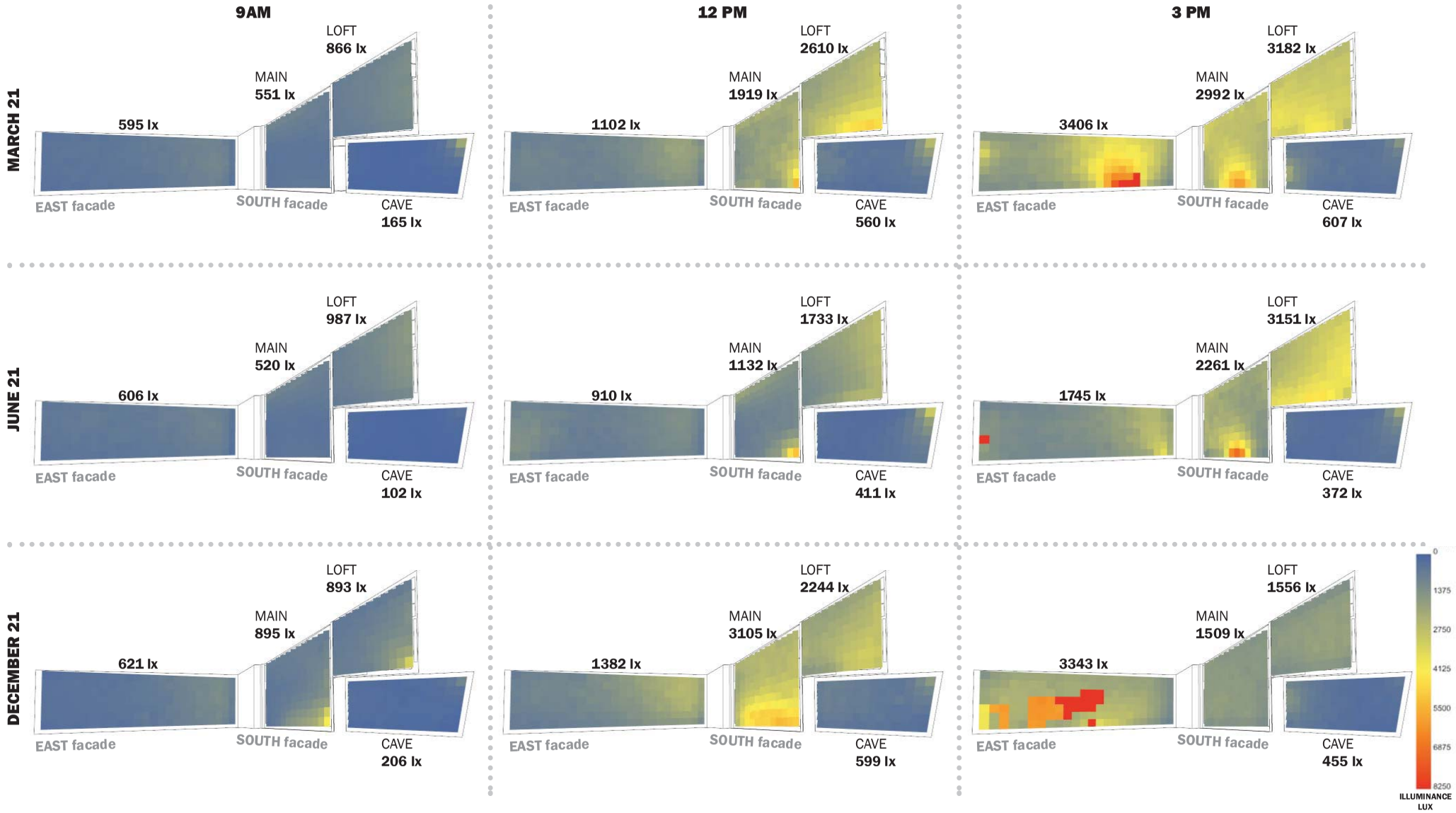
Mean illumance lux values listed for point-in-time simulations



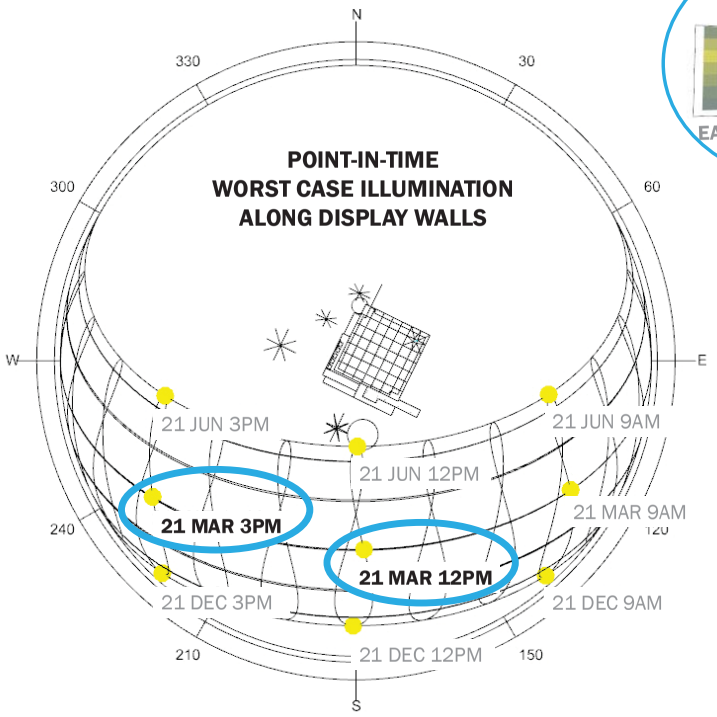
NAKASHIMA ART STUDIO

baseline_DAYLIGHTING FOR OBJECTS_south + east facade

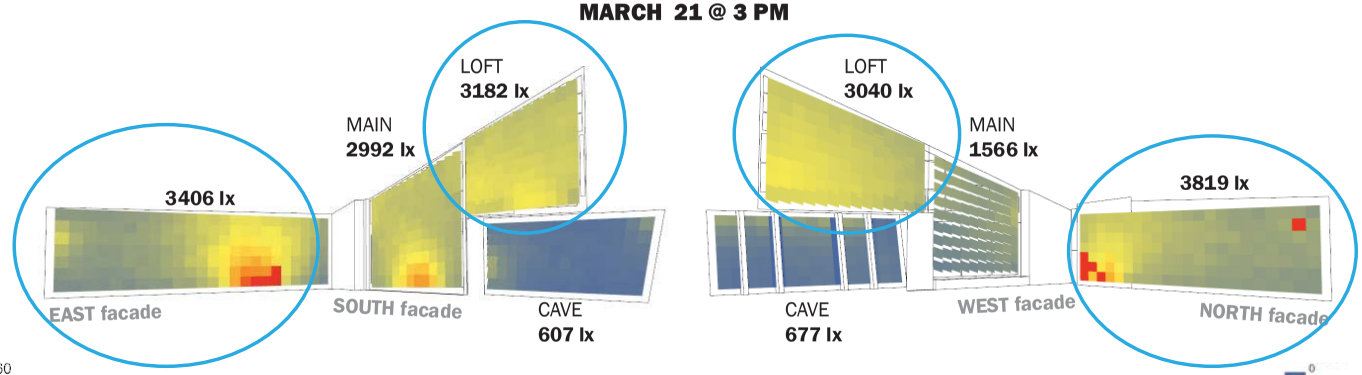
Mean illumance lux values listed for point-in-time simulations

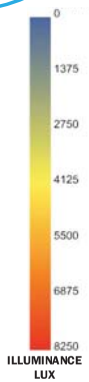


analysis_WORST CASE CONDITION_point-in-time identification

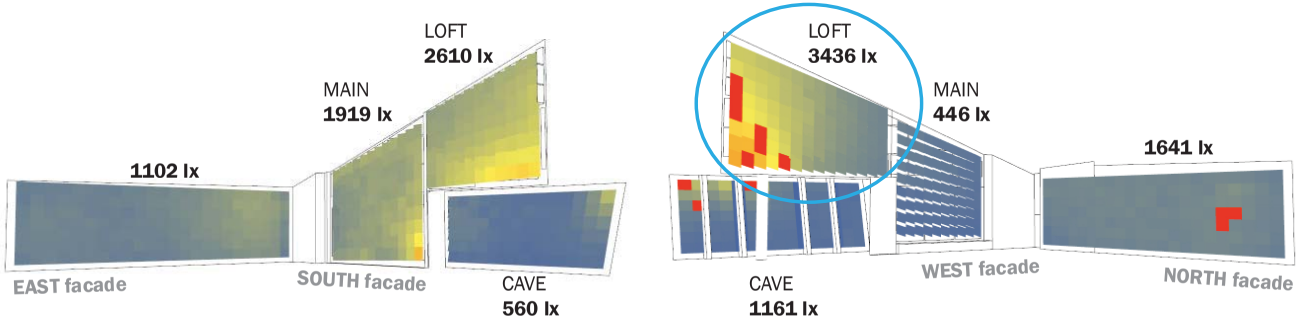


MARCH 21 @ 3 PM

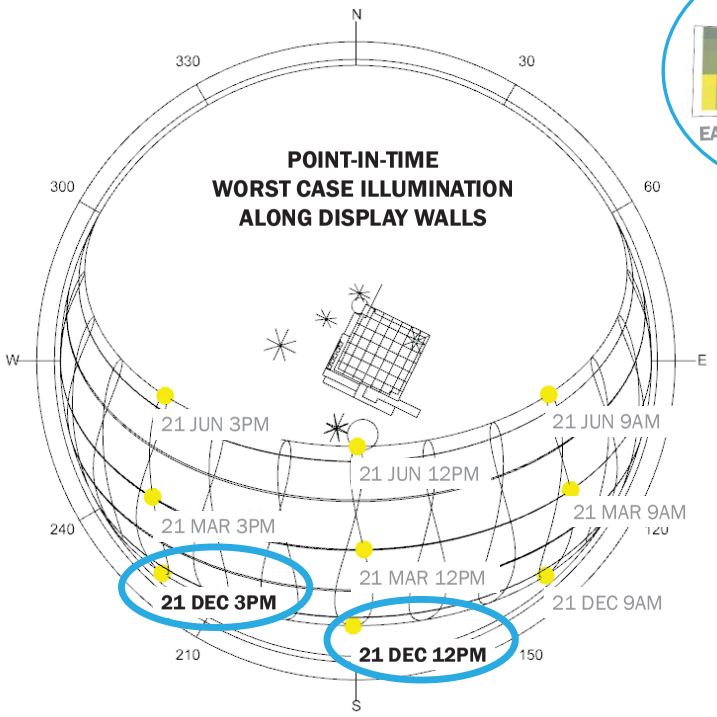




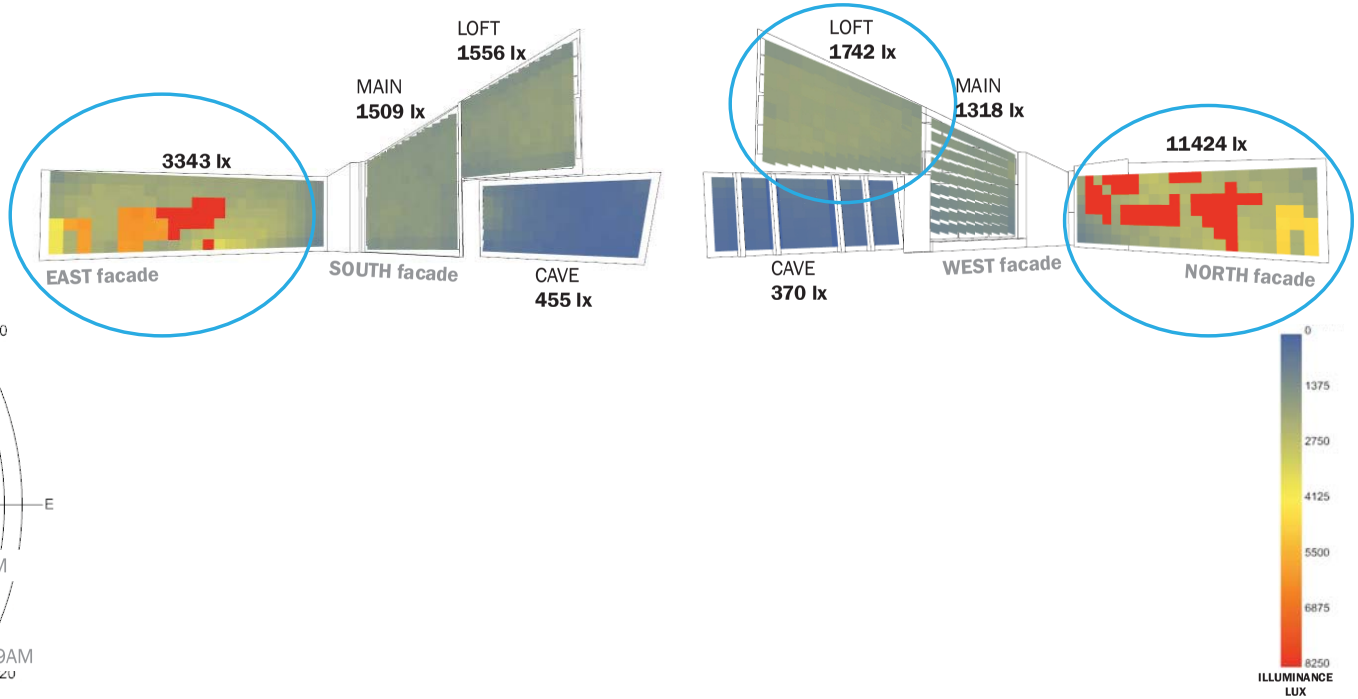
MARCH 21 @ 12 PM



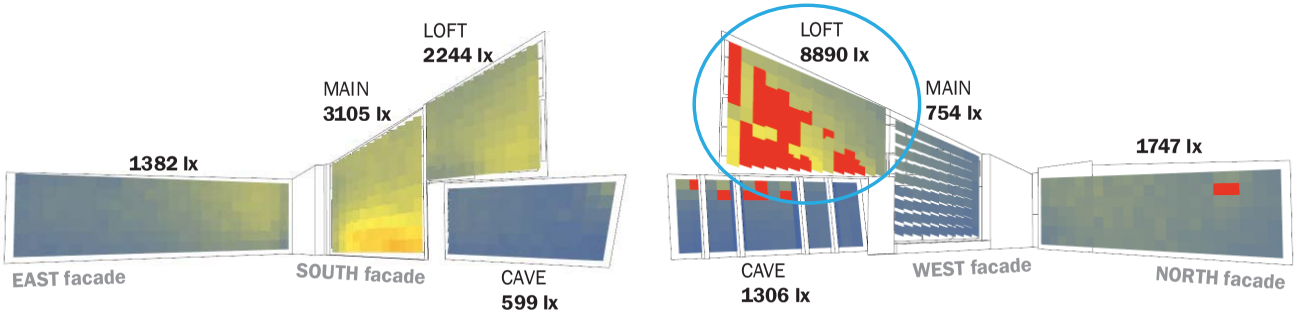
analysis_WORST CASE CONDITION_point-in-time identification



DECEMBER 21 @ 3 PM



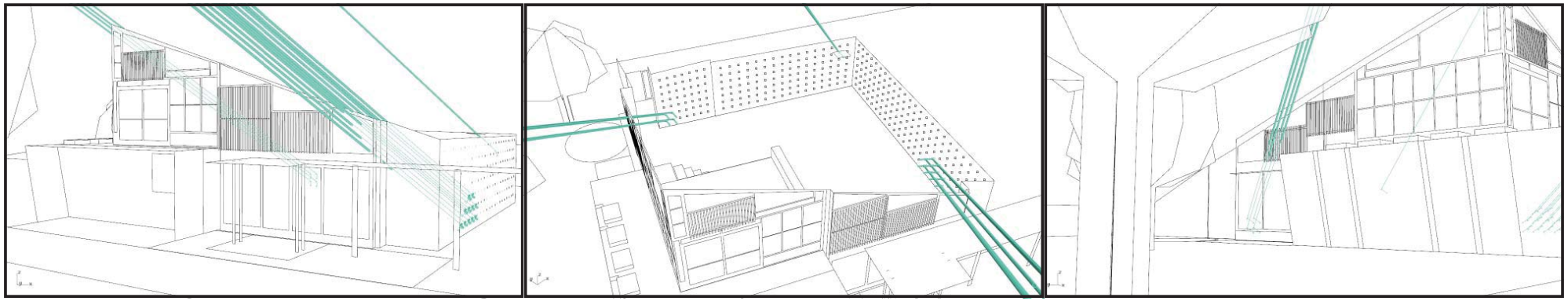
DECEMBER 21 @ 12 PM



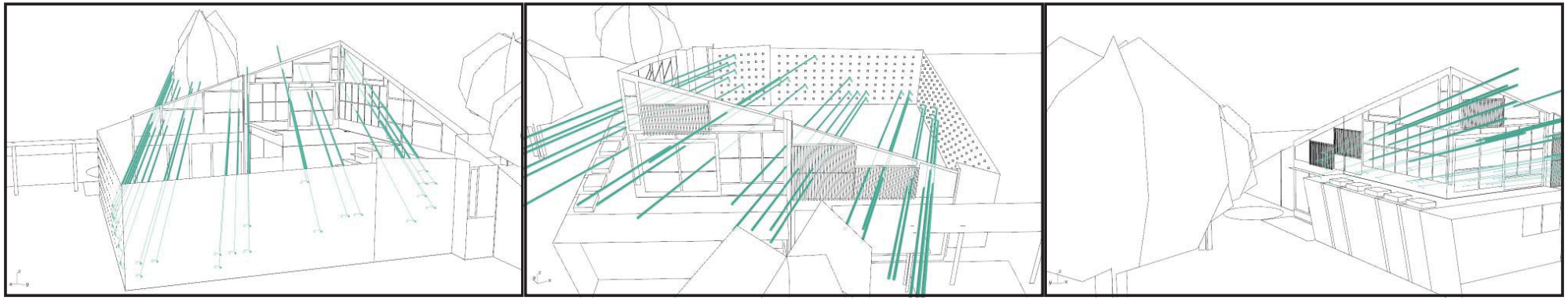
analysis_WORST CASE CONDITION_raytracing

Raytracing the suns path allows us to see which windows are contributing to the harshest direct solar radiation levels, so that we may devise a plan to minimize the amount of direct solar gain.

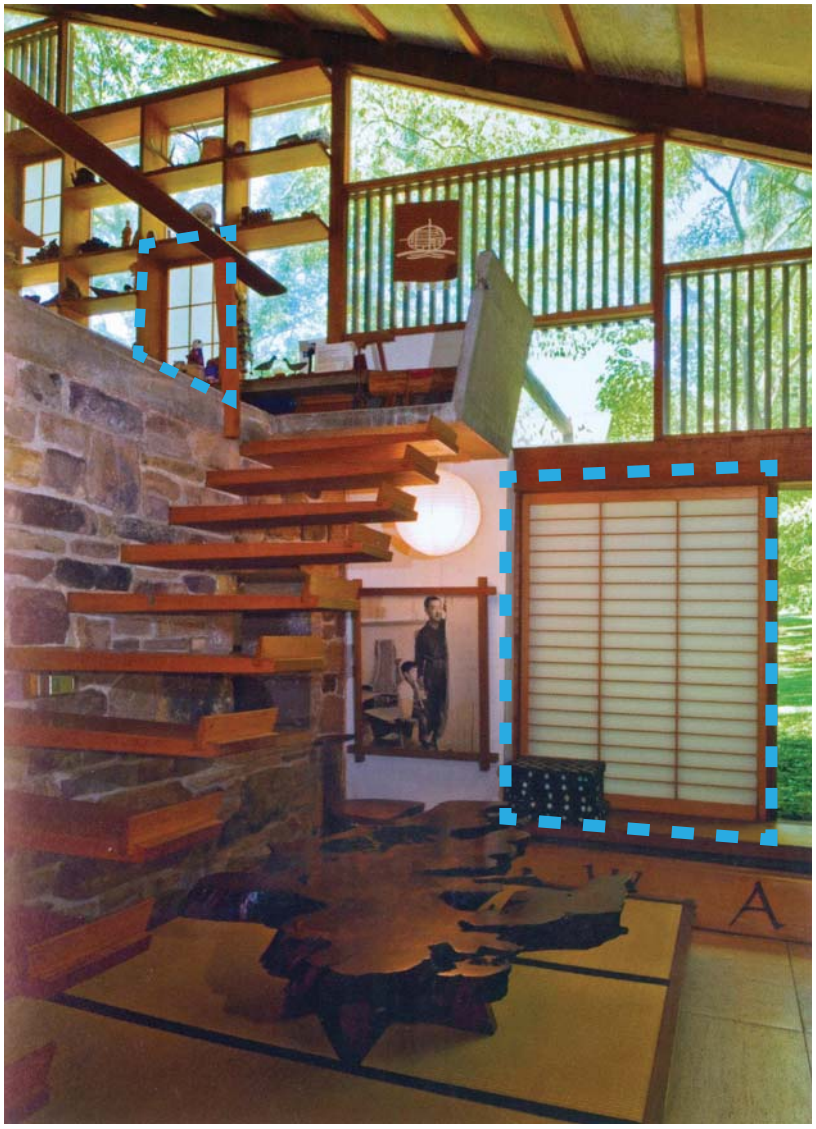
MARCH 21 @ 3 PM



DECEMBER 21 @ 3 PM



analysis_HISTORIC CONDITION_minimal intervention approach







In conjunction with the raytracing exercise we researched the buildings history to determine what, if any, changes occured to the buildings original design. This helped us to take field observation and historical research into account when determining what minimial interventions we can pursue to minimize direct solar gain. There were three main findings:

1. At the south facade there are curtains that the client can pull closed during harsh sun light hours.

2. There is a free standing shoji screen in the loft that can be relocated over the course of the day based on where the sun is.

3. There used to be shoji panels built-in the loft display shelving along the west facade.

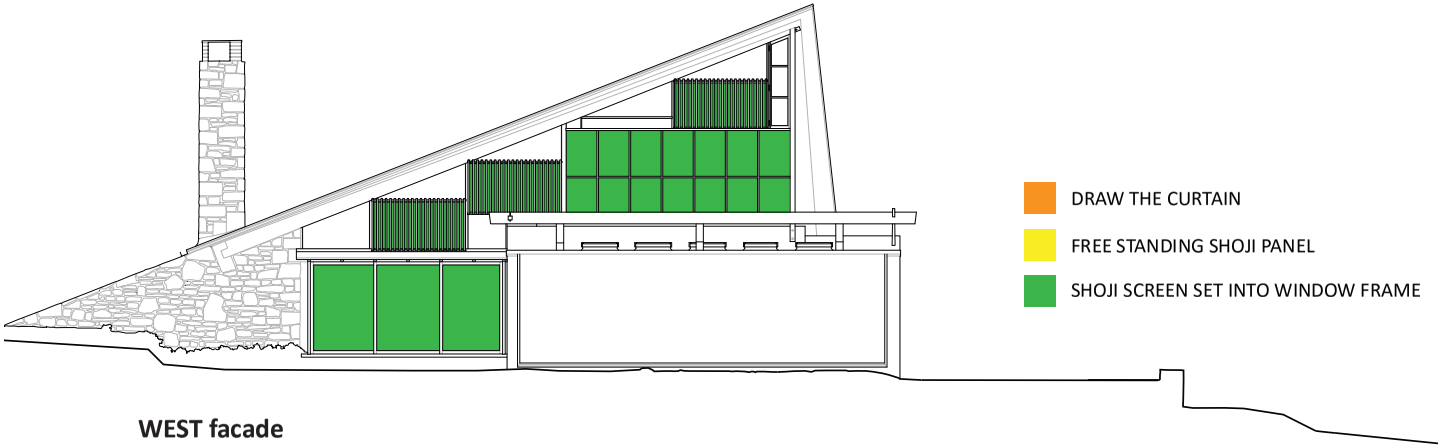
Our design proposal looks at the effects of pulling shades, locating the freestanding shoji panel and reinstalling the built-in shoji panels along the west facade. In addition, our raytracing found that light was making it's way into the building from the exterior slatted wood screening, so we proposed additional shoji panels to be installed interior of the glazing at the screen.

NAKASHIMA ART STUDIO

proposed_INTERVENTION PLAN



SOUTH facade



WEST facade

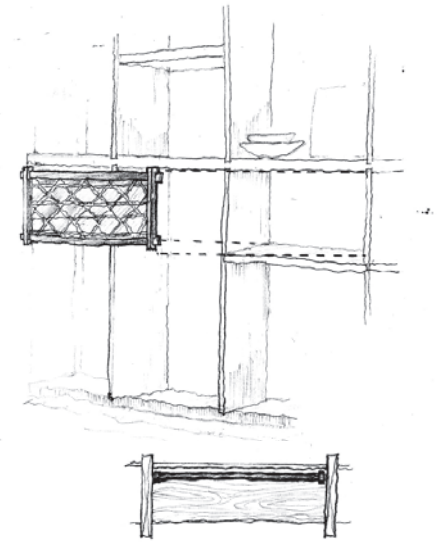
DRAW THE CURTAIN

FREE STANDING SHOJI PANEL

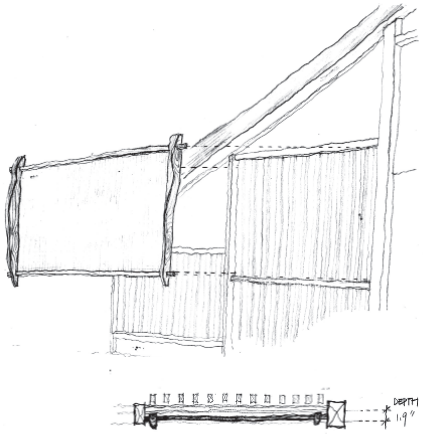
SHOJI SCREEN SET INTO WINDOW FRAME

0 3 12

1 6

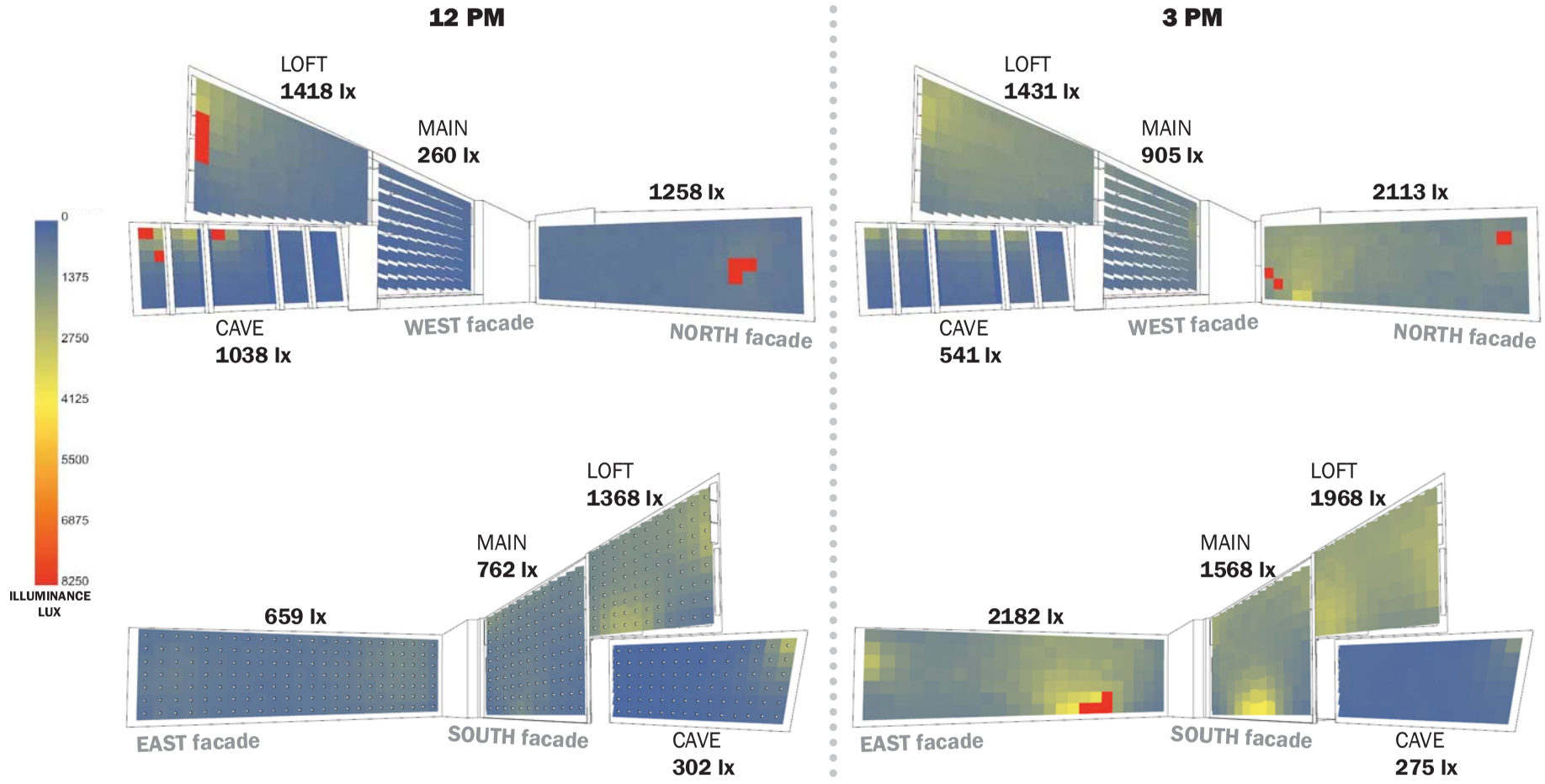


SHOJI SCREEN SET @ LOFT SHELVING

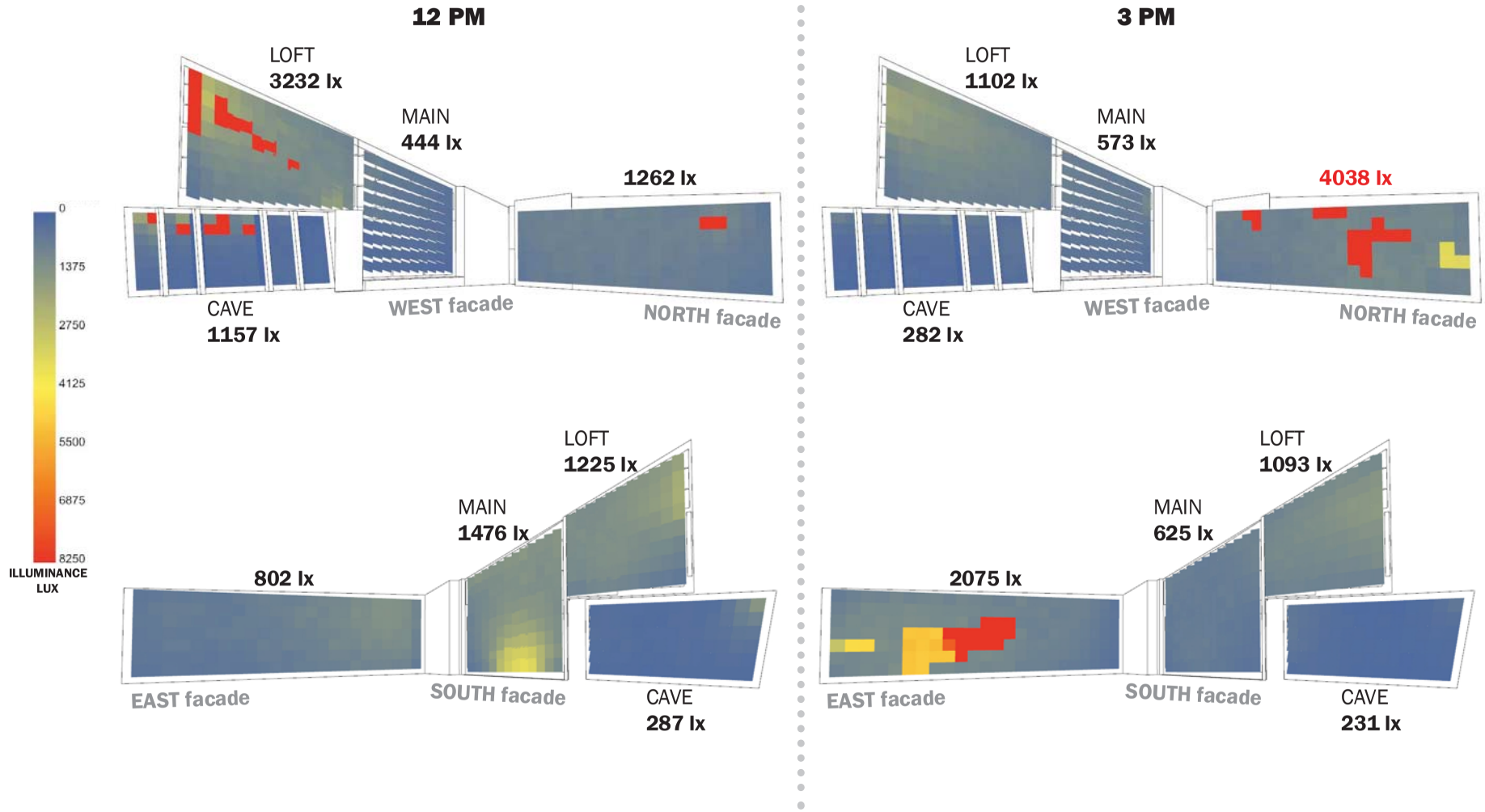


SHOJI SCREEN SET @ EXTERIOR SLATTED WOOD SCREENS

proposed_DAYLIGHTING FOR OBJECTS_march 21

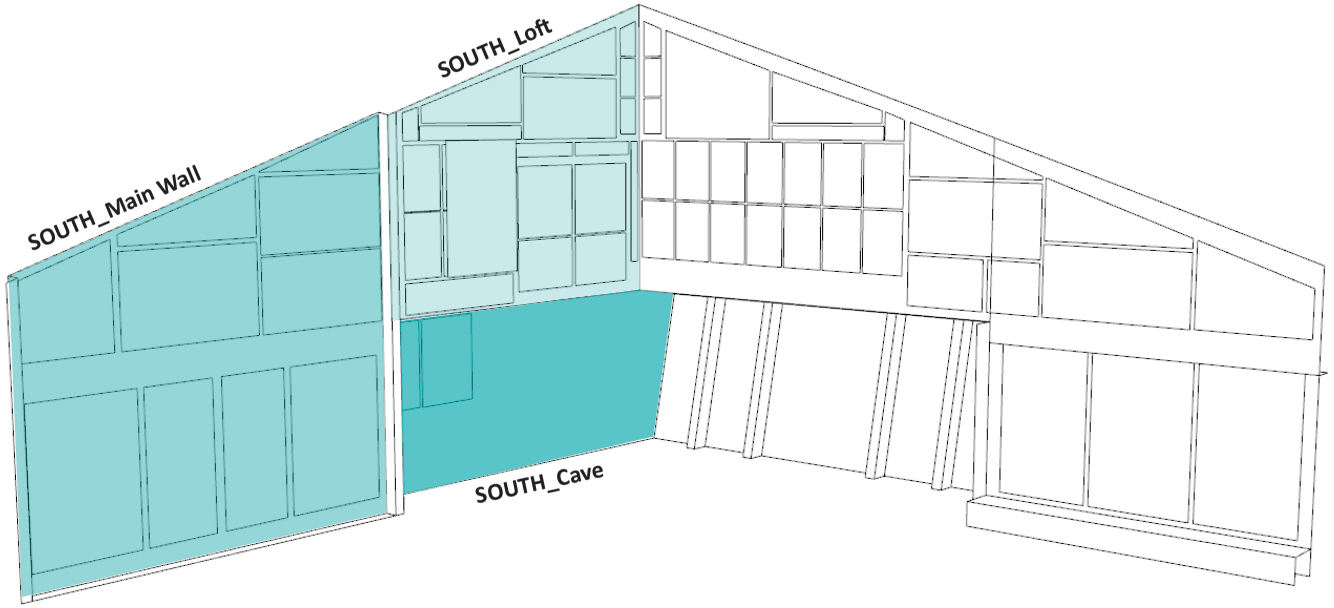


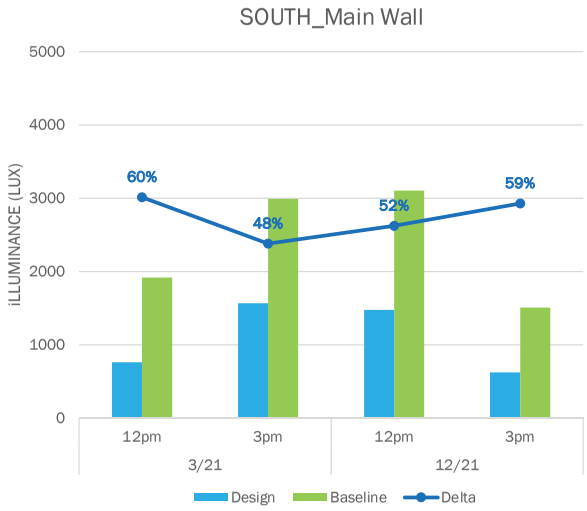
proposed_DAYLIGHTING FOR OBJECTS_december 21

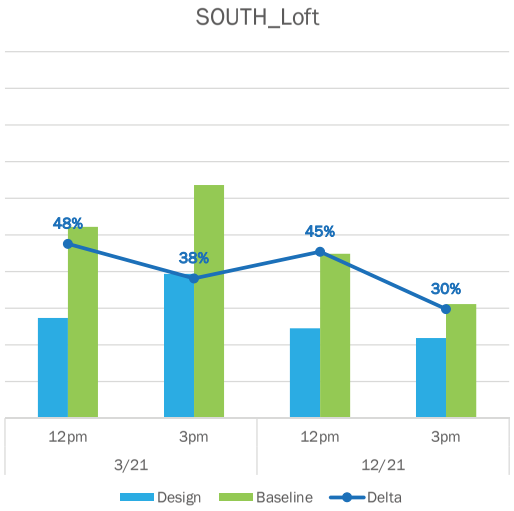


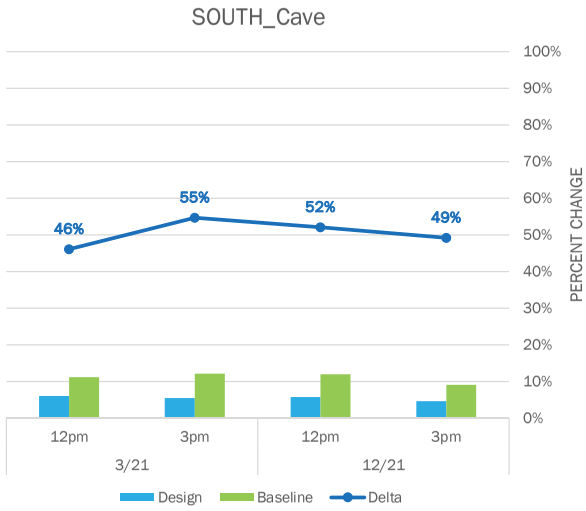
NAKASHIMA ART STUDIO

baseline + proposed_COMPARISON



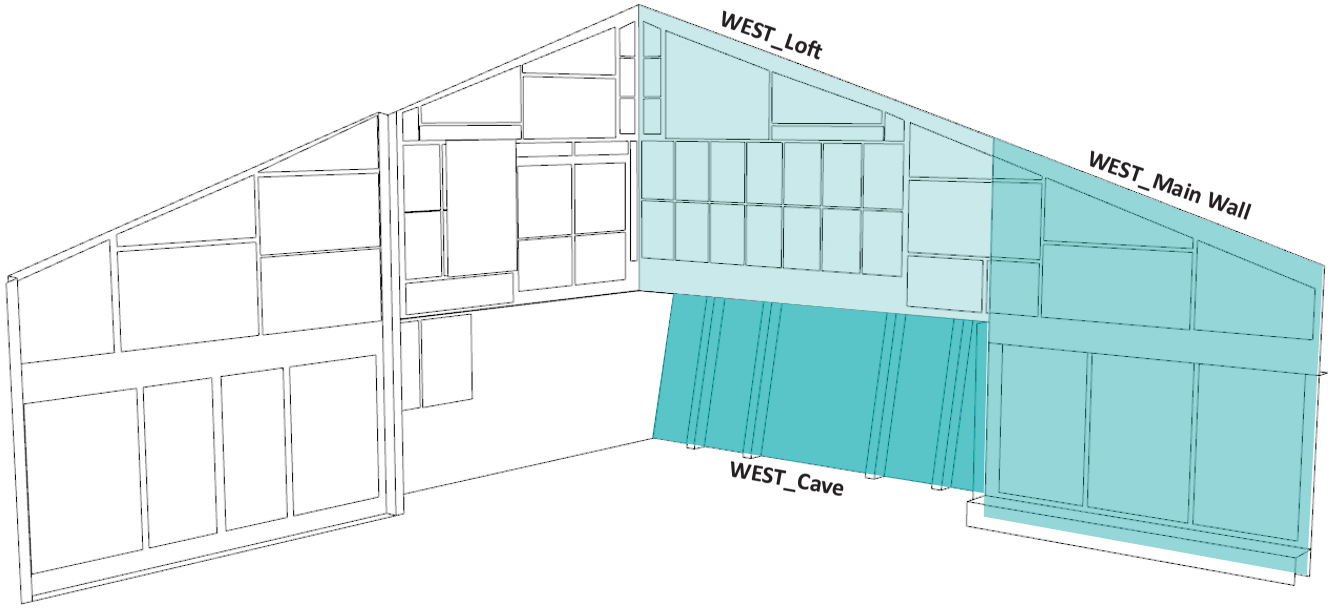


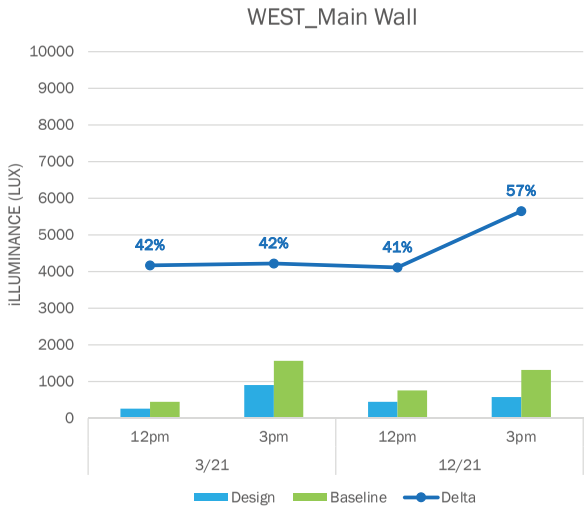


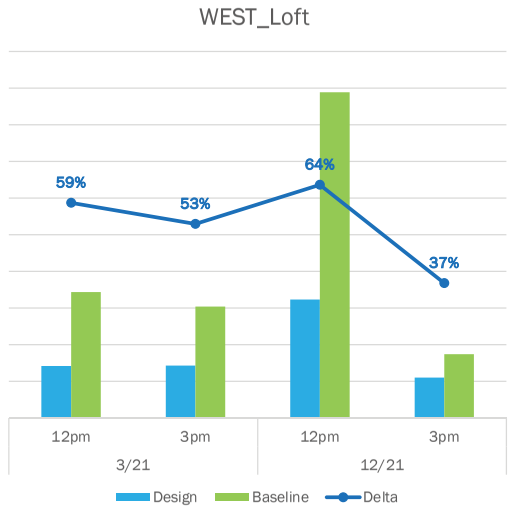


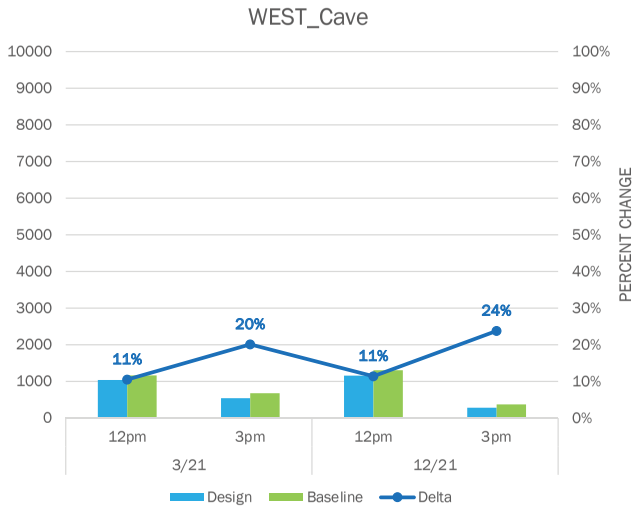
NAKASHIMA ART STUDIO

baseline + proposed_COMPARISON

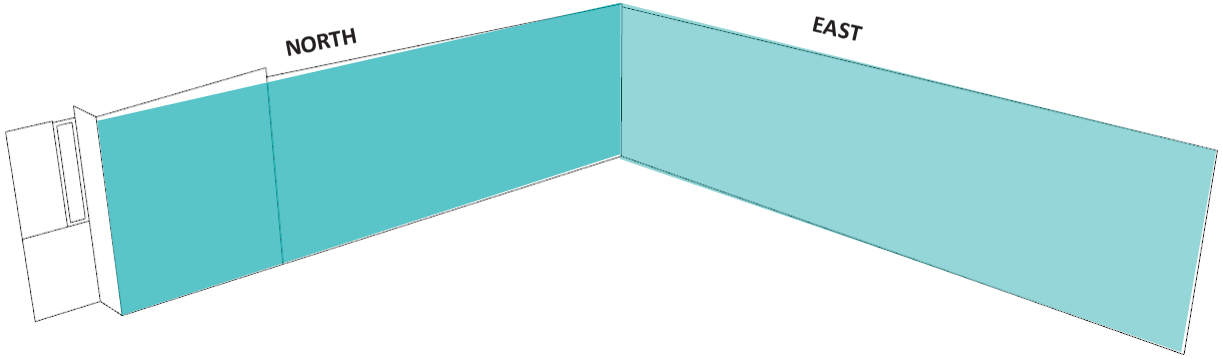


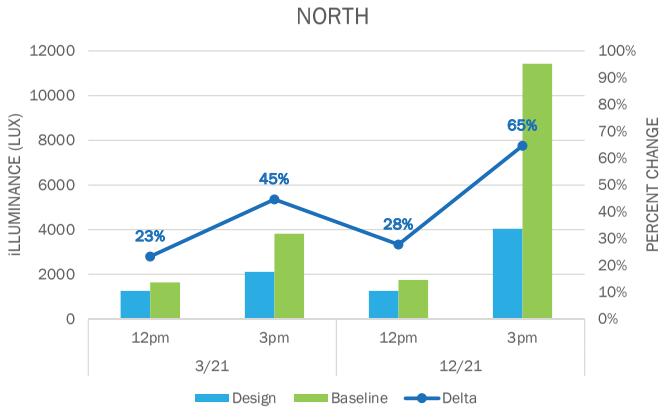


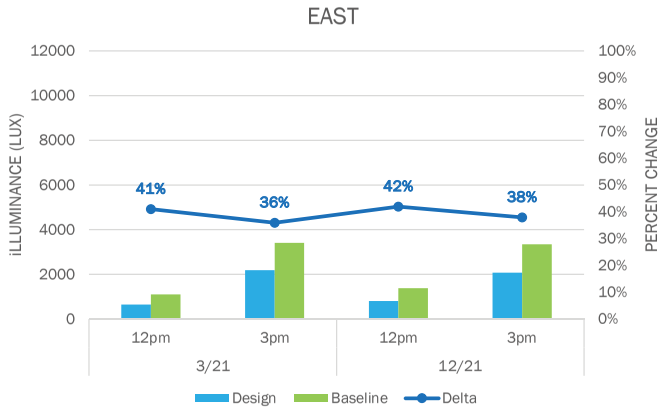




baseline + proposed_COMPARISON

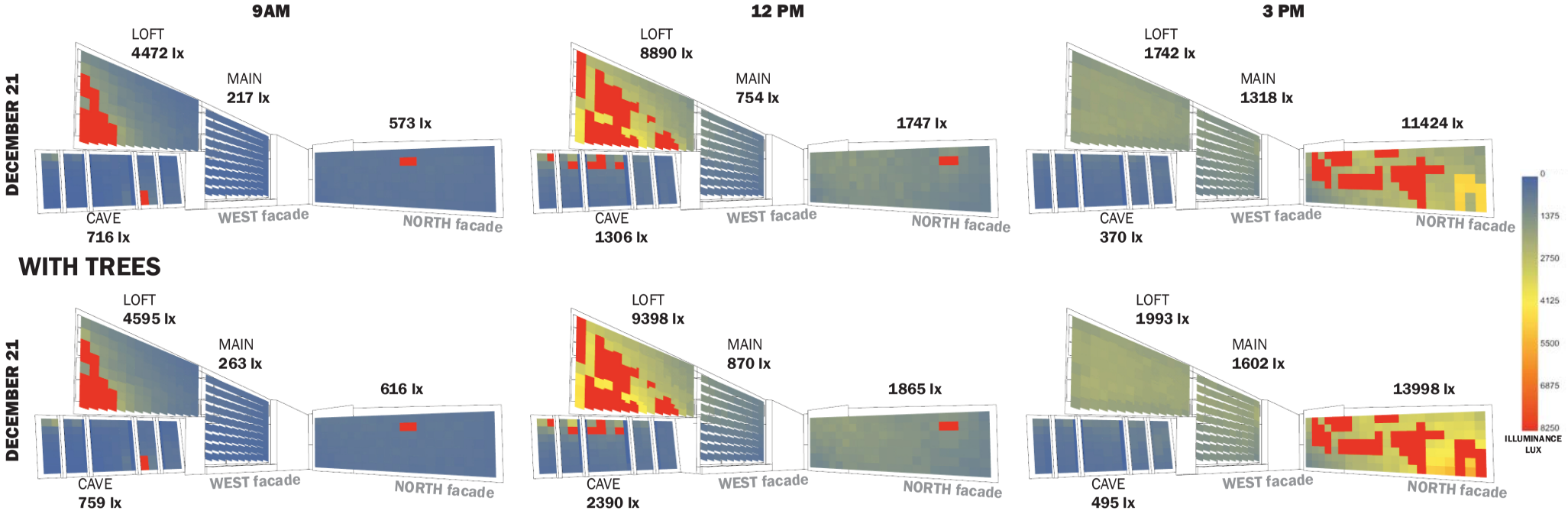






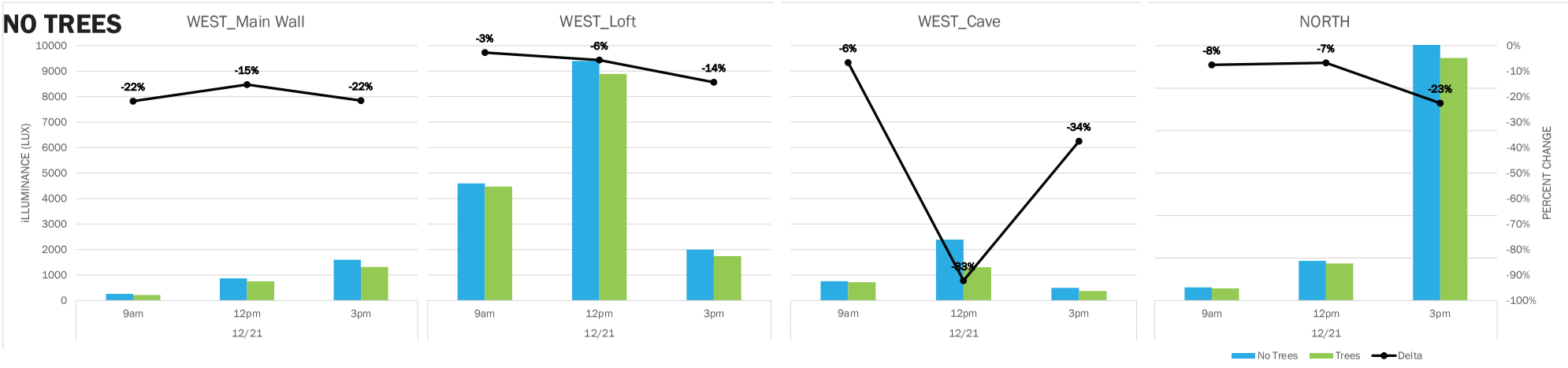
NAKASHIMA ART STUDIO

Effect of Vegetation



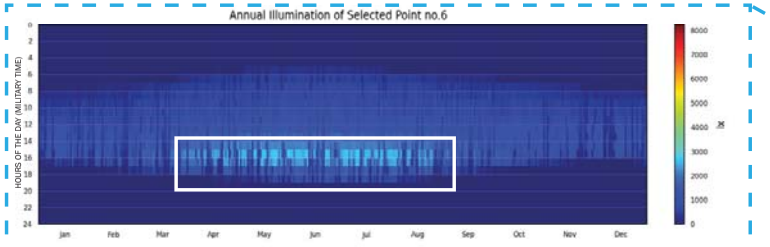
WITH TREES

NO TREES

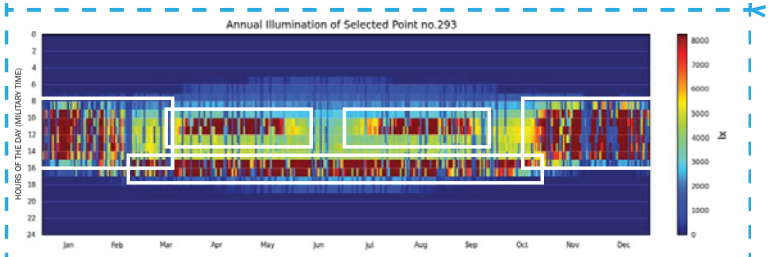


NAKASHIMA ART STUDIO

baseline_DAYLIGHTING FOR OCCUPANTS_main space



ANNUAL DAYLIGHT ILLUMINANCE @ 1 POINT NEAR WEST DOORS

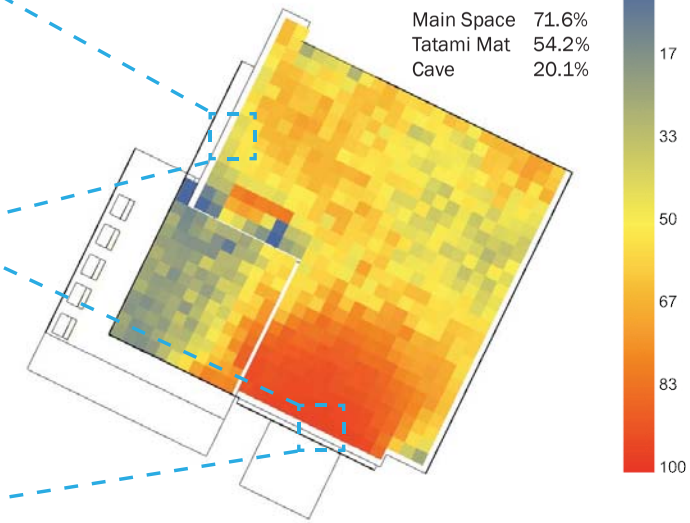


ANNUAL DAYLIGHT ILLUMINANCE @ 1 POINT NEAR SOUTH DOORS

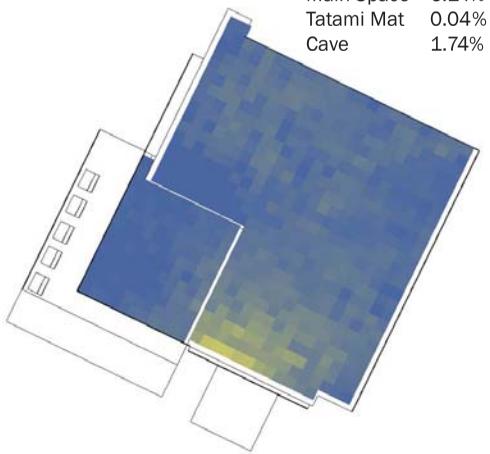
SPATIAL DAYLIGHT AUTONOMY

% of area recieving 300 lux of daylight for 50% of daylight hours

Main Space	71.6%
Tatami Mat	54.2%
Cave	20.1%

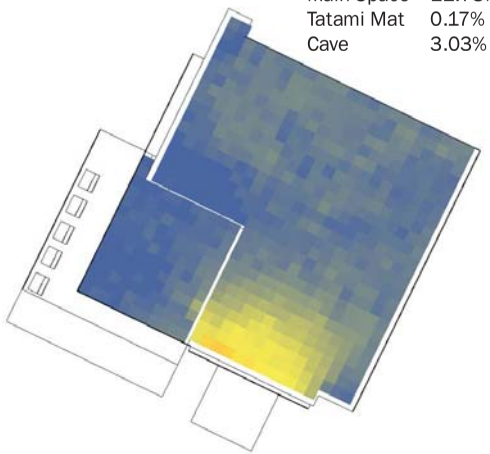


Main Space	6.14%
Tatami Mat	0.04%
Cave	1.74%



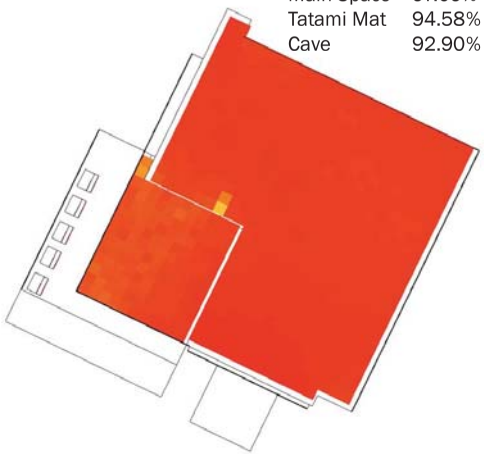
DAYLIGHT AUTONOMY (5,000 LX)

Main Space	12.78%
Tatami Mat	0.17%
Cave	3.03%



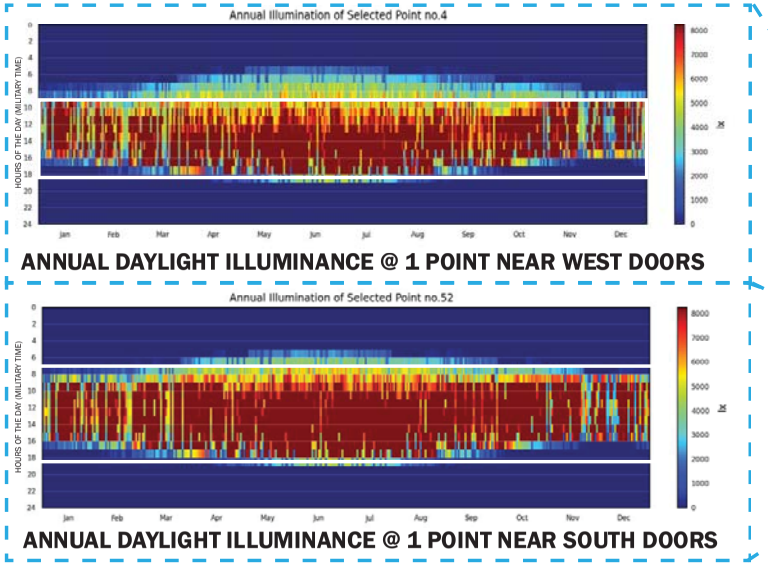
DAYLIGHT AUTONOMY (2,500 LX)

Main Space	97.09%
Tatami Mat	94.58%
Cave	92.90%



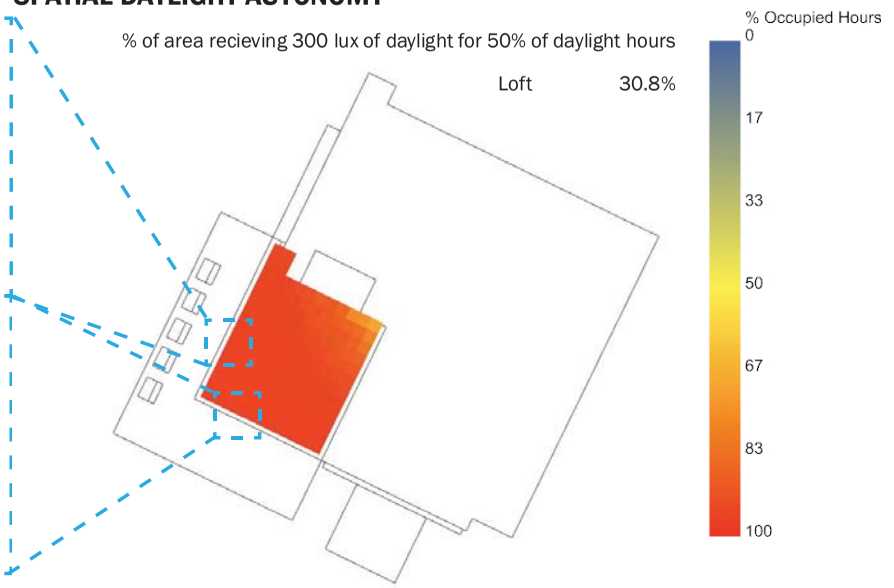
DAYLIGHT AUTONOMY (50 LX)

baseline_DAYLIGHTING FOR OCCUPANTS_loft

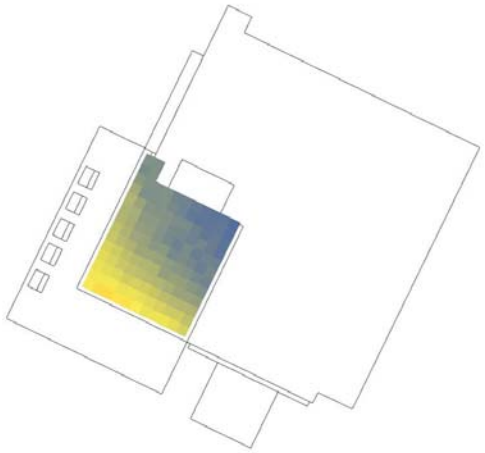


SPATIAL DAYLIGHT AUTONOMY

% of area recieving 300 lux of daylight for 50% of daylight hours

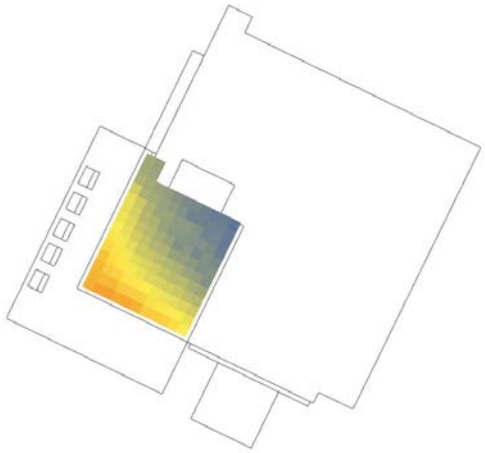


Loft 24.15%



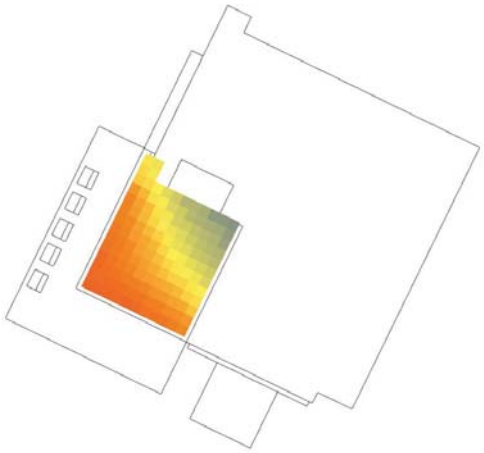
DAYLIGHT AUTONOMY (7,500 LX)

Loft 34.36%



DAYLIGHT AUTONOMY (5,000 LX)

Loft 59.54%



DAYLIGHT AUTONOMY (2,500 LX)

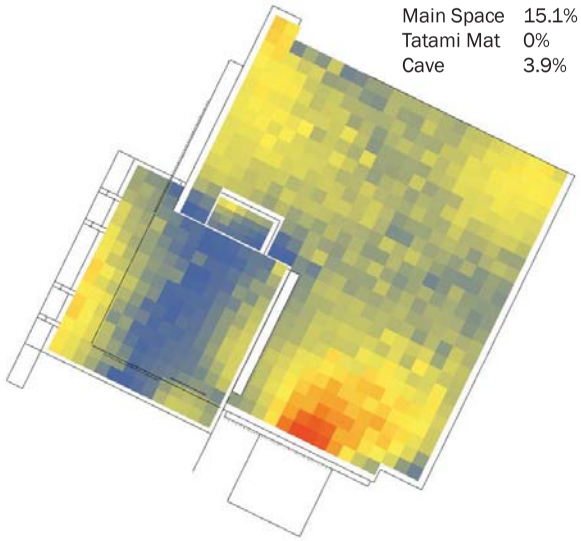
NAKASHIMA ART STUDIO

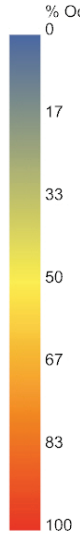
design_DAYLIGHTING FOR OCCUPANTS_main space

SPATIAL DAYLIGHT AUTONOMY

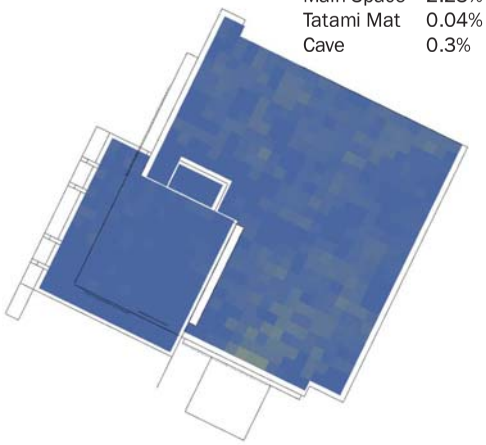
% of area recieving 300 lux of daylight for 50% of daylight hours

Main Space	15.1%	79% Reduction
Tatami Mat	0%	100% Reduction
Cave	3.9%	81% Reduction



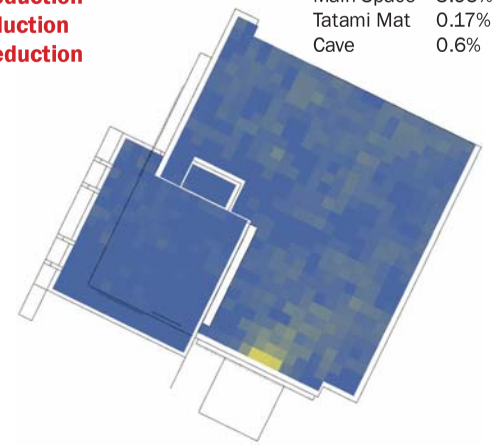


Main Space	2.23%	64% Reduction
Tatami Mat	0.04%	0% Reduction
Cave	0.3%	83% Reduction



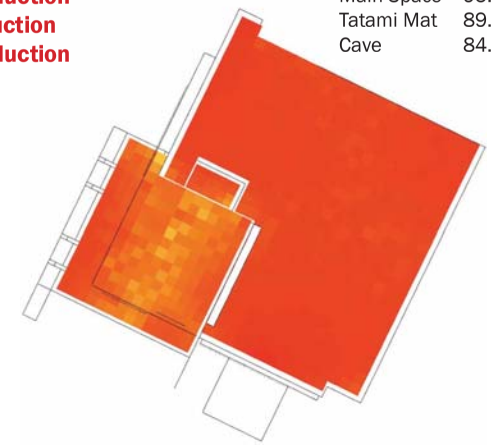
DAYLIGHT AUTONOMY (5,000 LX)

Main Space	3.95%	69% Reduction
Tatami Mat	0.17%	0% Reduction
Cave	0.6%	80% Reduction



DAYLIGHT AUTONOMY (2,500 LX)

Main Space	95.01%	2% Reduction
Tatami Mat	89.50%	5% Reduction
Cave	84.78%	9% Reduction

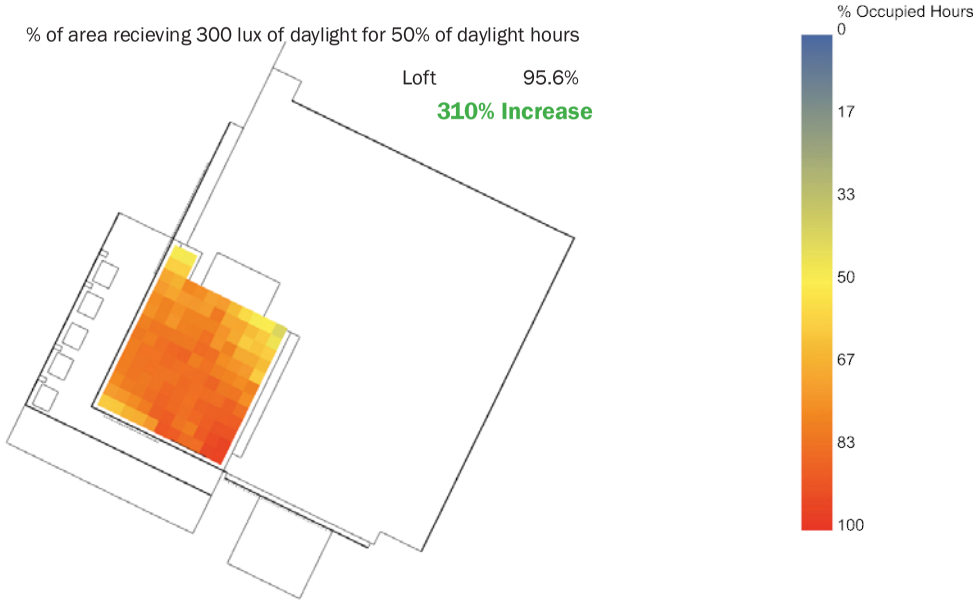


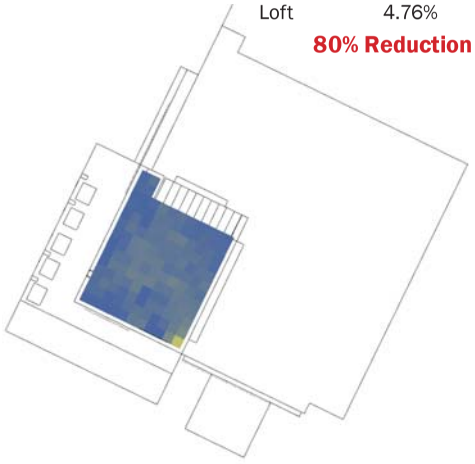
DAYLIGHT AUTONOMY (50 LX)

design_DAYLIGHTING FOR OCCUPANTS_loft

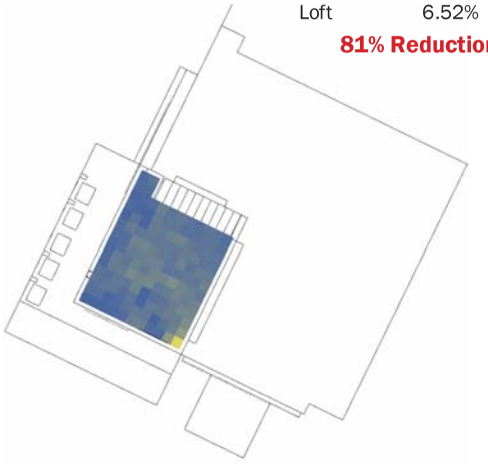
Since these design case simulations show the extreme case condition where all shades are drawn and all panels are employed, it is possible that actual conditions are quite different. However, based on the extreme case, natural lighting levels in the loft area are greatly improved, at the expense of lighting levels in the main space and cave which may require artificial lighting.

SPATIAL DAYLIGHT AUTONOMY

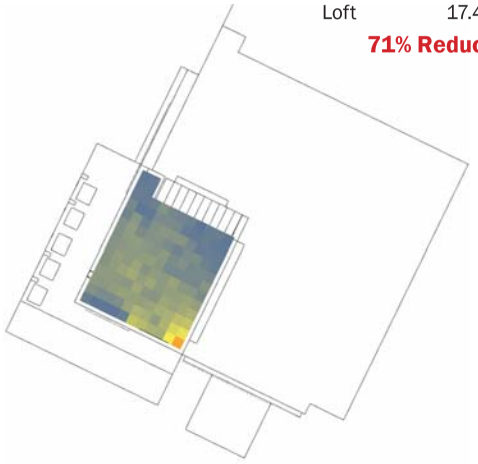




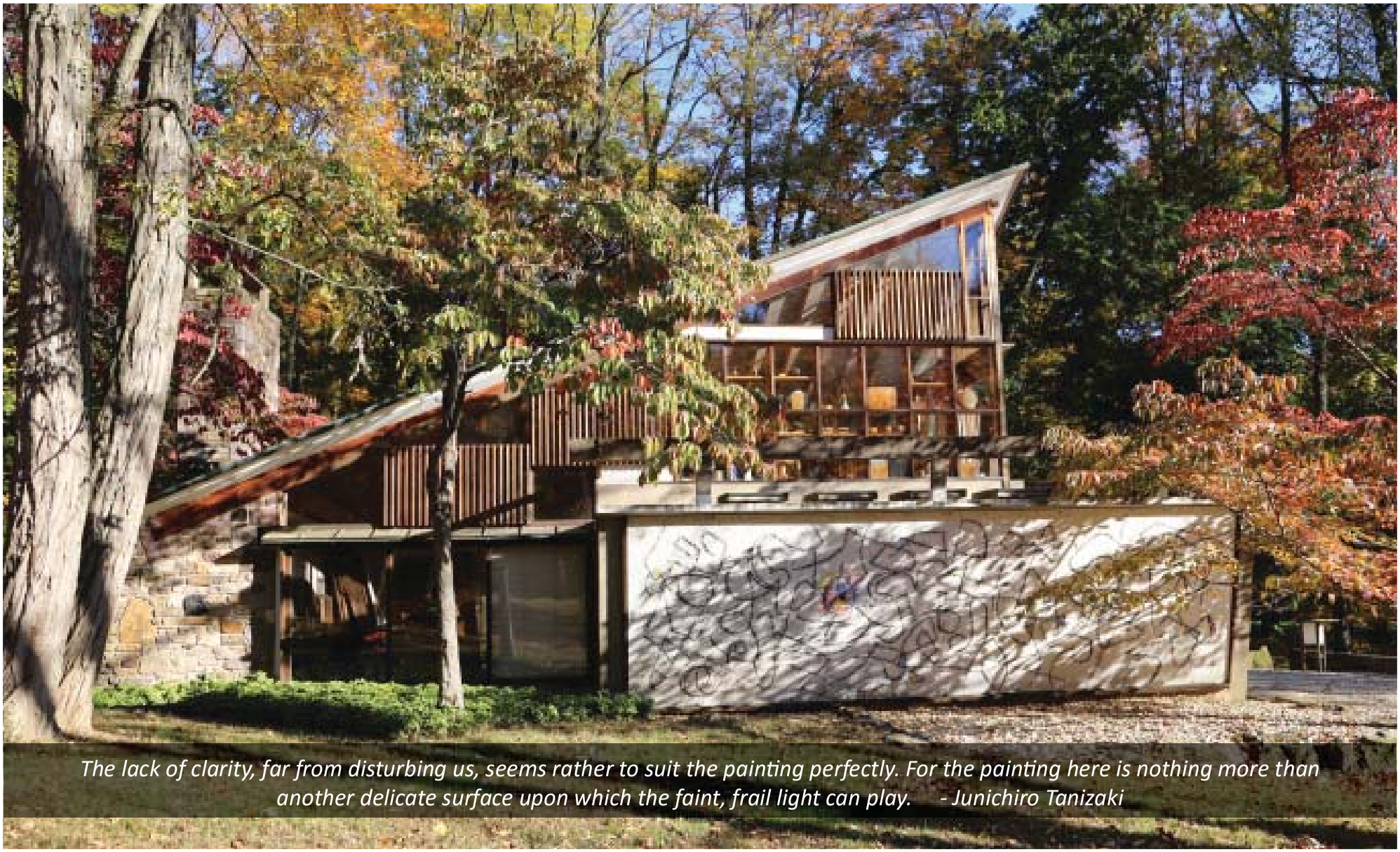
DAYLIGHT AUTONOMY (7,500 LX)



DAYLIGHT AUTONOMY (5,000 LX)



DAYLIGHT AUTONOMY (2,500 LX)



The lack of clarity, far from disturbing us, seems rather to suit the painting perfectly. For the painting here is nothing more than another delicate surface upon which the faint, frail light can play. *- Junichiro Tanizaki*

Appendix D

Weahter Data for Trenton/Mercer County Airport

TRENTON/MERCER NJ	
Latitude = 40.28 N	WMO No. 724095
Longitude = 74.82 W	Elevation = 213 feet
Period of Record = 1973 to 1996	Average Pressure = 29.77 inches Hg

Design Criteria Data

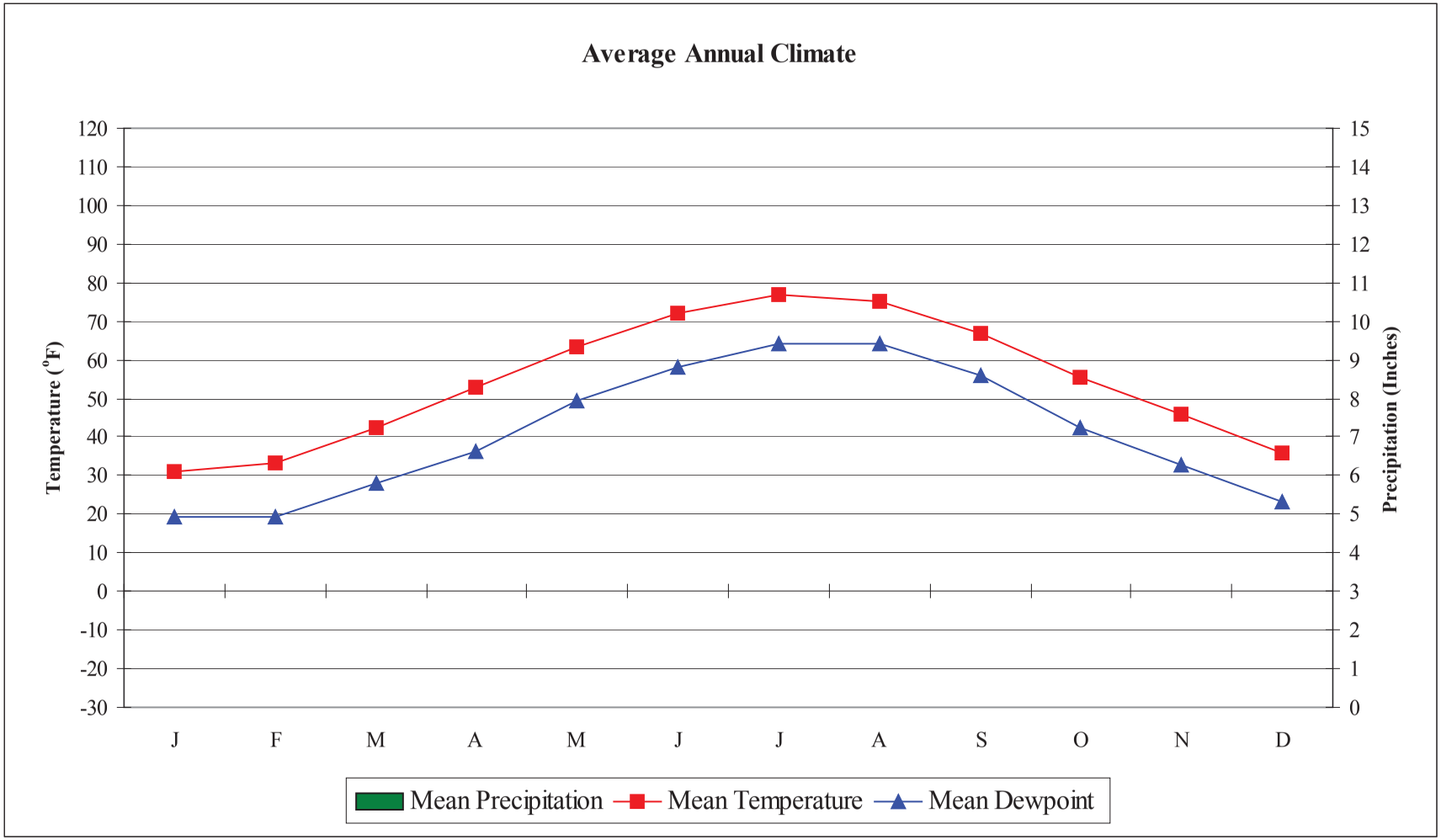
		Mean Coincident (Average) Values			
Dry Bulb Temperature (T)	**Design Value (^oF)**	Wet Bulb Temperature (^oF)	Humidity Ratio (gr/lb)	Wind Speed (mph)	Prevailing Direction (NSEW)
Median of Extreme Highs	97	78	117	11.9	W
0.4% Occurrence	93	76	109	11.0	W
1.0% Occurrence	90	75	105	10.7	W
2.0% Occurrence	87	73	100	10.6	W
Mean Daily Range	18	-	-	-	-
97.5% Occurrence	18	15	7	11.4	NW
99.0% Occurrence	13	11	5	11.9	NW
99.6% Occurrence	8	6	4	11.8	NW
Median of Extreme Lows	2	0	3	13.1	W
		Mean Coincident (Average) Values			
Wet Bulb Temperature (T_{wb})	**Design Value (^oF)**	Dry Bulb Temperature (^oF)	Humidity Ratio (gr/lb)	Wind Speed (mph)	Prevailing Direction (NSEW)
Median of Extreme Highs	81	90	141	9.8	W
0.4% Occurrence	78	87	128	10.0	WSW
1.0% Occurrence	77	86	125	9.9	WSW
2.0% Occurrence	75	83	117	9.6	WSW
		Mean Coincident (Average) Values			
Humidity Ratio (HR)	**Design Value (gr/lb)**	Dry Bulb Temperature (^oF)	Vapor Pressure (in. Hg)	Wind Speed (mph)	Prevailing Direction (NSEW)
Median of Extreme Highs	142	83	0.94	9.3	SW
0.4% Occurrence	136	83	0.90	8.8	WSW
1.0% Occurrence	128	82	0.85	8.5	WSW
2.0% Occurrence	120	80	0.79	9.4	W
Air Conditioning/		$T \geq 93^oF$	$T \geq 80^oF$	$T_{wb} \geq 73^oF$	$T_{wb} \geq 67^oF$
Humid Area Criteria	# of Hours	34	714	331	1052

Other Site Data

Weather Region	Rain Rate 100 Year Recurrence (in./hr)	Basic Wind Speed 3 sec gust @ 33 ft 50 Year Recurrence (mph)	Ventilation Cooling Load Index (Ton-hr/cfm/yr) Base 75^oF-RH 60% Latent + Sensible
7	3.1	110	1.1 + 0.6
Ground Water Temperature (^oF) 50 Foot Depth *	Frost Depth 50 Year Recurrence (in.)	Ground Snow Load 50 Year Recurrence (lb/ft^2)	Average Annual Freeze-Thaw Cycles (#)
56.9	N/A	N/A	56

*Note: Temperatures at greater depths can be estimated by adding 1.5^oF per 100 feet additional depth.

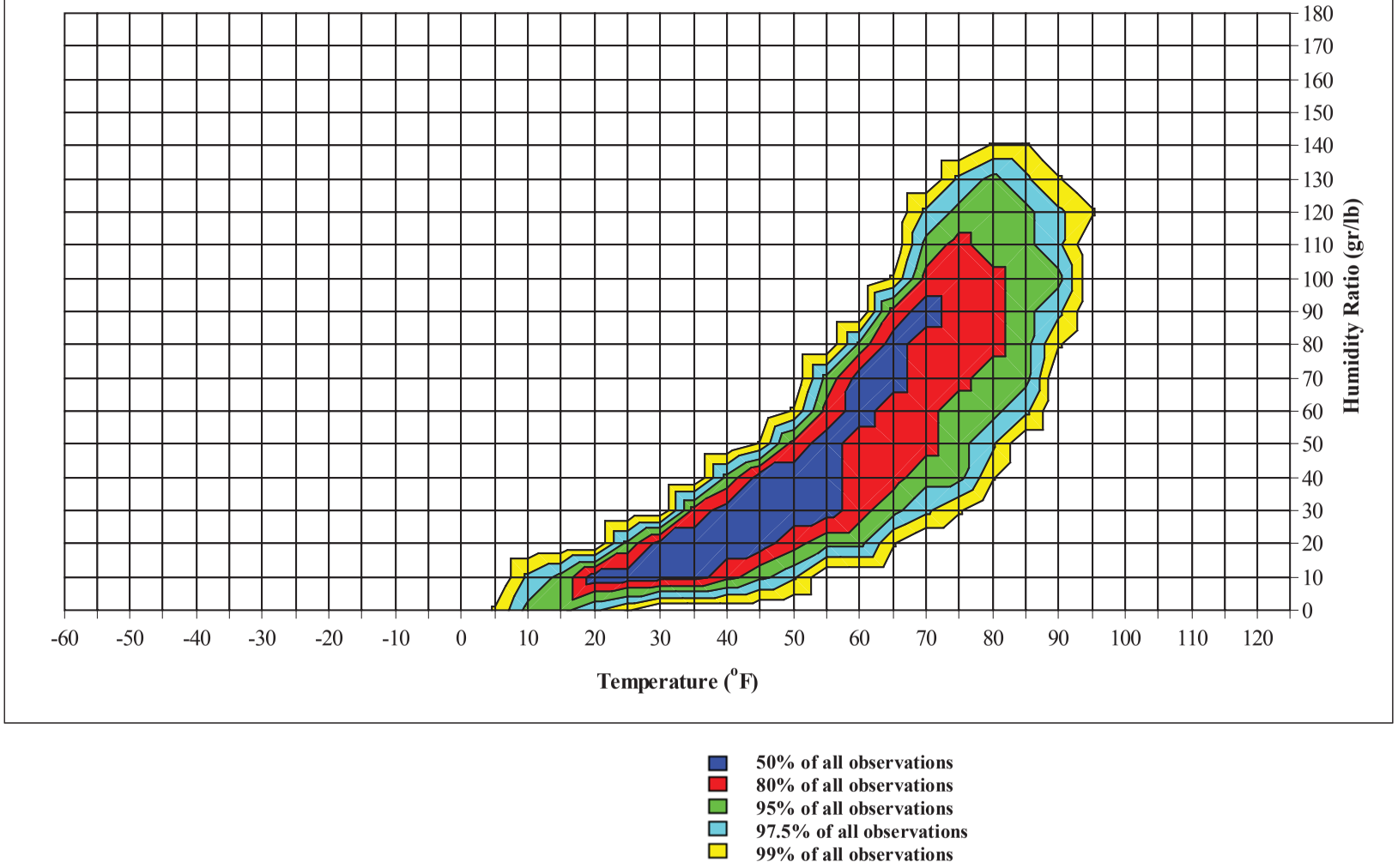
TRENTON/MERCER NJ WMO No. 724095



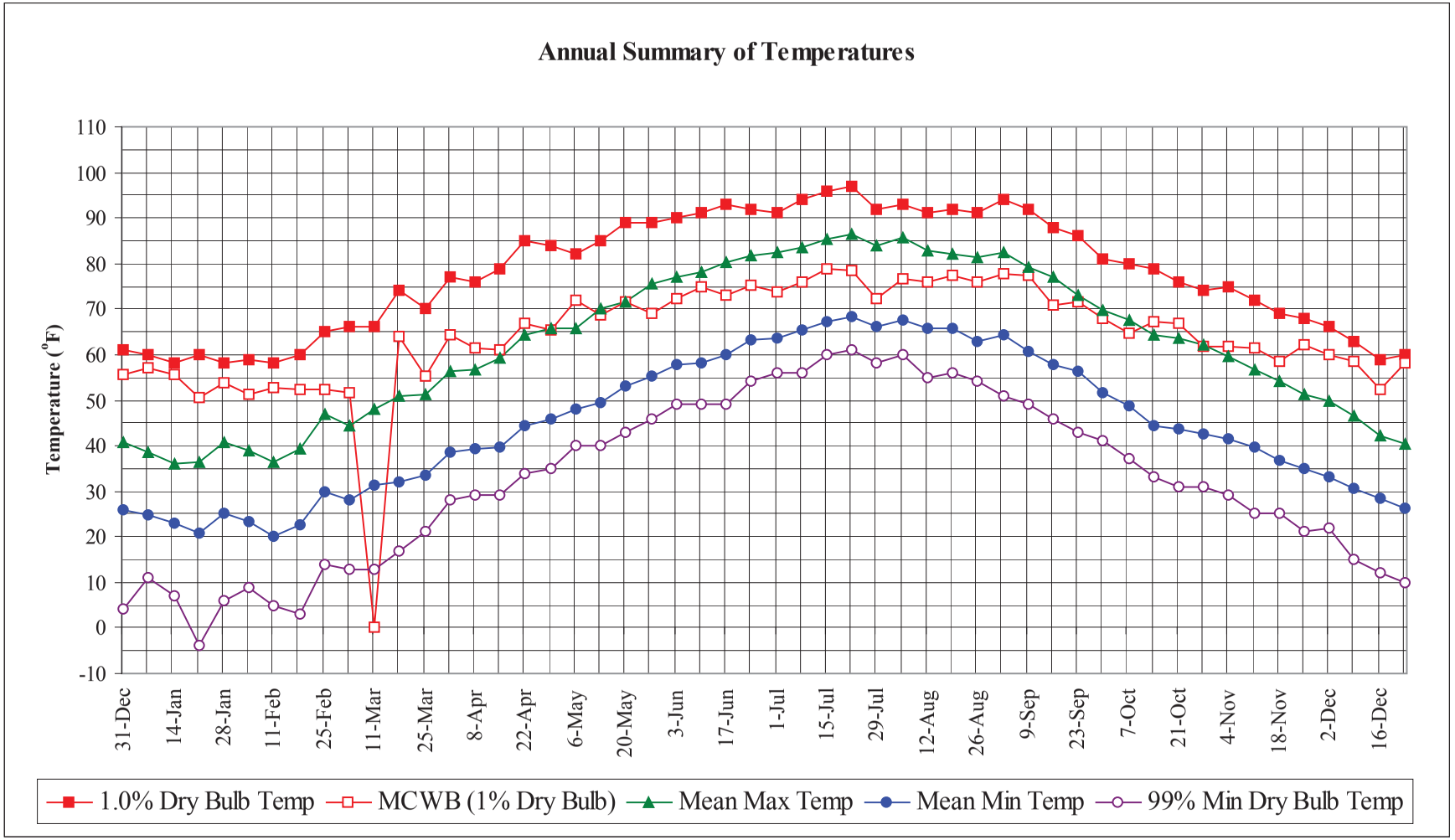
No Precipitation Data Available

TRENTON/MERCER NJ WMO No. 724095

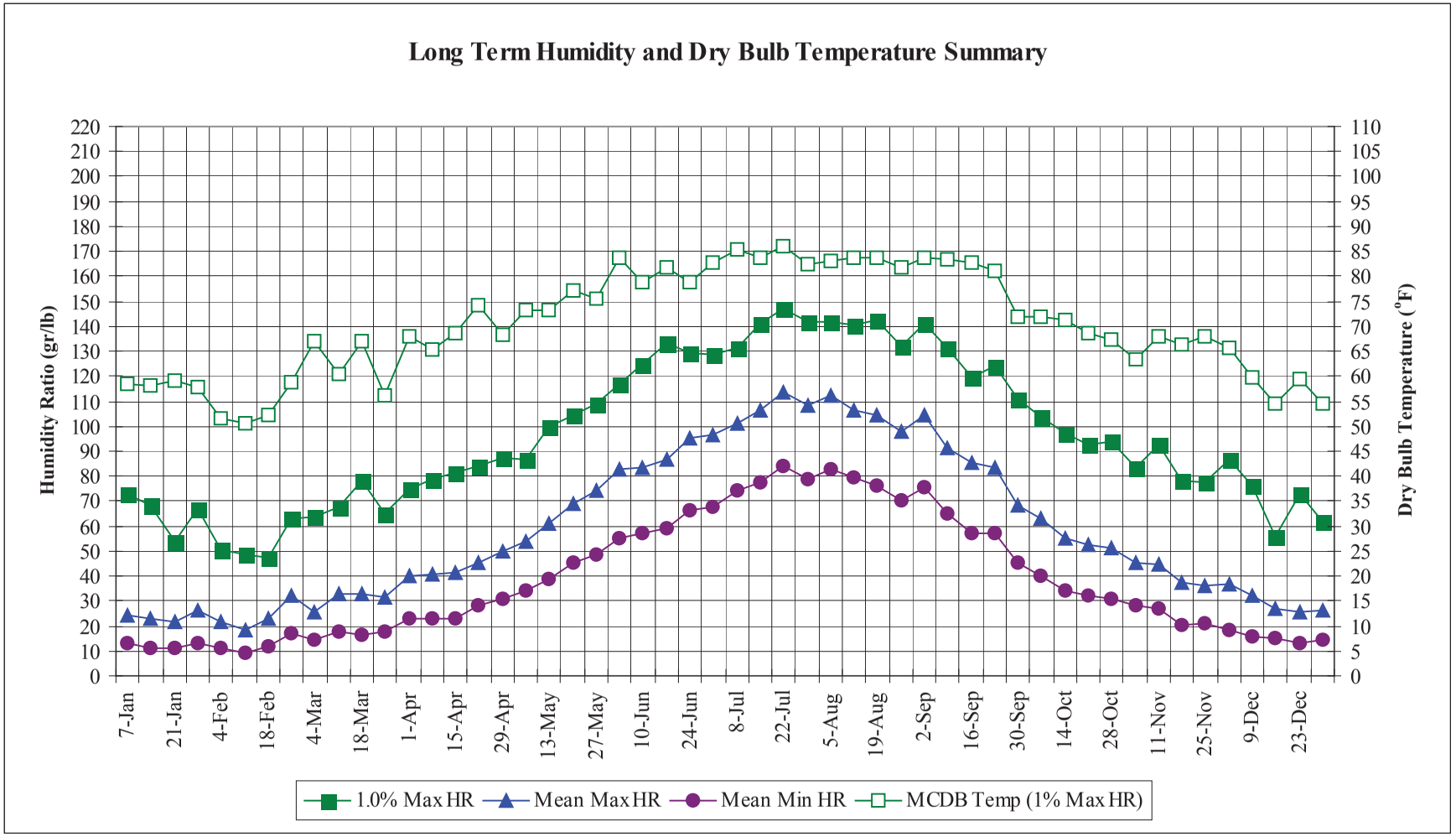
Long Term Psychrometric Summary



TRENTON/MERCER NJ WMO No. 724095



TRENTON/MERCER NJ WMO No. 724095



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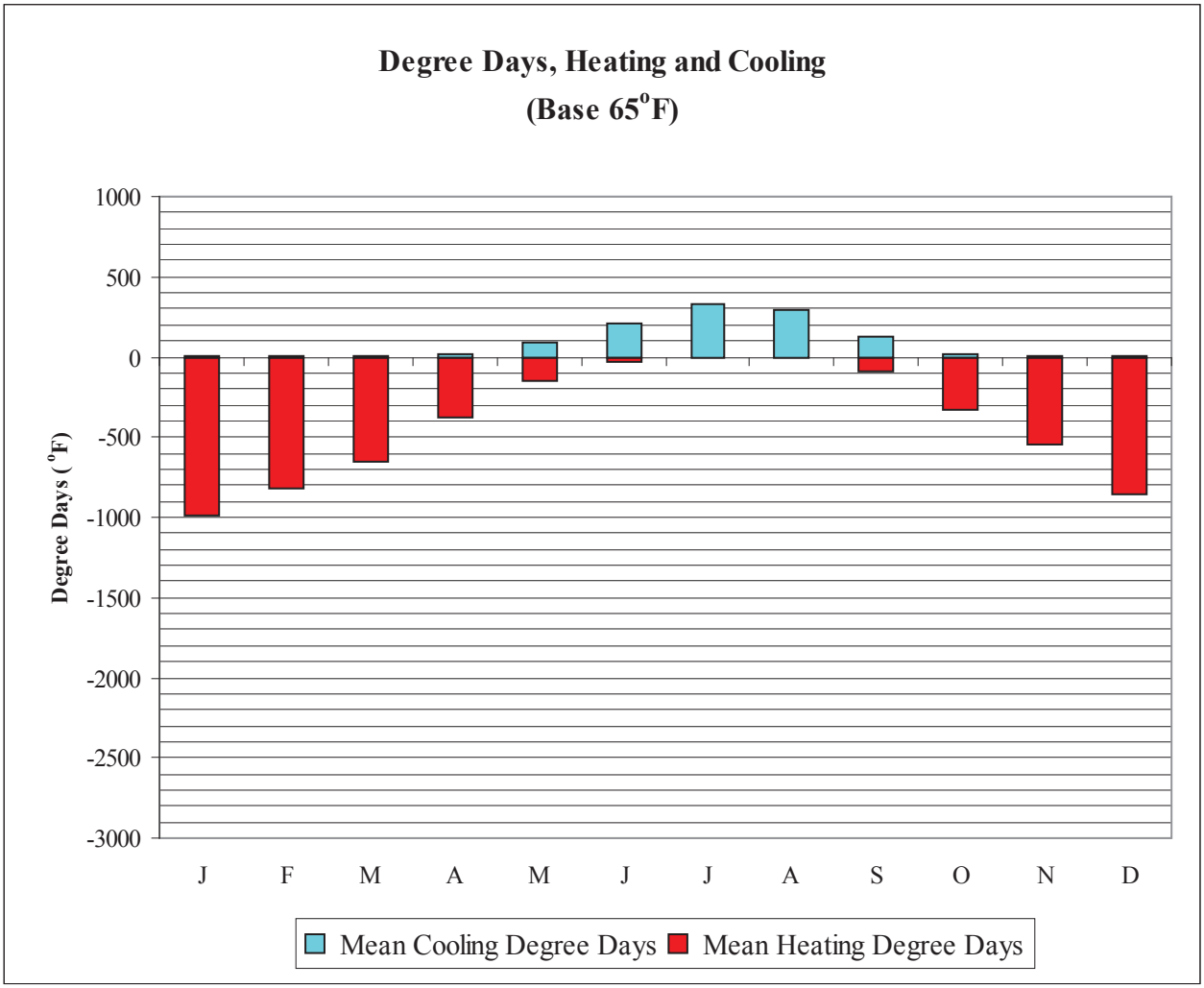
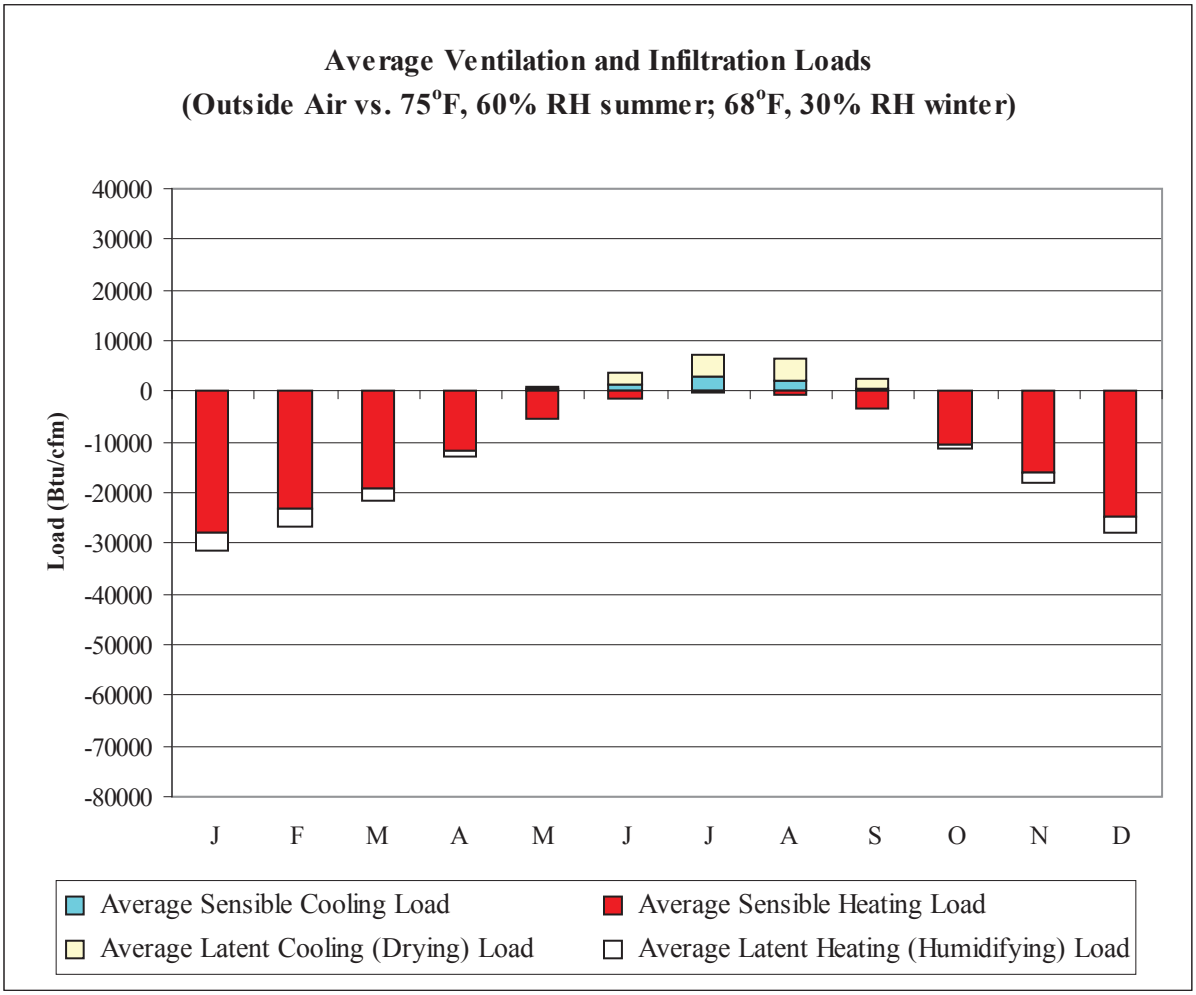


	Mean Cooling Degree Days (°F)	Mean Heating Degree Days (°F)
JAN	0	986
FEB	0	821
MAR	4	656
APR	21	376
MAY	85	151
JUN	214	29
JUL	329	6
AUG	288	11
SEP	131	85
OCT	23	326
NOV	4	539
DEC	0	862
ANN	1102	4848

TRENTON/MERCER NJ WMO No. 724095



	Average Sensible Cooling Load (Btu/cfm)	Average Sensible Heating Load (Btu/cfm)	Average Latent Cooling Load (Btu/cfm)	Average Latent Heating Load (Btu/cfm)
JAN	0	-27810	2	-3455
FEB	0	-23267	0	-3256
MAR	8	-19178	2	-2343
APR	90	-11765	28	-1169
MAY	469	-5436	531	-149
JUN	1462	-1346	2045	-5
JUL	2871	-356	4517	0
AUG	2063	-599	4458	0
SEP	684	-3358	1780	-19
OCT	42	-10538	202	-614
NOV	3	-16120	39	-1809
DEC	0	-24634	3	-3307
ANN	7692	-144407	13607	-16126

Average Annual Solar Radiation – Nearest Available Site

(Source: National Renewable Energy Laboratory, Golden CO, 1995)

City: PHILADELPHIA
State: PA
WBAN No: 13739
Lat(N): 39.88
Long(W): 75.25
Elev(ft): 30

Stn Type: Secondary
SHADING GEOMETRY IN DIMENSIONLESS UNITS
Window: 1
Overhang: 0.53
Vert Gap: 0.32

AVERAGE INCIDENT SOLAR RADIATION (Btu/sq.ft./day), Percentage Uncertainty = 11

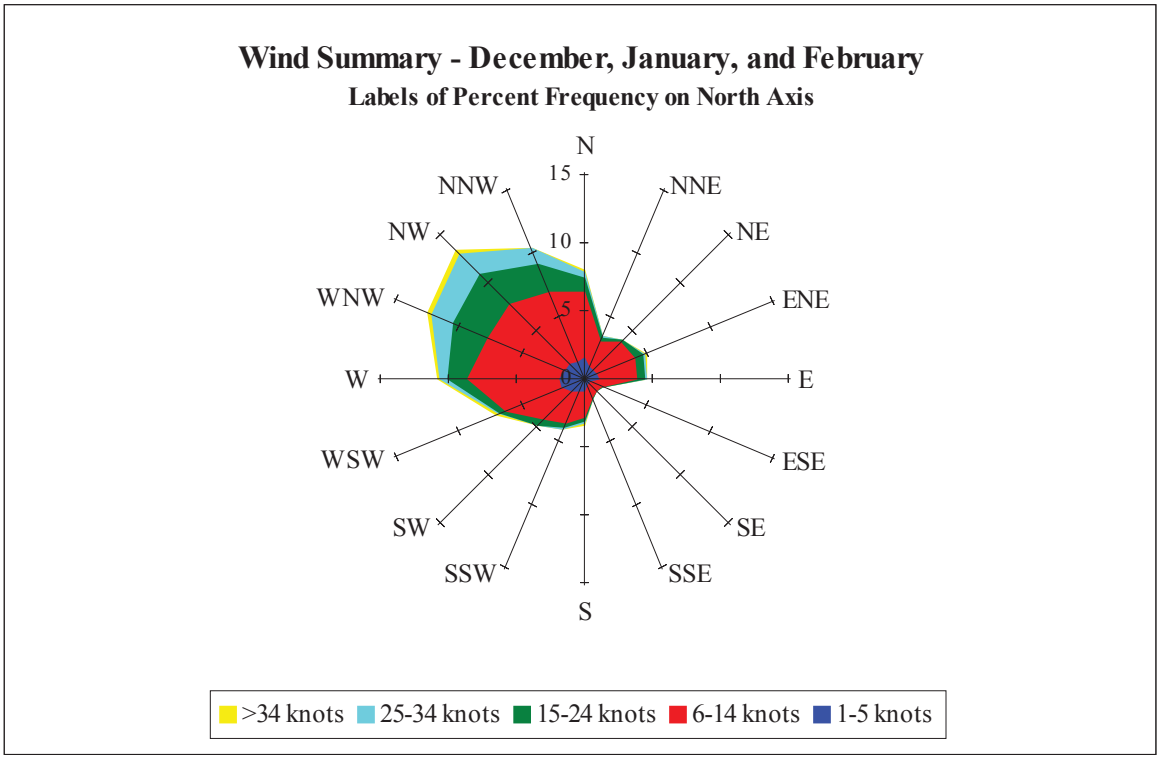
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
HORIZ	Global	620	870	1200	1520	1760	1940	1890	1710	1380	1020	680	530	1260
	Std Dev	42	72	91	118	135	115	116	88	100	74	55	39	35
	Minimum	520	770	1010	1230	1530	1640	1580	1530	1180	880	560	430	1200
	Maximum	710	1080	1370	1740	2050	2220	2110	1850	1560	1150	800	610	1350
	Diffuse	310	420	550	700	840	880	870	760	610	450	330	280	580
Clear Day	Global	890	1240	1710	2190	2490	2590	2510	2240	1820	1340	940	780	1730
NORTH	Global	190	260	340	430	540	610	580	480	380	290	210	170	370
	Diffuse	190	260	340	430	500	530	520	460	380	290	210	170	360
Clear Day	Global	180	240	330	430	580	680	620	480	360	270	200	160	380
EAST	Global	420	570	740	900	970	1050	1030	970	820	650	450	370	740
	Diffuse	240	320	420	520	600	630	630	570	470	360	250	210	430
Clear Day	Global	680	870	1110	1310	1410	1430	1400	1310	1140	910	690	610	1070
SOUTH	Global	1000	1080	1070	950	830	790	820	940	1070	1150	990	900	960
	Diffuse	340	410	480	540	570	580	580	570	520	450	360	310	480
Clear Day	Global	1880	1930	1780	1410	1080	940	990	1240	1580	1810	1830	1800	1520
WEST	Global	430	560	730	880	970	1050	1030	960	820	650	450	370	740
	Diffuse	240	320	420	520	610	640	630	580	470	360	260	210	440
Clear Day	Global	680	870	1110	1310	1410	1430	1400	1310	1140	910	690	610	1070

Average Annual Solar Heat and Illumination – Nearest Available Site

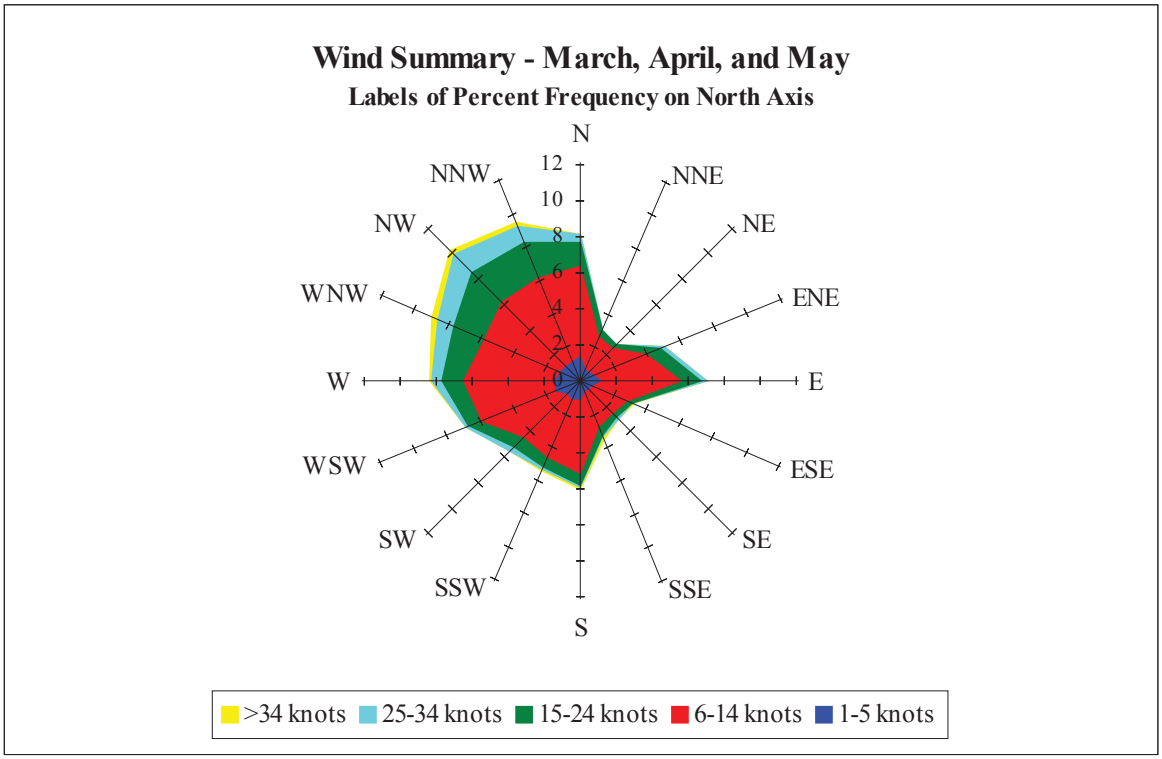
(Source: National Renewable Energy Laboratory, Golden CO, 1995)

AVERAGE TRANSMITTED SOLAR RADIATION (Btu/sq.ft./day) FOR DOUBLE GLAZING, Percentage Uncertainty = 11														
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
HORIZ	Unshaded	400	600	850	1090	1270	1410	1370	1240	990	710	450	340	890
NORTH	Unshaded	130	180	240	300	360	400	380	330	260	200	140	120	250
	Shaded	120	160	210	260	320	350	340	290	230	180	130	100	220
EAST	Unshaded	290	400	520	640	690	740	730	690	580	450	310	250	520
	Shaded	260	350	460	550	580	620	610	580	500	400	280	230	450
SOUTH	Unshaded	750	790	740	620	520	480	500	600	730	830	740	680	660
	Shaded	730	730	590	410	350	360	360	390	520	730	710	660	540
WEST	Unshaded	300	390	520	620	690	740	730	680	580	450	310	250	520
	Shaded	270	350	450	530	590	630	620	580	500	400	280	220	450

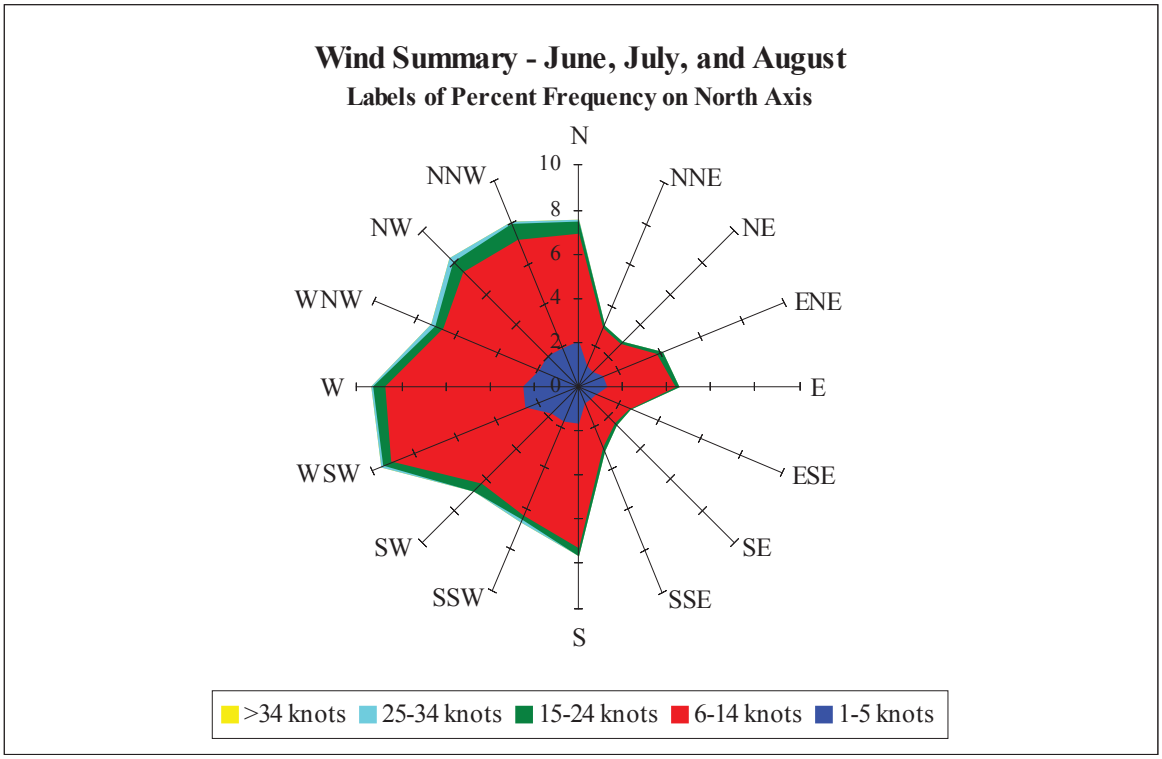
AVERAGE INCIDENT ILLUMINANCE (klux-hr) FOR MOSTLY CLEAR AND MOSTLY CLOUDY CONDITIONS, Percentage Uncertainty = 11											
		March					June				
		9am	11am	1pm	3pm	5pm	9am	11am	1pm	3pm	5pm
HORIZ.	M.Clear	39	71	80	63	25	47	83	100	94	66
	M.Cloudy	22	43	48	37	15	28	55	69	66	44
NORTH	M.Clear	10	14	15	13	8	18	17	17	17	16
	M.Cloudy	9	15	16	13	6	13	18	20	19	15
EAST	M.Clear	72	55	15	13	8	75	71	30	17	16
	M.Cloudy	25	29	16	13	6	31	42	26	19	15
SOUTH	M.Clear	39	73	82	64	25	12	33	47	42	21
	M.Cloudy	17	35	40	30	11	11	25	35	32	17
WEST	M.Clear	10	14	24	66	61	12	17	17	53	76
	M.Cloudy	9	15	19	31	20	11	18	20	38	42
M.Clear	(% hrs)	36	33	31	32	35	40	39	37	35	37
		Sept					Dec				
		9am	11am	1pm	3pm	5pm	9am	11am	1pm	3pm	5pm
HORIZ.	M.Clear	28	66	83	76	45	14	40	45	27	2
	M.Cloudy	16	40	53	50	28	8	22	26	16	2
NORTH	M.Clear	9	14	16	16	12	5	10	10	8	1
	M.Cloudy	7	14	18	16	11	4	9	10	7	1
EAST	M.Clear	62	68	27	16	12	39	37	10	8	1
	M.Cloudy	20	33	22	16	11	10	16	10	7	1
SOUTH	M.Clear	21	57	75	67	37	36	79	85	58	5
	M.Cloudy	10	29	42	39	20	10	27	31	19	1
WEST	M.Clear	9	14	16	53	71	5	10	22	46	7
	M.Cloudy	7	14	18	33	31	4	9	13	16	2
M.Clear	(% hrs)	43	45	43	39	40	33	32	30	31	36



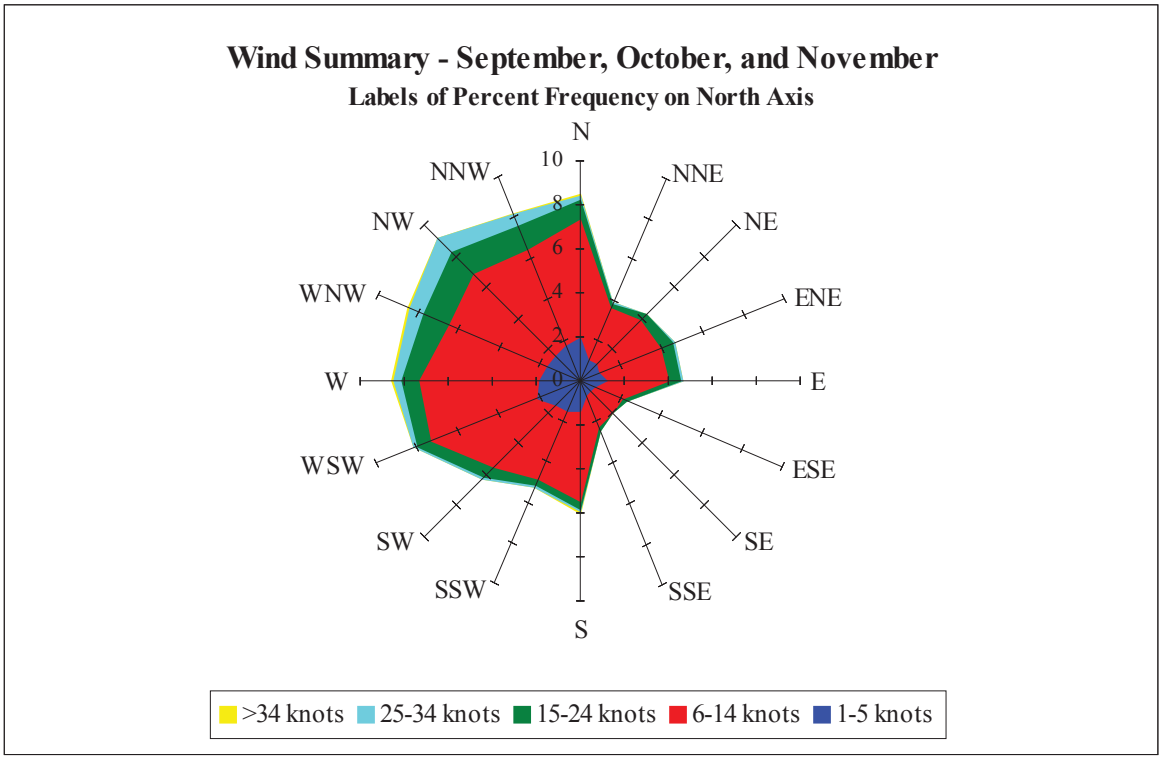
Percent Calm = 6.00



Percent Calm = 4.69



Percent Calm = 7.20



Percent Calm = 7.35

Appendix E

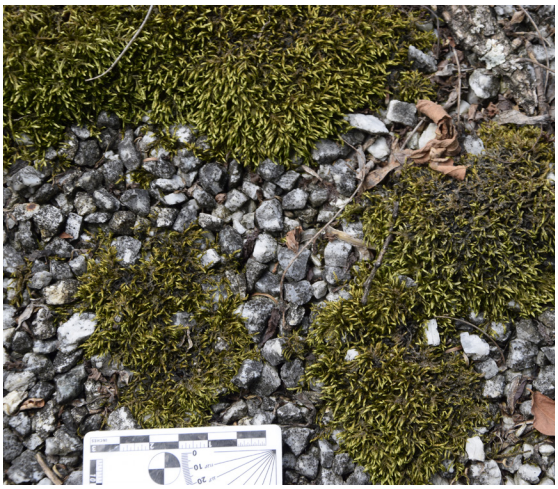
Conditions Glossary

Roofing system

Conditions

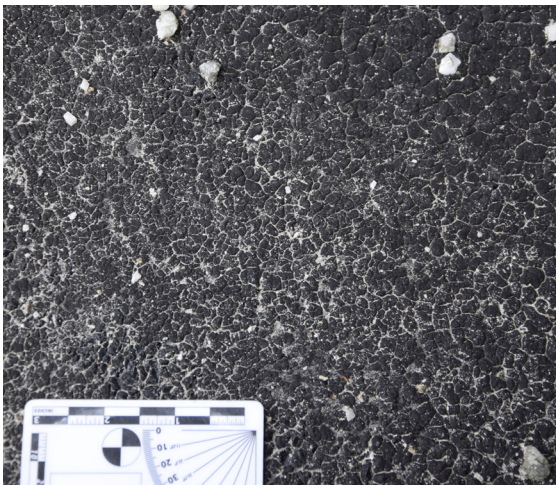
Biological Colonization

Presence of mosses and lichens on the roof slope contributing to moisture retention.



Asphalt Alligatoring

Asphalt exposed layer is deteriorated as a result of its exposure to UV radiation.



Clogged gutters

Presence of marble chips and leaves accumulated in the base of gutters contributing to poor drainage and water overflow.

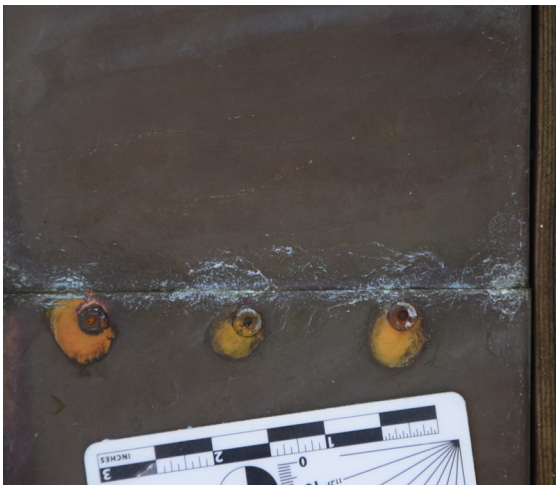


Roofing system

Conditions

Corrosion

Greenish-blue corrosion occurs in the flashing joints due to water retention and redox reactions.



Impact Damage

Elements show distress due to mechanical impact of fallen branches.



Open Flashing

Sections of copper sheets are out of plane because of lack of adhesion or insufficient adhesion.



Roofing system

Conditions

Active Leak

Moisture stains and wet surface from water seepage through the roofing system.



Plywood Deformation

Plywood board is bent and not flush with the contiguous boards.



Plywood Checking

Multiple hairline cracks or slightly open parallel splits of different length.



Roofing system

Conditions

Rib Crack

Single crack visible in rib joint.



Rib checks

Checks limited to the lower middle section of the rib.



Moisture Stain

Color alteration in the ribs because of exposure to moisture. Water source can be a leak in the past, exposure during construction, or water vapor that condesates.

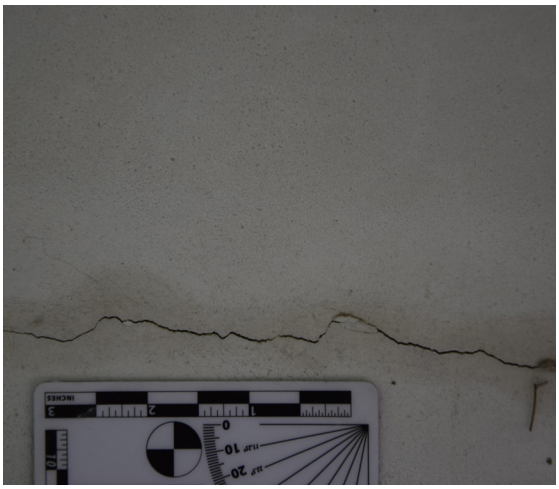


Rendered Concrete Block Masonry Wall

Conditions

Crack

Cracks of variable lenght with a width between 1/32 and 1/16 inch, primarily longitudinal along the bedding joint. It can be accompanied by calcium carbonate deposits.



Hairline Crack

Cracks in the stucco surface having widths so small as to be barely perceptible. Orientation may vary and they can intersect other cracks forming a pattern.



Mineral Accretion

Salts transported by water has evaporate and crystallized on the stucco surfaces forming mineral deposits in association with a reddish bronw stain.



Rendered Concrete Block Masonry Wall

Conditions

Soiling

Water splash deposited soil particles upon the rendered surfaces creating a thin brown film disrupting the aesthetics qualities of the white stucco.



Superficial Erosion

Increased surface roughness due to moisture infiltration and salt crystallization. Surfaces constrast with the smoother sour-rounding surfaces.



Previous Repair

Repair of eroded and cracked surfaces with a white cementitious material that shows a coarse-grain texture.



Stone Masonries

Conditions

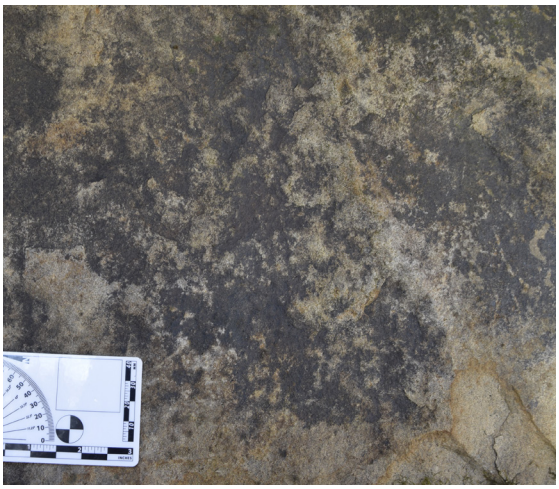
Efflorescence

Generally whitish, powdery salts crystallized on the surface. Efflorescences are generally poorly cohesive and commonly soluble salt. This condition has been observed in the exterior and interior walls.



Soiling

Deposit of a very thin layer of particles giving a dirty appearance to the stone surface. It may be a direct effect of earlier biological colonization with algae.



Insect Nest

Mud dauber wasps have constructed their nest on the stone surface. Nests are also localized on other substrates in the other areas of the building.



Flaking

Scaling in thin flat or curved scales. The detachment is located near to the stone surface.



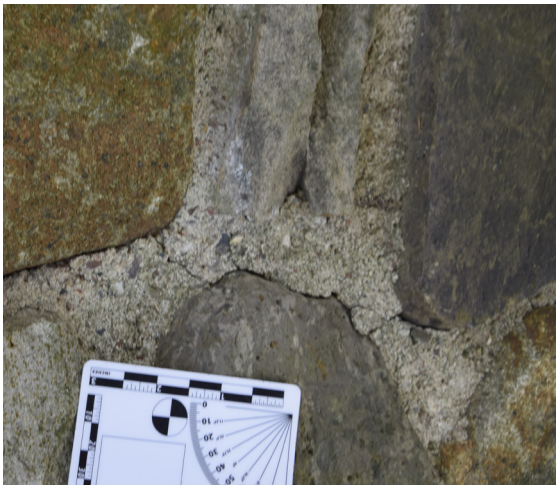
Blistering

Surface erupts into blisters and crumbles away leading to a loss of stone surface.



Hairline cracks

Thin cracks between mortar joints and stone units.



Biological Colonization

Presence of mosses, lichens, and algae on the stone masonry.



Concrete

Conditions

Hairline Crack

Cracks in the concrete elements having widths so small as to be barely perceptible. Hairline cracks show a variety of direction and can be accompanied by efflorescence or rust staining.



Rust Staining

Rust brownish red stains in a limited area of the concrete surface as a consequence of moisture intrusion and rebar corrosion.



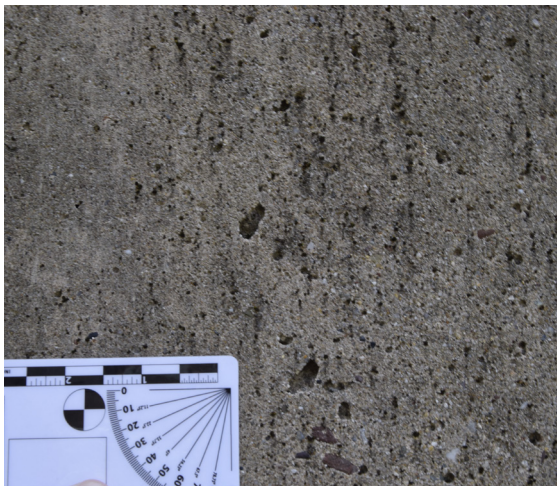
Honeycombing

Voids left in concrete due to poor mixing of the aggreagate and vibration during the placing process.



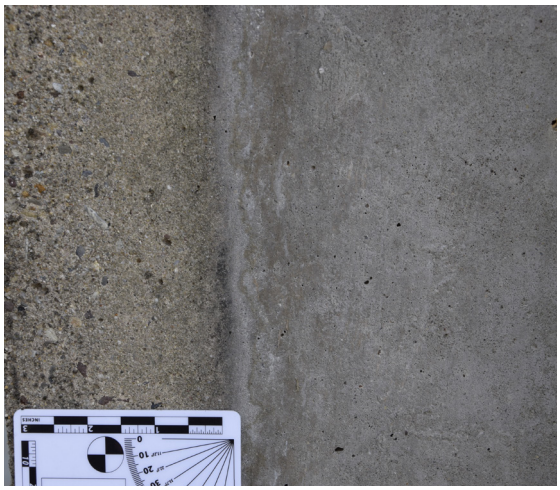
Bugholes

Small regular or irregular cavities as a result of entrapped bubbles during the placing process. Overall, they do not exceed 5/8 inch in diameter.



Superficial Erosion

Overall rough surfaces due to exposure to rainwater, which has dissolved the outer layer of the cement paste leaving the aggregate particles exposed.



Moisture Stains

Discoloration of the concrete surface as a consquence of temporary wetting episodes.

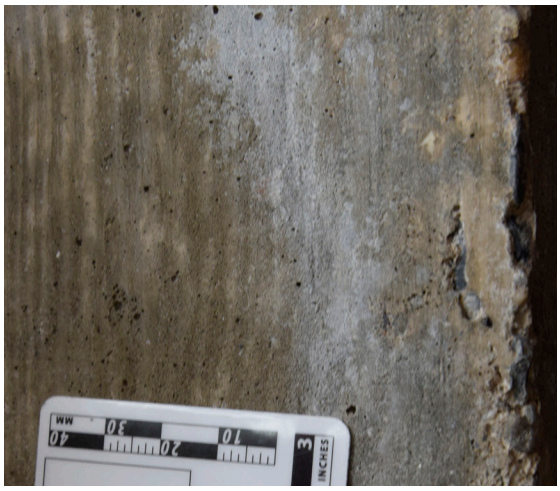


Concrete

Conditions

Efflorescence

A whitish deposit of salts crystallized on the concrete surface precipitated by carbonation or evaporation.



Biological Colonization

Presence of algae covering surfaces exposed to permanent moisture or regular wetting episodes.



Impact Damage

Mechanical damage on the outer surface of the concrete.



Concrete

Conditions

Ferrous materials

Installation of metallic elements by insertion in a concrete element.



Scratches

Mechanical damage to the outer surfaces of the concrete thus damaging the fragile woodprint pattern.



Stains

Color alteration due to cleaning and refinishing procedures in the loft.



Wood elements

Conditions

Rot

Areas of wood, showing color alteration, that have been attacked by fungus. These areas are soft and easily penetrable with an awl.



Checking

Longitudinal openings extending along the length of the wood member facitilitating moisture infiltration. Structural stability appears not to be comprosised though.



Moisture Stains

Uneven color alteration because of wetting episodes. Wood may be wet or dry.



Wood elements

Conditions

Natural Weathering

Wood surfaces showing the symptoms of slow degradation from a combination of natural factors: sunlight, moisture, temperature, chemicals, suspended particles carried by wind, and biological agents.



Scratches

Damages from animal activity, probably squirrels.



Previous repair

Holes perforated by woodpeckers repaired with the use of a brown epoxy resin.



Wood elements

Conditions

Woodpecker damage

Woodpeckers, probably attracted by carpenter bee activty, pecked holes on wood.



Fungal growth

Fungal growth on the undeside of the north railing on the terrace at the Arts Building. Photo by Ron Anthony.

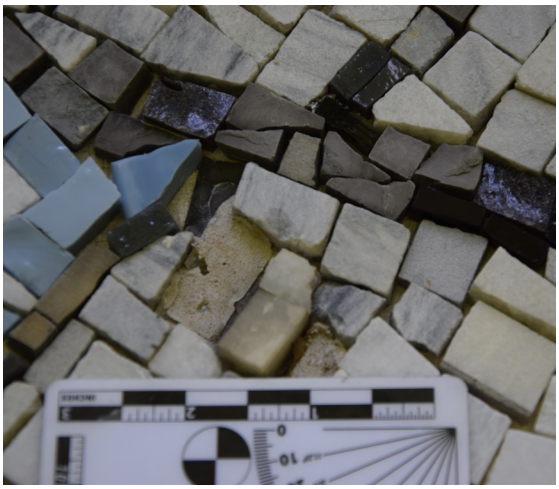


Mosaic

Conditions

Missing Tessera

Single or multiple tesserae have detached because of lack of adhesion between the tesserae and the substrate.



Granular Disintegration

Eroded and detached surface of tesserae.



Color Alteration

Discoloration due to the use of epoxy resin to adhere the tesserae and hide the screw heads fastening the mosaic to a wood substructure.



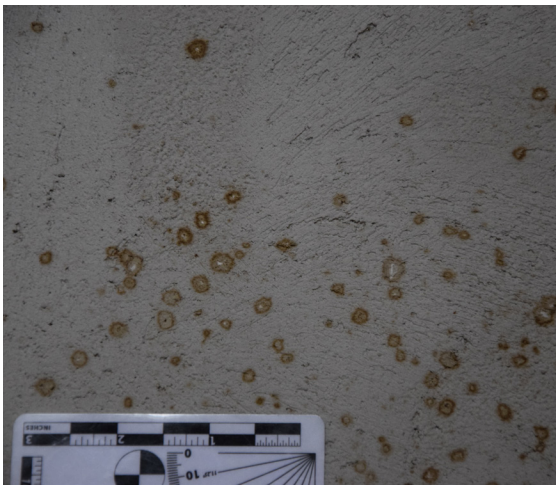
Biological Colonization

Microflora and soiling covering the lower section of the mosaic panels.



Spotting

Circular staining that might be related to the oxidation of metallic components in the Structolite™ or to an unknown chemical reaction between constituents.



Efflorescence

Chiefly whitish powdery deposit of salts crystallized on the plaster surface.



Moisture Stains

Color alterations of the surfaces caused by active leakage or past moisture infiltration.



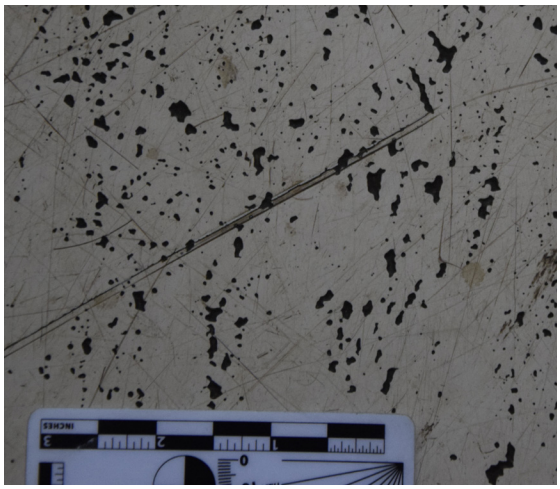
Fire Damage

Vinyl flooring has been damage by fire in the proximity to the fireplace hearth.



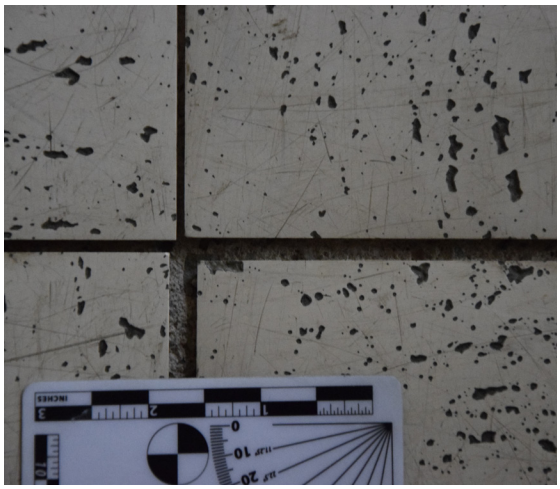
Wear

Scratches and superficial damage from visitation and use are visible on the vinyl flooring.



Tile shrinkage

The vinyl flooring presents a contraction in comparison to their original dimension due to sunlight exposure.



Flooring Materials

Conditions

Stains

Both stone pavement and vinyl flooring show stains as a consequence of catering activities. Also, it was visible stains related to water leaking from the wooden planters, which are usually placed indoors during the cold months.



Missing & Failing Joints

Joints in the Cave stone pavement show loose and are missing in some locations.



Scaling

Detachment of stone as a scale parallel to the stone surface. Presumably, the stone cannot withstand the high temperatures of a fire. Cracks are also visible.



Appendix F

Material Characterization

GRAVIMETRIC ANALYSIS OF ARTS BUILDING'S CHIMNEY MORTAR

New Hope, Pennsylvania

Prepared by Araba Prah, Nicole Declet, and Cesar Bargues

1. INTRODUCTION

A sample of joint mortar taken from the south elevation of the chimney at the Arts Building in New Hope, Pennsylvania was analyzed by gravimetric analysis in order to determine approximate ratios of aggregate, binder, and fines relative to the overall mortar. Results of this analysis will eventually inform the type of aggregates to use, as well as the choice of a compatible replacement mix for repair and repointing of the stone masonry as a part of the training program for Summer 2016. Essentially, mortars are composite materials comprised of binders, aggregates, water, and additives in various proportions. Gravimetric analysis of any mortar presumes that the bulk sample can be separated by mechanical and chemical action in order to estimate the ratios of these main constituents, to characterize the aggregates, as well as to determine possible type of binding agent (clay, gypsum, lime, hydraulic limes, natural and artificial cements).

Generally, the application of acid to the mortar samples will produce the acid digestion of all soluble components, while those constituents not susceptible to this process will remain. This can be chemically defined as the reaction of carbonaceous materials with the hydrochloric acid that produces chloride salts, water, and carbon dioxide. The soluble materials together with the remaining fines are believed to represent the binder. The ratio of binder and aggregates can be quantitatively measured by weighing the samples before and after acid digestion. The insoluble materials, aggregates and fines, can be separated by sieve analysis and their physical characteristics determined by qualitative and quantitative analysis, which include particle size, shape, color, and distribution.

The gravimetric analysis has proved to be a useful tool to replicate and specify compatible mortar replacements; however, the limitations of this technique need to be considered before its application. Calcareous aggregates and some silicates will also be dissolved by the action of hydrochloric acid, which, consequently, will affect the ratio of binder aggregate and will offer a misleading result. Other characteristics, such as the original water/binder proportion, the mixing and placing method, the rate of drying, and the cleanliness and condition of the aggregates, cannot be determined by implementing this methodology. Finally, as this analysis was performed for a

particular sample form the chimney mortar, it is not applicable for the rest of the stone masonries present at the Arts Building and other construction on the site.

2. METHODOLOGY

The mortar analysis and characterization was performed following the methodology established by the Architectural Conservation Laboratory at the University of Pennsylvania; particularly, "Experiment 12: Gravimetric Analysis of Mortars (Acid Digestion Method)" and "Experiment 01: Characterization of Granular Samples by Sieve Analysis", both in accordance with ASTM, professional and scholar recommendations.

On June 6, 2016, two members of the Architectural Conservation Laboratory took representative samples of the south and east chimney walls (about 100 grams). Samples were identical in color, texture, and hardness. No previous repair campaign was observed on site, and it is possible to conclude the locations relate to the original fabric as built between 1964 and 1967.

Half of the original sample, about 54 grams, was powdered using a clean ceramic mortar and pestle. The other half was kept separately for further examination and comparison with new mortar samples prepared for a possible repair project. A few traces of biogrowth and soiling could not be fully removed prior to analysis. It is probable this would have an impact on the color of the soluble. 14% hydrochloric acid was added to the sample in order to dissolve the binder and separate the fines from the aggregates. Throughout the experiment great care was taken to avoid measurement deviations and to ensure environmental conditions, such as temperature and humidity, could not affect the experiment. Precautions included keeping the ground sample and the resulting aggregates and fines in the oven and the desiccator throughout the experiment, which was performed in the span of a week. This would warrant comparable weights and minimum experimental error.

Resultant aggregate and fines were observed and characterized with the aid of a stereo binocular microscope and compared with sands in the reference library held at the Architectural Conservation Laboratory. Lastly, sand was sieved to determine the particle size distribution. Traces of iron were observed after acid digestion.

3. DATA AND OBSERVATIONS

Image Of George Nakashima's Arts Building Chimney Mortar Bulk Sample

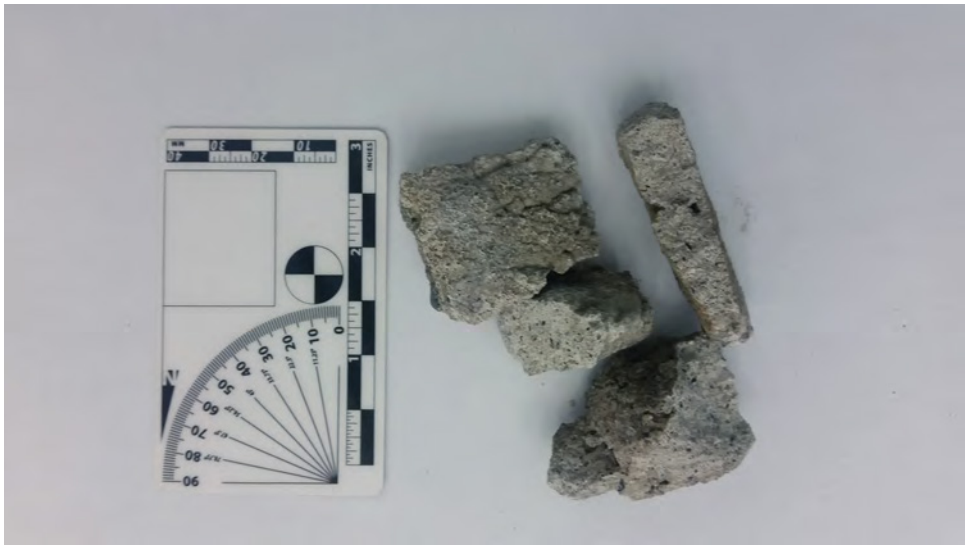


Image Of Ground Mortar Bulk Sample Prior To Acid Digestion



Table 5.1 - MORTAR COMPONENTS BY ACID DIGESTION									
	Dry powdered sample + container	Container	Dry powdered sample	Filter paper	Filter paper + dry fines	Dry Fines	Dry aggregate beaker	Dry aggregate + beaker	Dry aggregate
	M_0	M_C	M_1	M_2	M_3	M_F	M_{C1}	M_{C2}	M_4
Sample	**318.91**	**264.84**	**54.07g**	**3.91**	**7.34**	**3.43**	**264.84**	**299.65**	**34.81**

Site / Sample ID	NAKA_chimney mortar_south
Sampled by	Cesar Bargues and Araba Prah
Sampled on	6/6/16
Analyzed by	Cesar Bargues and Araba Prah
Analyzed on	6/8/16
Description	Mortar sample from Art Building chimney (exterior) above roof line
Appearance	Some soiling present on surface Aggregates of different colors visible
Snap Strength	Not possible to snap
Layering	Not visible
Bulk Color (Munsell)	2.5Y 8/1 white/light gray
Streak (Munsell)	2.5Y 8/1 white
Hardness (Mohs)	#4
Magnetic	None
	Sample fizzed when HCL solution was applied

NOTES & CALCULATIONS							
	Organics	**Magnetic**	**Reaction**	**Color**	**Weight (g)**	**% total weight**	**Weight ratio**
FINES	no	no	n/a	2.5 Y 7/2 light gray	3.43	6.12%	1:10
SOLUBLE	n/a	n/a	reaction with release of CO_2	cloudy, greenish	17.83	31.8%	3:10
AGGREGATE	no	YES	n/a	2.5 Y 7/2 light gray	34.81	62.08%	6:10

Table 5.2 -							
SIEVE TEST DATA							
ASTM Sieve Number	**Screen Size (µm)**	**Mass of container (g)**	**Mass of sample & container (g)**	**Mass retained (g)**	**Percent mass retained**	**Percent on or above**	**Percent Passing**
		M_c	**M_2**	**M_r** ($M_2 - M_c$)	**$\%M_r$** (M_r / M_s) *100%	**$\%M_{rt}$** **$\Sigma \%M_r$** (on or above)	**$\%M_{pt}$** 100% - M_{rt}%
8	*2360*	1.78	3.37	1.59	4.58	4.58%	95.42%
16	*1180*	1.72	5.35	3.63	10.45	15.03%	84.97%
30	*600*	1.73	7.88	6.15	17.71	32.74%	67.26%
50	*300*	1.76	13.6	11.84	34.09	66.83%	33.17%
100	*150*	1.74	9.77	8.03	23.12	89.95%	10.05%
200	*75*	1.89	4.33	2.44	7.03	96.98%	3.02%
PAN	*1*	1.72	2.77	1.05	3.02	100.00%	0.00%

Table 5.3					
AGGREGATE CHARACTERIZATION AFTER ACID DIGESTION					
SIEVE #	**SIZE (µm)**	**SPHERICITY**	**ROUNDNESS**	**SORTING**	**COLOR**
8	2500-7000	Medium	Angular to subangular	fair	2.5Y 6/2 Gray
16	1180-2360	Low	Very angular to angular	Well	2.5 Y 7/2 Light gray
30	600-1180	Low	Very angular to angular	Well	2.5Y 8/1 White
50	300-600	Low	Very angular to angular	Well	2.5 Y 7/1 Light gray
100	150-300	Medium	Very angular to angular	Well	2.5 Y 7/1 Light gray
200	75-150	Medium	Very angular to angular	Well	2.5 Y 7/1 Light gray
Pan	Less than 75	Medium	Very angular to angular	Well	2.5 Y 7/1 Light gray
Fines	Less than 75	Medium	angular	Well	2.5 Y 7/1 Light gray

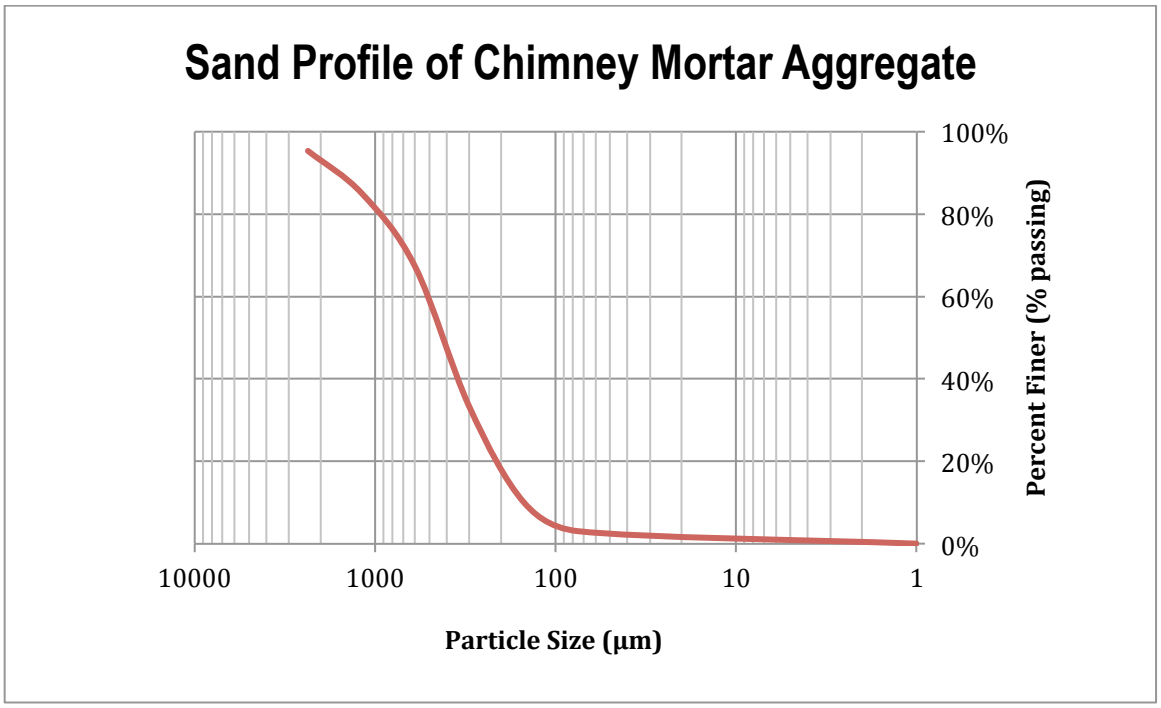
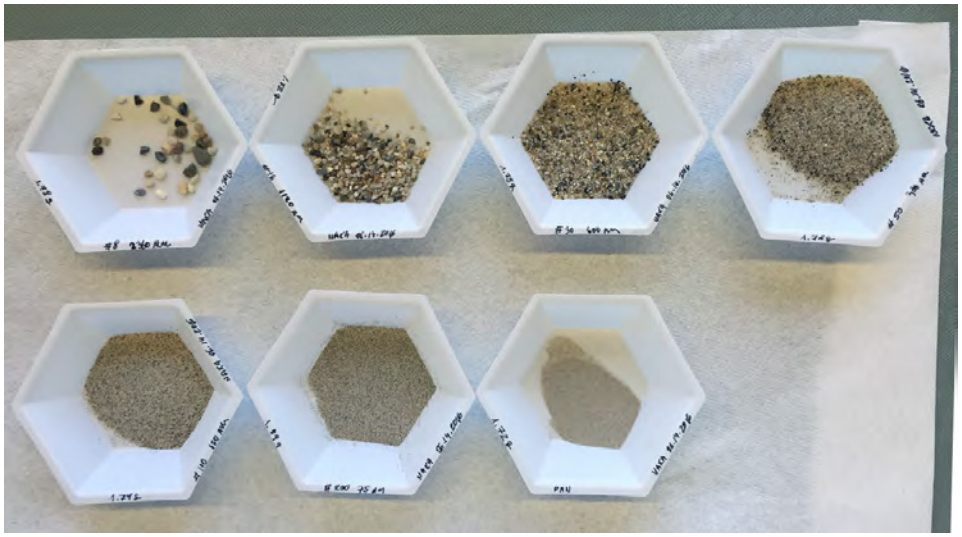


Image Of George Nakahima's Arts Building Mortar Aggregate After Sieving



5. DISCUSSION AND CONCLUSIONS

The experimentally determined ratios of aggregate to binder for the George Nakashima's Arts Building mortar was characterized to be approximately 1:10 fines, 3:10 soluble, and 6:10. The

reaction of the 14% hydrochloric acid with the powdered mortar sample confirms the existence of certain concentration of calcium carbonate, while the visual observation of a freshly broken piece of the bulk sample as well as its hardness suggests that the binder was a combination of lime and, probably, white cement portland.

According to the results, the following is a list of three sands selected from the Architectural Conservation Sand Library to prepare mock-up mortar samples:

i. Superior Rock Products: Mason Sand 77
ii. Hanson Aggregates Inc.: Type A Concrete Sand
iii. Hanson Aggregates Inc.: Mason Sand C-144

Of these three sands, the mix prepared with Hanson Aggregates Inc. Mason Sand C-144 proved the appropriate match for the repair work to be conducted at the chimney stone masonry and crown.

Image Of The Mortar Sample Prepared With Mason Sand C-144



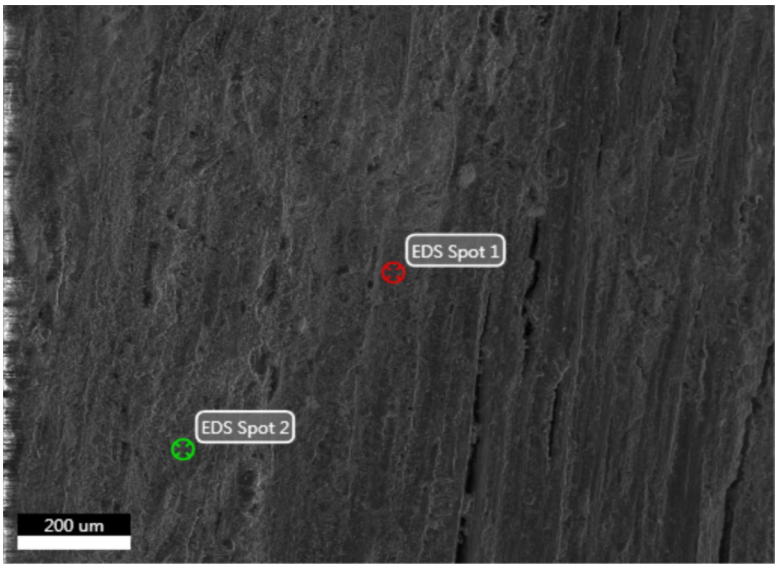
SEM-EDS analysis for translucent white finish on plywood ceilings and soffits

Matero

Author: prnuser
Creation: 12/21/2016

Sample Name: P1

Area 1

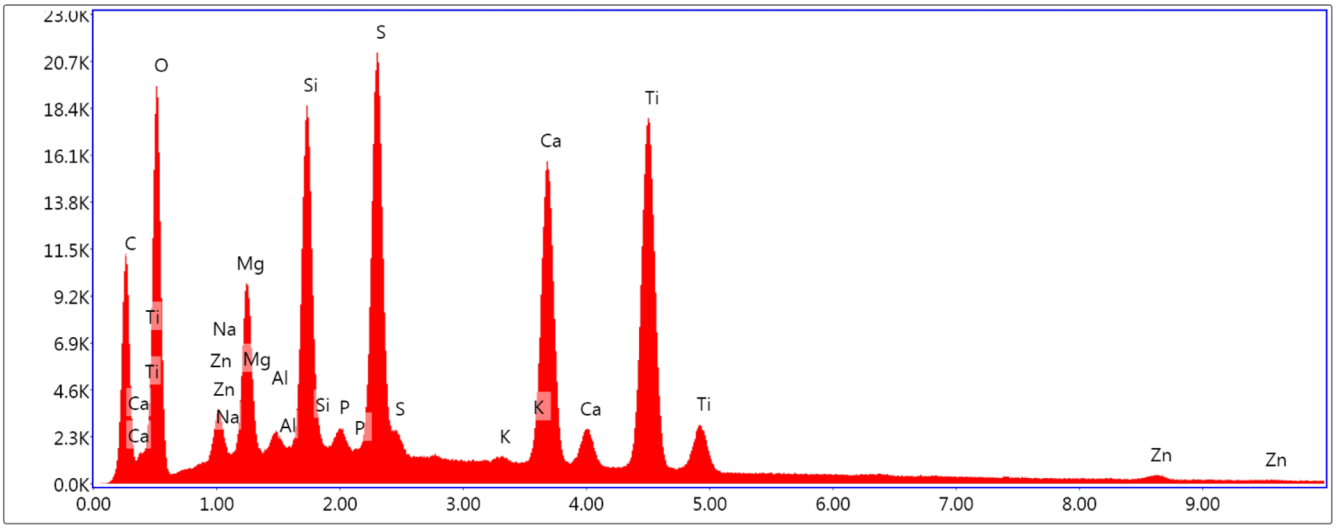


Notes:

EDS Spot 1

kV: 15 Mag: 200 Takeoff: 36 Live Time(s): 30 Amp Time(µs): 1.92 Resolution:(eV)134.

EDS Spot 1



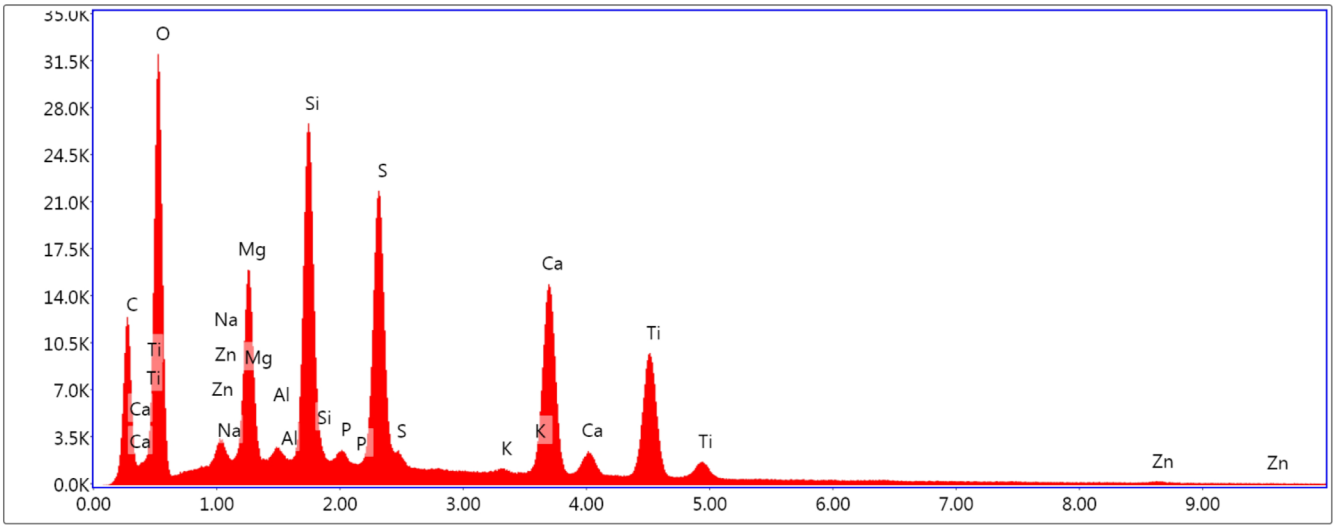
eZAF Smart Quant Results

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	16.57	28.87	1405.44	9.44	0.0458	0.0458	1.1305	0.9381	0.2444	1.0000
O K	33.16	43.38	4902.29	9.68	0.0654	0.0654	1.0784	0.9604	0.1828	1.0000
NaK	0.00	0.00	0.04	99.99	0.0000	0.0000	0.9757	0.9870	0.4499	1.0035
MgK	2.95	2.54	2422.41	5.76	0.0177	0.0177	0.9914	0.9947	0.6022	1.0056
AlK	0.31	0.24	291.00	7.69	0.0022	0.0022	0.9537	1.0018	0.7137	1.0099
SiK	5.41	4.03	5489.36	3.56	0.0434	0.0434	0.9737	1.0085	0.8139	1.0126
P K	0.67	0.45	548.03	4.89	0.0054	0.0054	0.9344	1.0148	0.8524	1.0207
S K	8.22	5.37	6988.38	2.69	0.0722	0.0722	0.9519	1.0207	0.9046	1.0200
K K	0.26	0.14	169.40	14.45	0.0025	0.0025	0.8987	1.0360	0.9642	1.0741
CaK	11.51	6.01	6024.29	2.34	0.1086	0.1086	0.9142	1.0402	0.9794	1.0534
TiK	19.34	8.45	7498.09	2.33	0.1595	0.1595	0.8268	1.0473	0.9763	1.0214
ZnK	1.61	0.51	112.04	18.20	0.0137	0.0137	0.7596	1.0410	0.9990	1.1255

EDS Spot 2

kV: 15 Mag: 200 Takeoff: 36 Live Time(s): 30 Amp Time(µs): 1.92 Resolution:(eV)134.

EDS Spot 2



Lsec: 30.0 0 Cnts 0.000 keV Det: Octane Super Det

eZAF Smart Quant Results

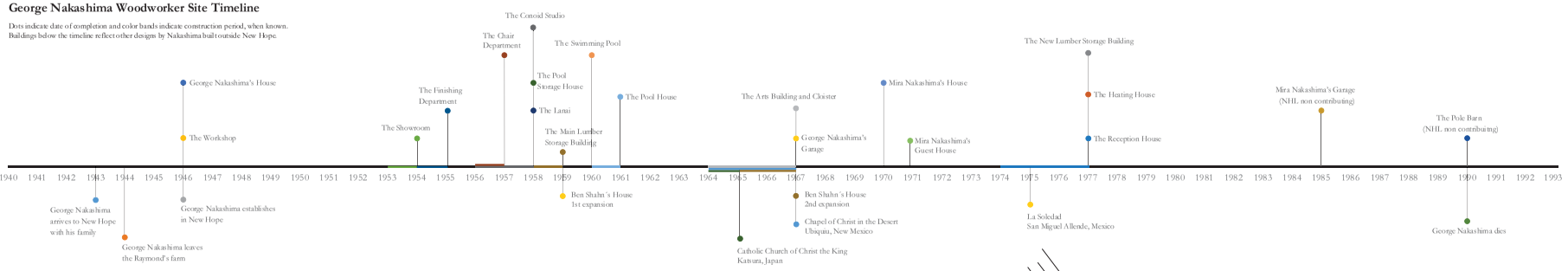
Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	18.04	28.81	1583.36	9.47	0.0463	0.0463	1.1042	0.9504	0.2323	1.0000
O K	39.93	47.89	7925.76	9.15	0.0948	0.0948	1.0524	0.9719	0.2255	1.0000
NaK	0.01	0.01	5.86	17.40	0.0000	0.0000	0.9515	0.9975	0.4758	1.0040
MgK	4.60	3.63	4322.34	5.30	0.0283	0.0283	0.9665	1.0048	0.6336	1.0059
AlK	0.41	0.29	421.16	6.29	0.0028	0.0028	0.9296	1.0116	0.7279	1.0106
SiK	7.35	5.02	8215.50	3.34	0.0583	0.0583	0.9489	1.0180	0.8252	1.0115
P K	0.58	0.36	513.27	4.92	0.0046	0.0046	0.9104	1.0239	0.8492	1.0188
S K	8.00	4.78	7340.95	2.67	0.0680	0.0680	0.9273	1.0295	0.9025	1.0168
K K	0.33	0.16	224.18	9.29	0.0029	0.0029	0.8751	1.0437	0.9647	1.0607
CaK	10.37	4.96	5799.40	2.26	0.0938	0.0938	0.8901	1.0476	0.9798	1.0368
TiK	9.61	3.85	4070.04	2.45	0.0777	0.0777	0.8047	1.0540	0.9790	1.0256
ZnK	0.77	0.23	60.21	20.71	0.0066	0.0066	0.7377	1.0439	1.0022	1.1573

Appendix G

Drawing Sheets

George Nakashima Woodworker Site Timeline

Dots indicate date of completion and color bands indicate construction period, when known.
Buildings below the timeline reflect other designs by Nakashima built outside New Hope.





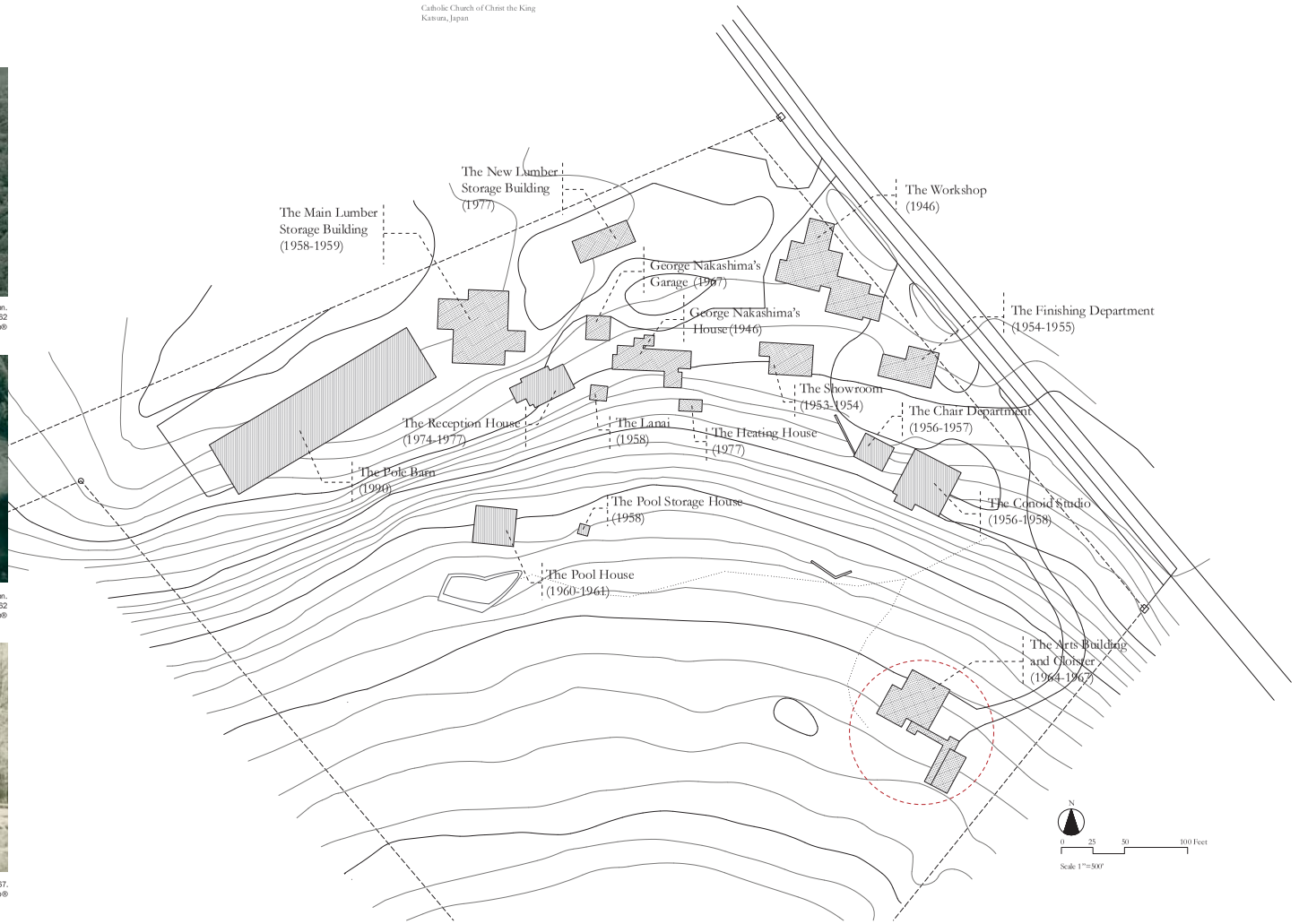
Aerial view of the property prior to the Arts Building construction.
Looking northward. Ca. 1962
Courtesy of Ezra Stoller/Esto®



Aerial view prior to the Arts Building construction.
Looking eastward. Ca. 1962
Courtesy of Ezra Stoller/Esto®



West elevation. George Nakashima in front of the Arts Building. 1967.
Courtesy of Ezra Stoller/Esto®



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace — 1847 Aquetong Road — New Hope, Pennsylvania

THE ARCHITECTURAL CONSERVATION LABORATORY
GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA

Frank Matero - Project Director
Jim Whitaker - Associate Director
Mills Ellington - Historical Research
Cesar Bargues Ballester - Project Manager

Delineators:
Cesar Bargues Ballester

Survey Date:
Based on site plan dated June 4, 1990

SHEET IDENTIFICATION
NAKA - A.01

SHEET DESCRIPTION
SITE PLAN OF
GEORGE NAKASHIMA WOODWORKER



South Patio in front of the Arts Building, September 2014



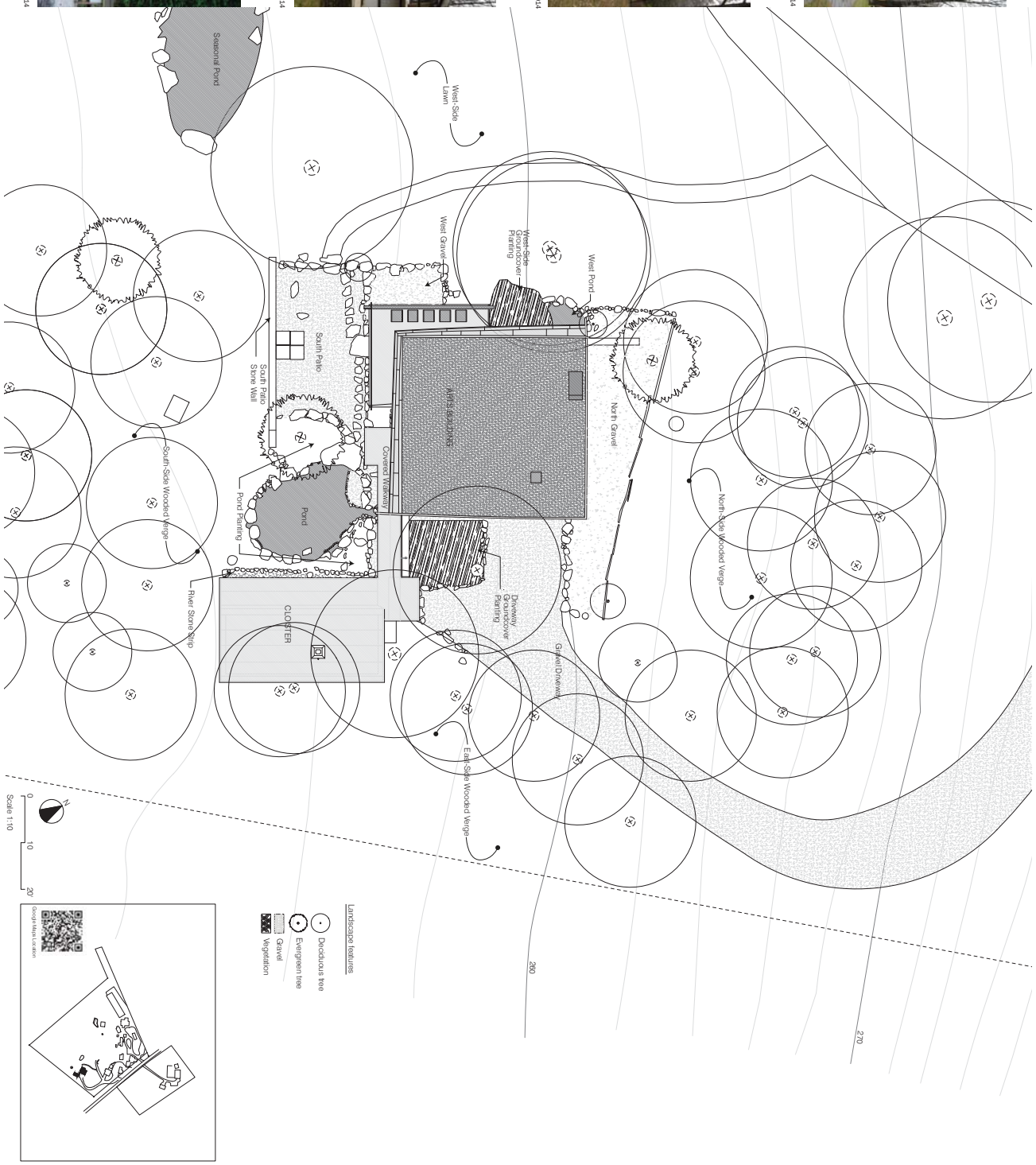
The Arts Building and the Studio in the background, December 2014



Rear view from road approaching the Arts Building December 2014



Rear view from pathway approaching the Arts Building - December 2014



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.02

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

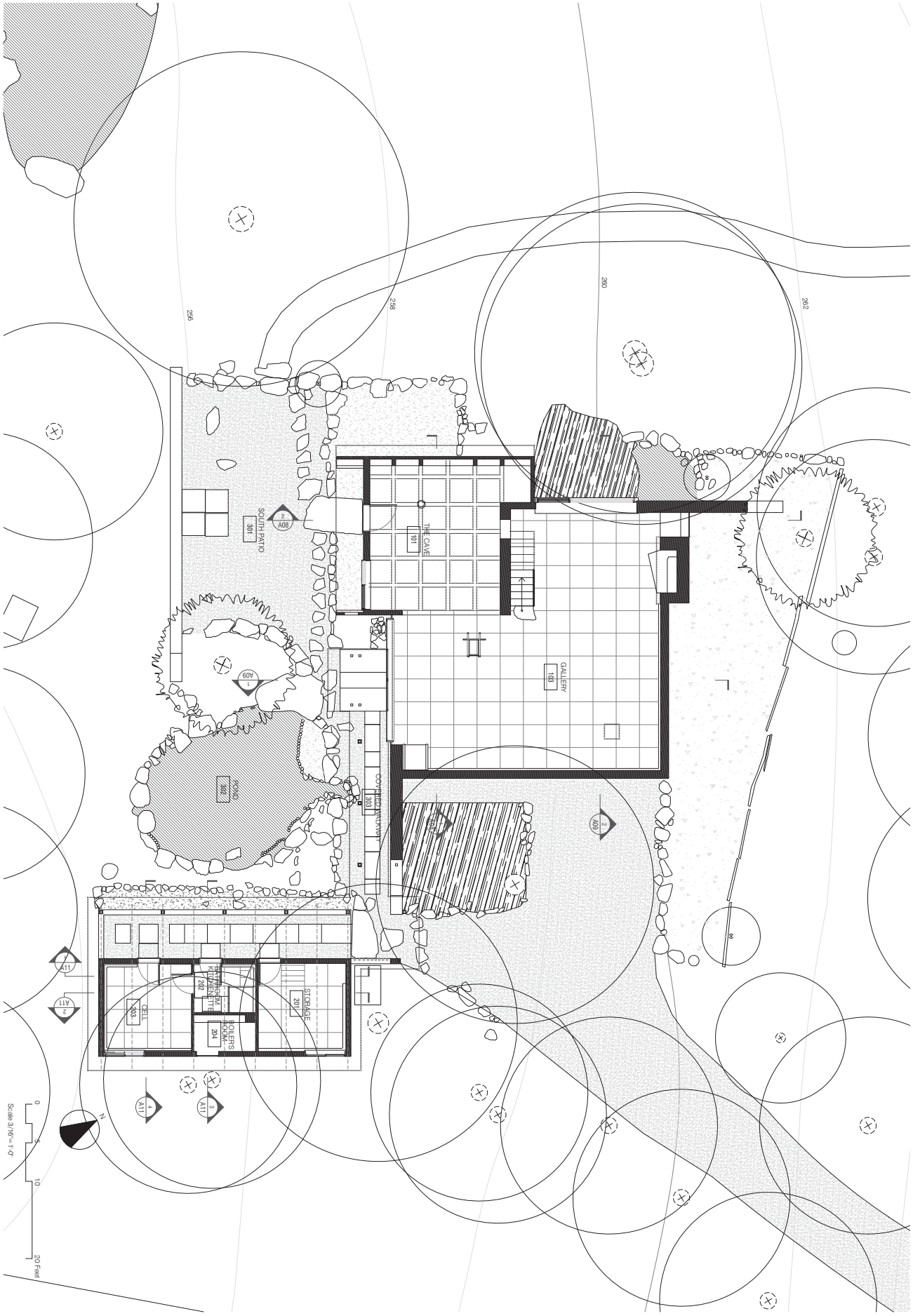
Nicholas Pevzner - Landscape Architect
Cesar Bargues Ballester

Survey Date:

Nicholas Pevzner, Jan. 2016

SHEET DESCRIPTION

THE ARTS BUILDING AND CLOISTER
SITE PLAN



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.03

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

Nicholas Pevzner - Landscape Architect
Cesar Bargues Ballester

Survey Date:

Building, Sept. - Dec. 2014
Landscape, Jan. 2016

SHEET DESCRIPTION

GROUND FLOOR



Building Detail, October 2015



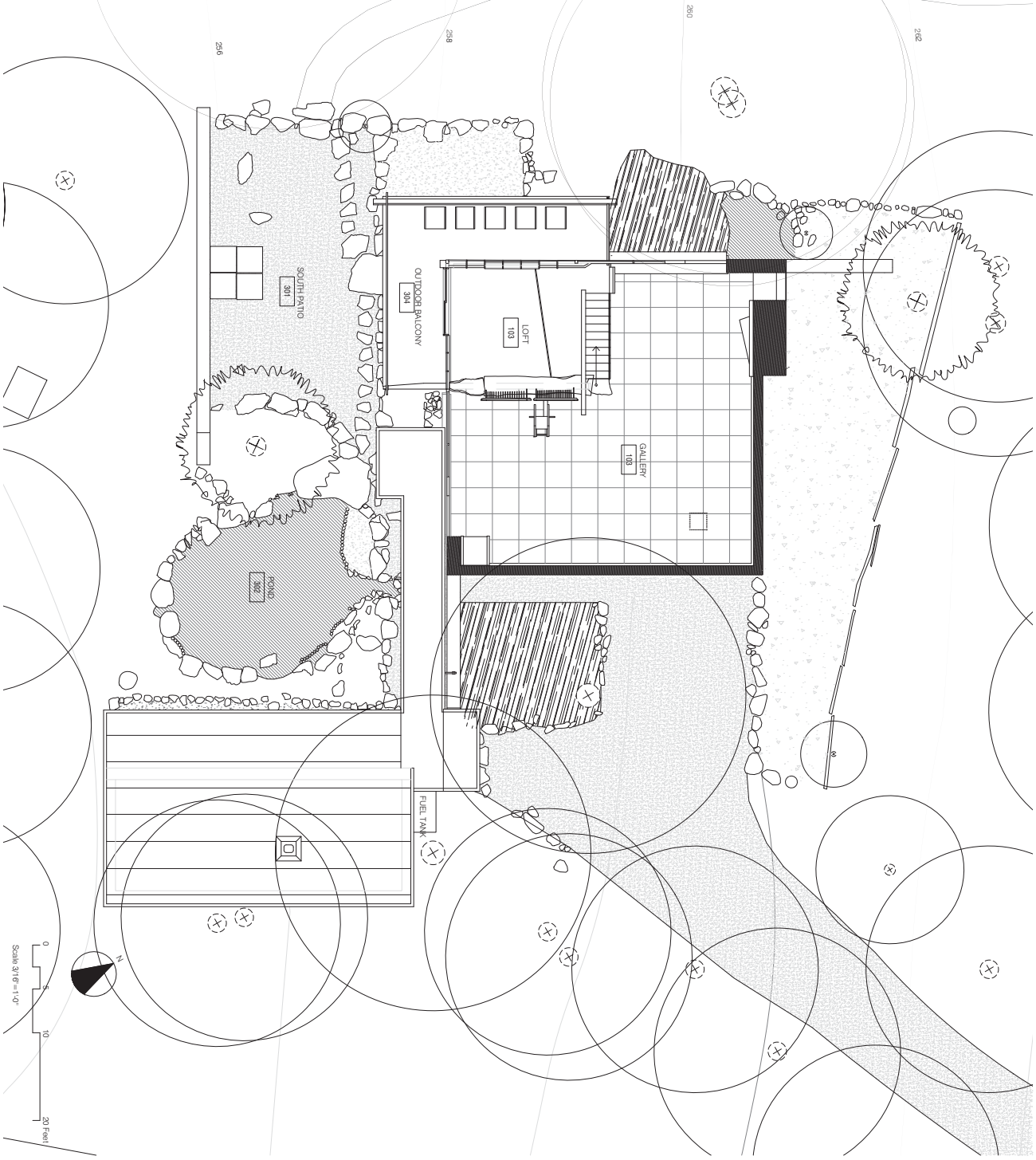
View from the Arts Building balcony towards the Cloister, October 2015



View of the covered walkway towards the Arts Building platform, November 2015



View of the balcony and access from the mezzanine, November 2015



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.04

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

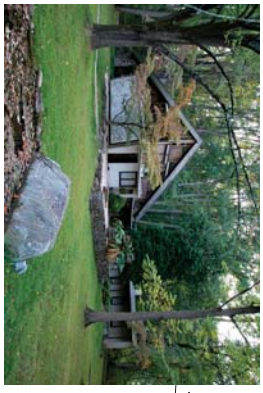
Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:
Cesar Bargues Ballester

Survey Date:
September- December 2014

SHEET DESCRIPTION

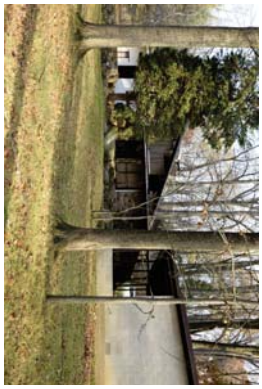
FIRST FLOOR



Exterior view of the Arts Building from the southwest. December 2014



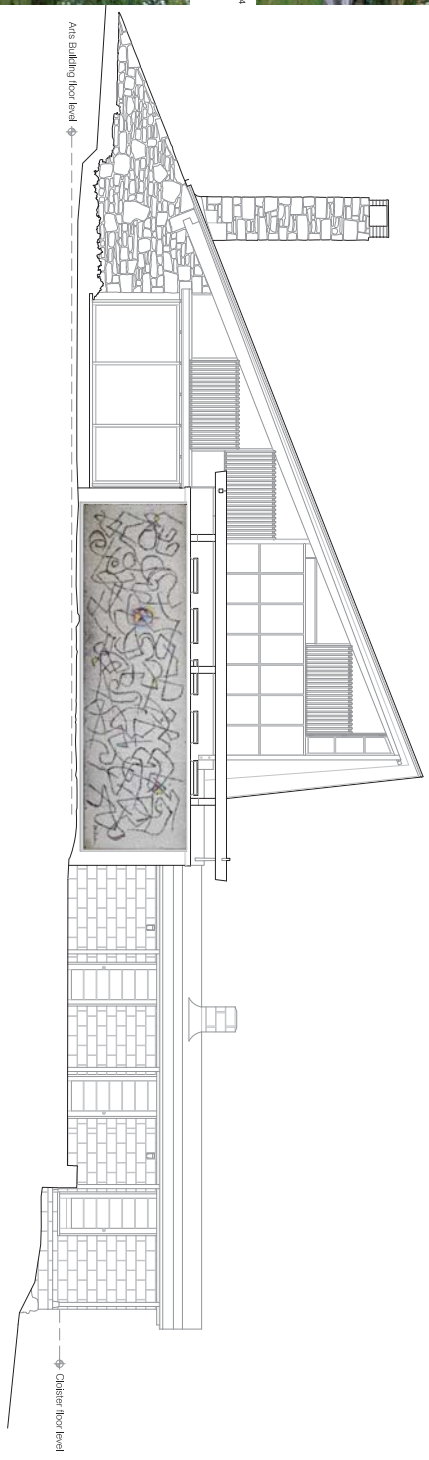
Exterior view of the Arts Building from the northwest. December 2014



View of the Arts Building and Cloister from southwest. December 2014



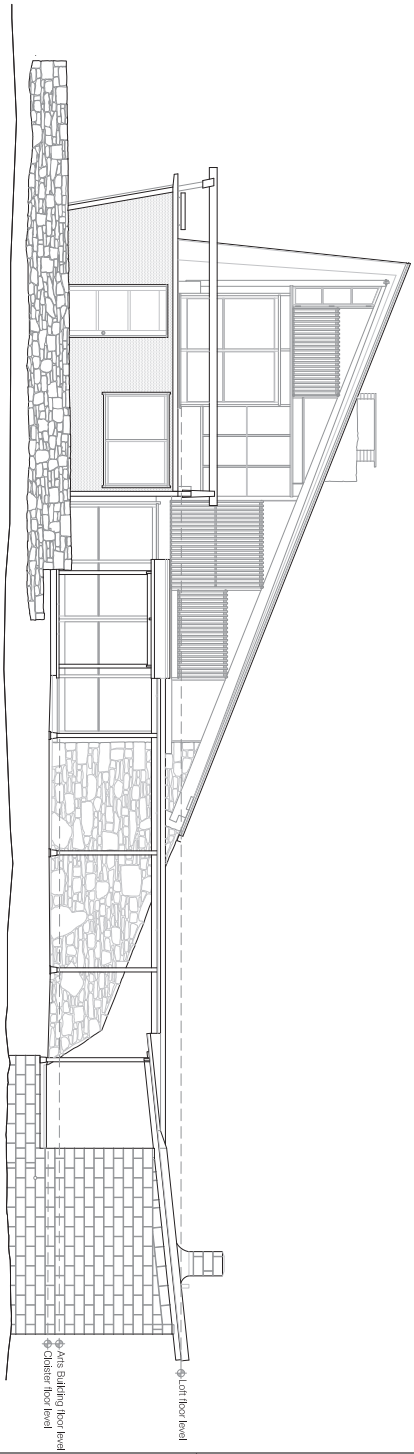
Exterior view of the Arts Building from the Cloister. December 2014



West Elevation

Scale 1/4" = 1 foot

0 1 3 6 12 Feet



South Elevation

Scale 1/4" = 1 foot

0 1 3 6 12 Feet

THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.05

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

Cesar Bargues Ballester

Survey Date:

September- December 2014

SHEET DESCRIPTION

SOUTHWEST AND NORTHWEST ELEVATIONS



The Cloister and the connection to the Arts Building, January 2015



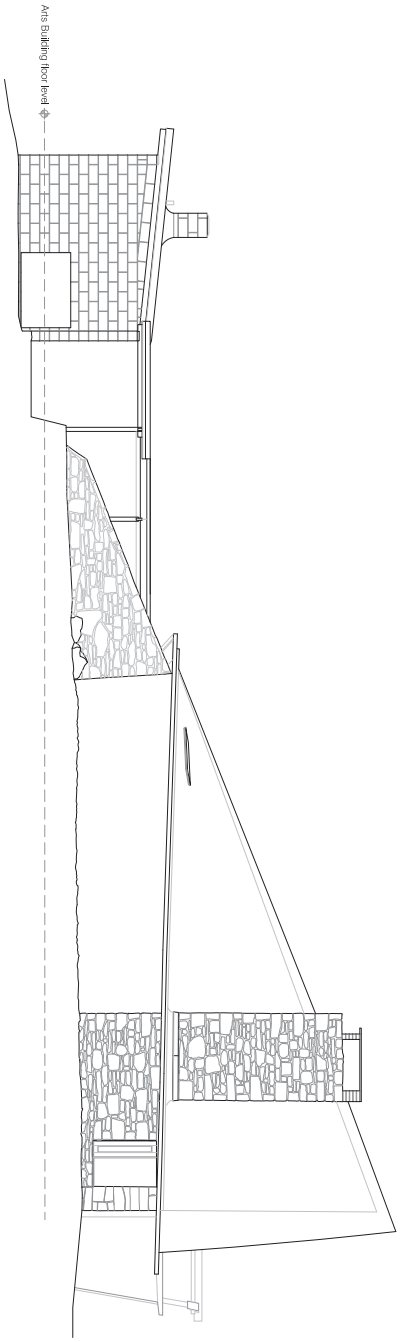
Exterior view of the Arts Building from the northeast, October 2014

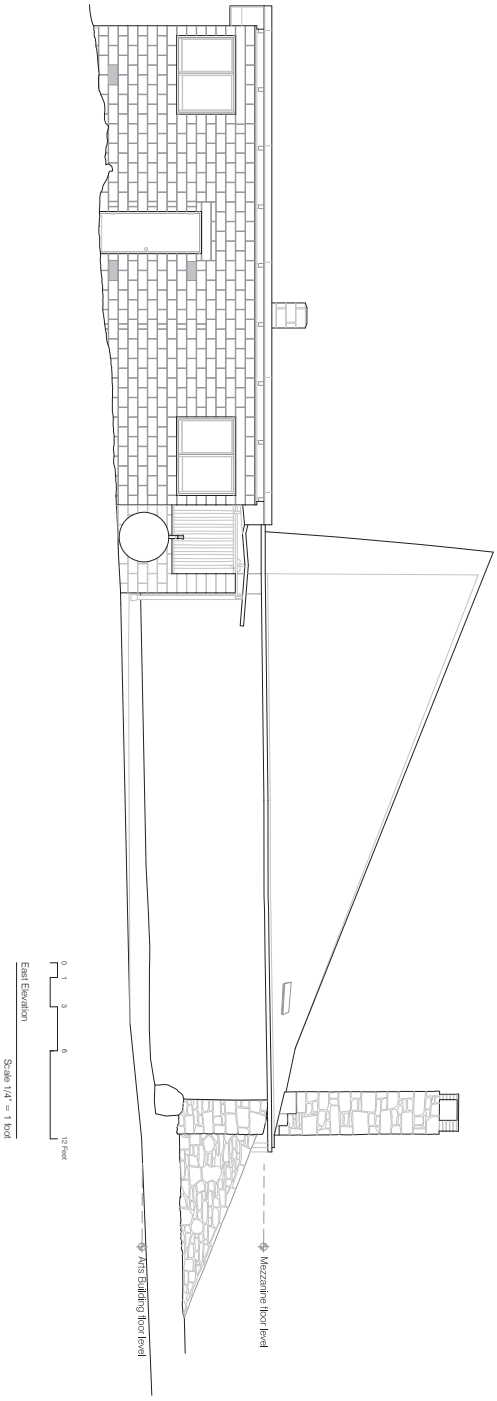


View of the Cloister from northeast, December 2014



Exterior view of the Arts Building from the northeast, September 2004





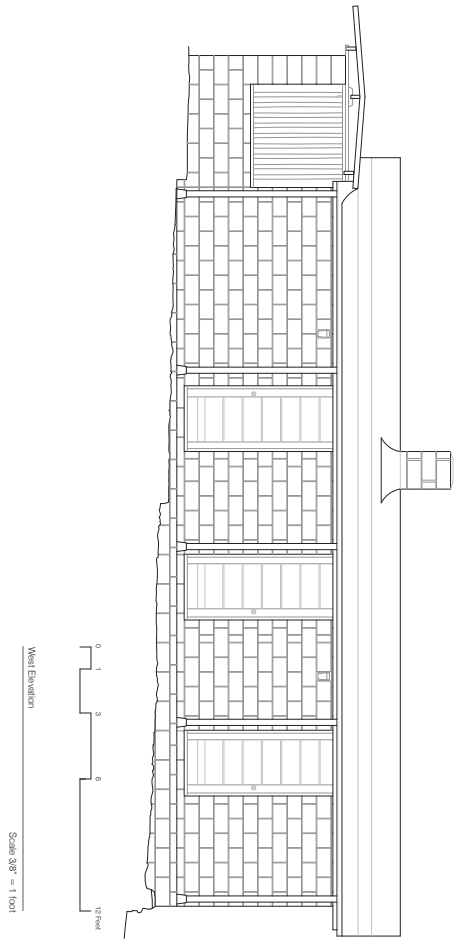
THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

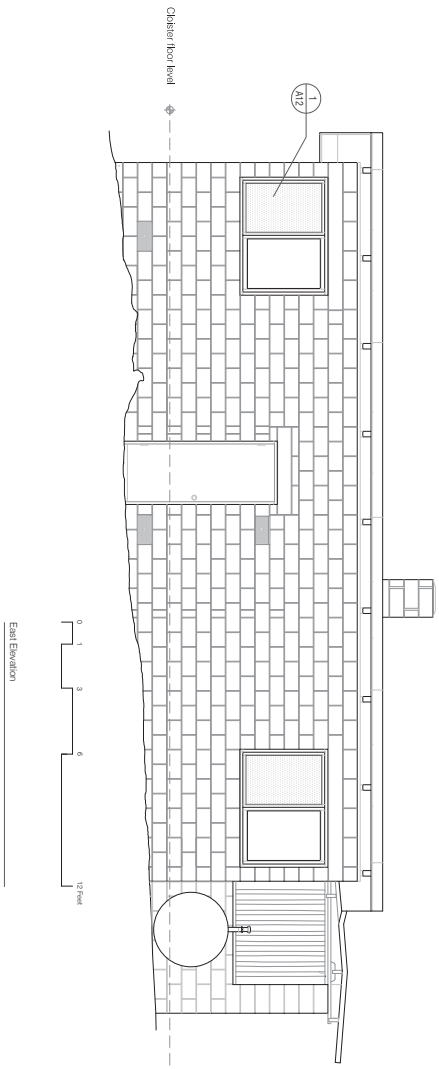
NAKA - A.06

THE ARCHITECTURAL CONSERVATION LABORATORY GRADUATE PROGRAM IN HISTORIC PRESERVATION SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA	Frank Matero - Project Director William Whitaker - Associate Director John Hinchman - Heritage Surveyor Cesar Bargues Ballester - Project Manager	Delineators: Cesar Bargues Ballester	Survey Date: September- December 2014	SHEET DESCRIPTION SOUTHEAST AND NORTHEAST ELEVATIONS



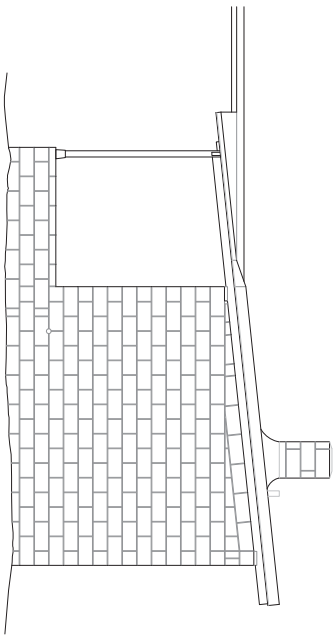
West Elevation

Scale 3/8" = 1 foot



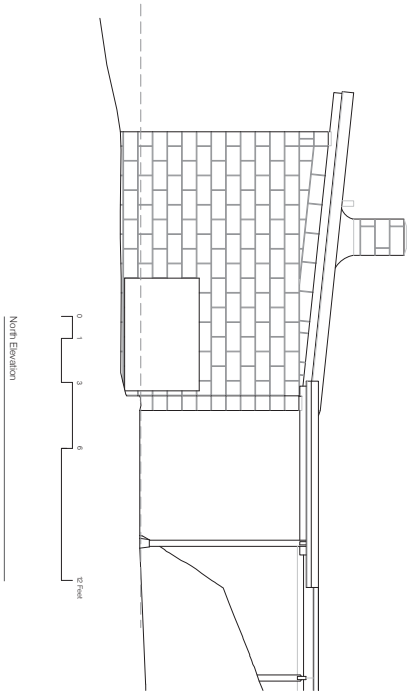
East Elevation

Scale 3/8" = 1 foot



South Elevation

Scale 3/8" = 1 foot



North Elevation

Scale 3/8" = 1 foot

THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.07

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

Cesar Bargues Ballester

Survey Date:

September- December 2014

SHEET DESCRIPTION

THE CLOISTER: ELEVATIONS



Interior view of the Cave. October 2014



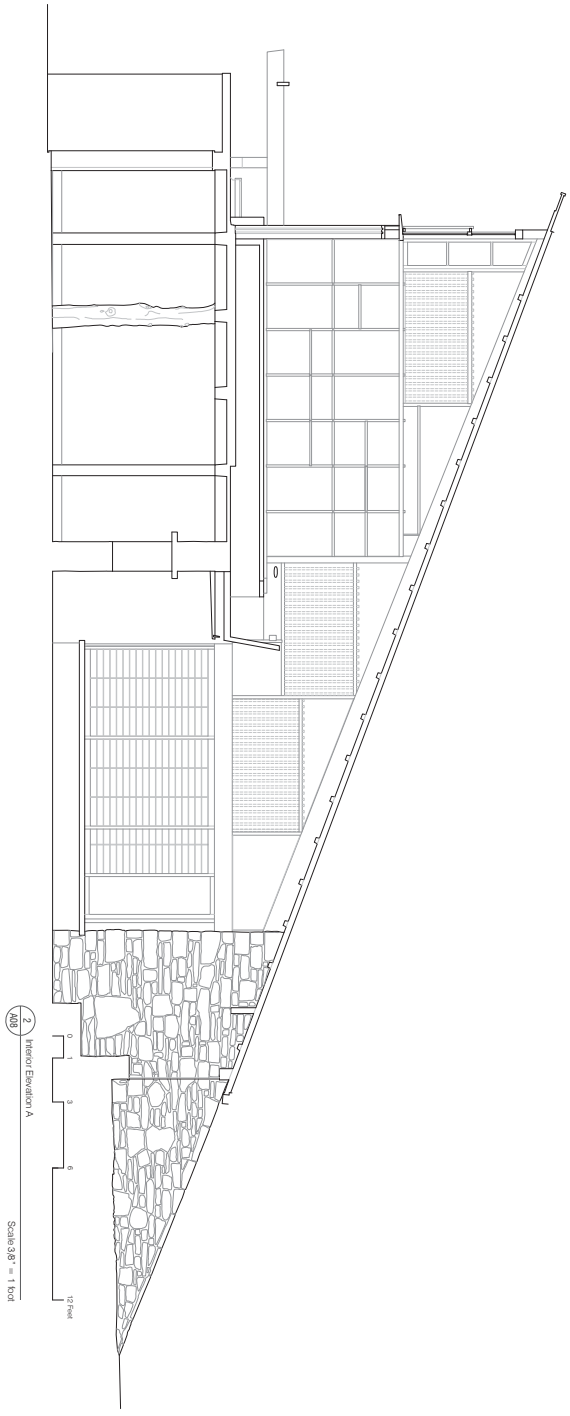
Cantilevered stairs and the Loft. September 2014

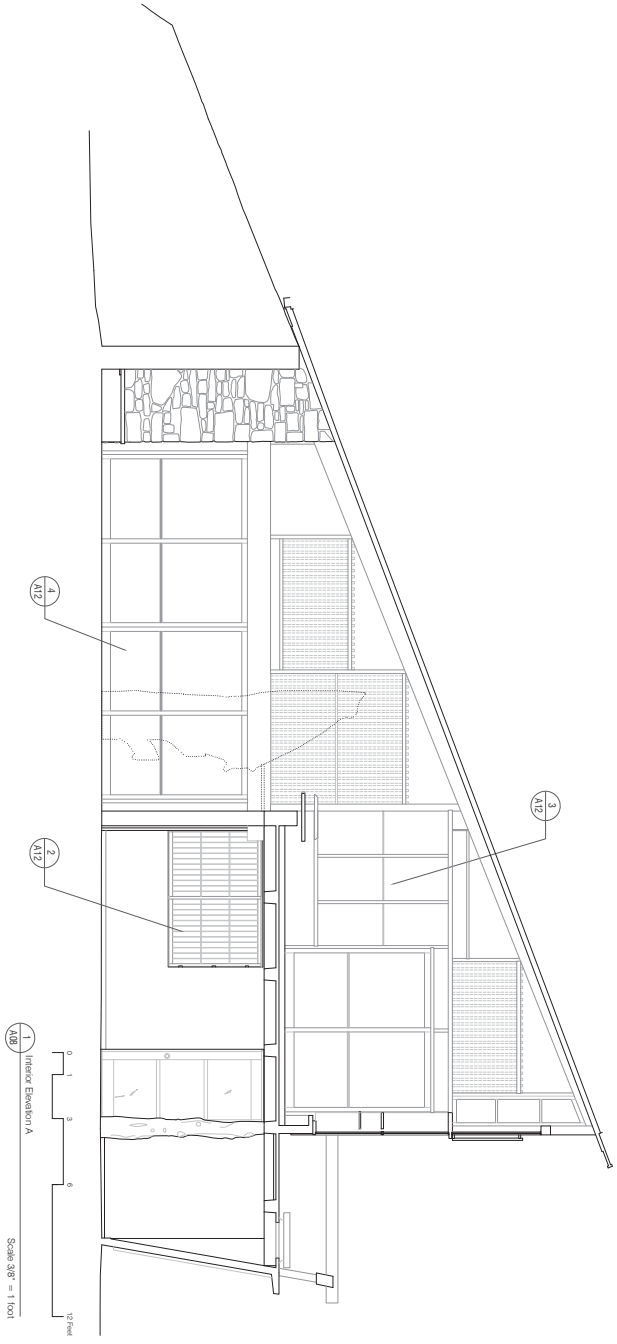


View towards the Cave and the Loft. May 2015



Interior view towards the south. May 2015





THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.08

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

Cesar Bargues Ballester

Survey Date:

September- December 2014

SHEET DESCRIPTION

THE ARTS BUILDING: INTERIOR ELEVATIONS



Interior view of the Arts Building along east wall. September 2014



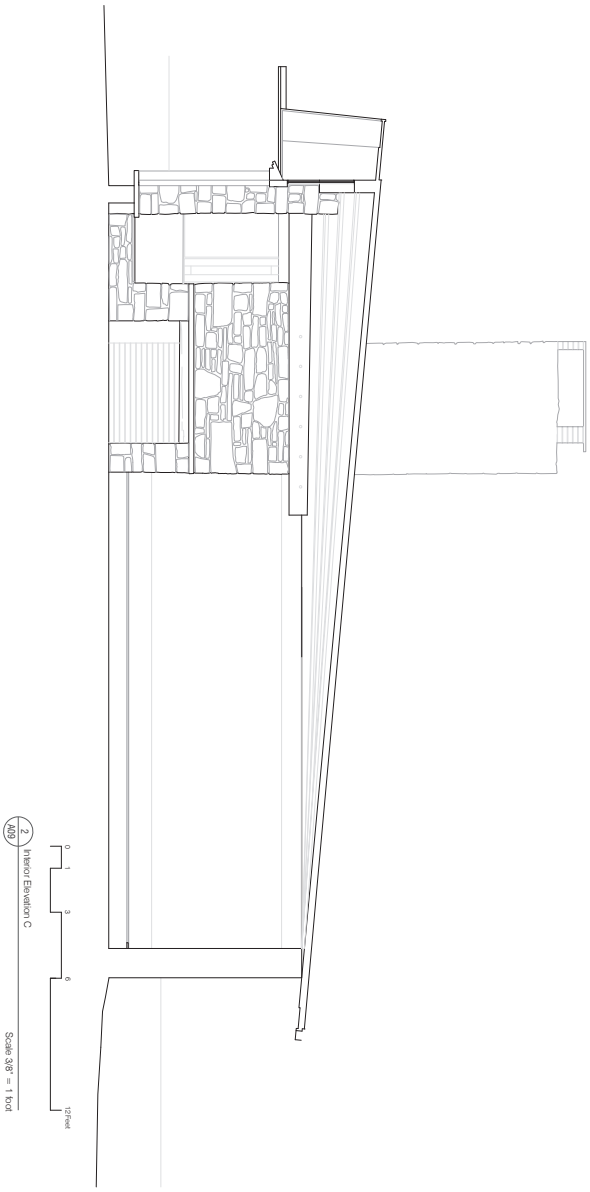
Interior view of the Arts Building. September 2014

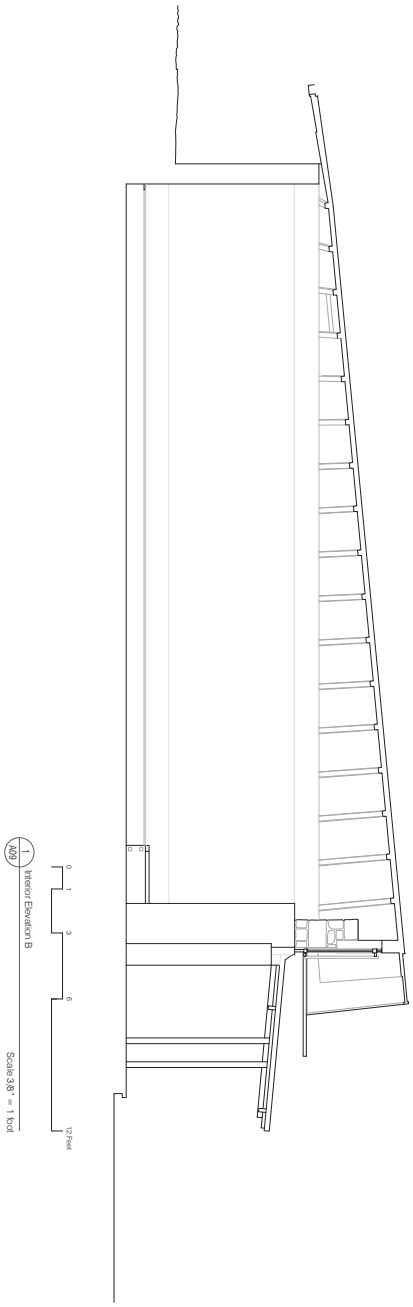


View of the fireplace area. October 2014



Interior view of the Arts Building. November 2014





THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.09

THE ARCHITECTURAL CONSERVATION LABORATORY GRADUATE PROGRAM IN HISTORIC PRESERVATION SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA	Frank Matero - Project Director William Whitaker - Associate Director John Hinchman - Heritage Surveyor Cesar Bargues Ballester - Project Manager	Delineators: Cesar Bargues Ballester	Survey Date: September- December 2014	SHEET DESCRIPTION THE ARTS BUILDING: INTERIOR ELEVATIONS



Exterior view of the Arts Building from the southwest, December 2015



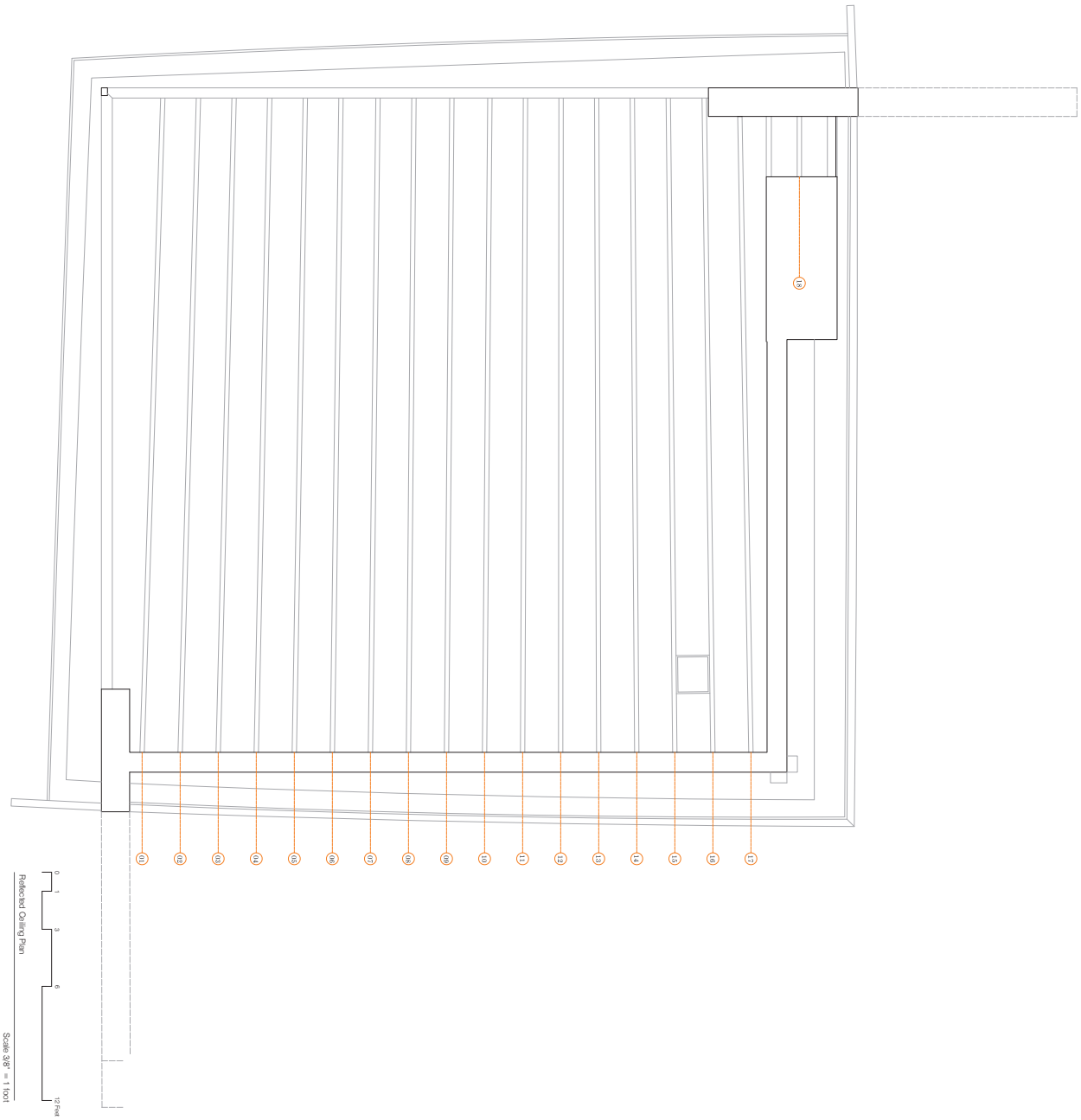
Exterior view of the Arts Building from the northwest, September 2014



Exterior view of the hyperbolic paraboloid roof upper corner, October 2014



Exterior view of the hyperbolic paraboloid roof upper corner, October 2014



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.10

THE ARCHITECTURAL CONSERVATION LABORATORY

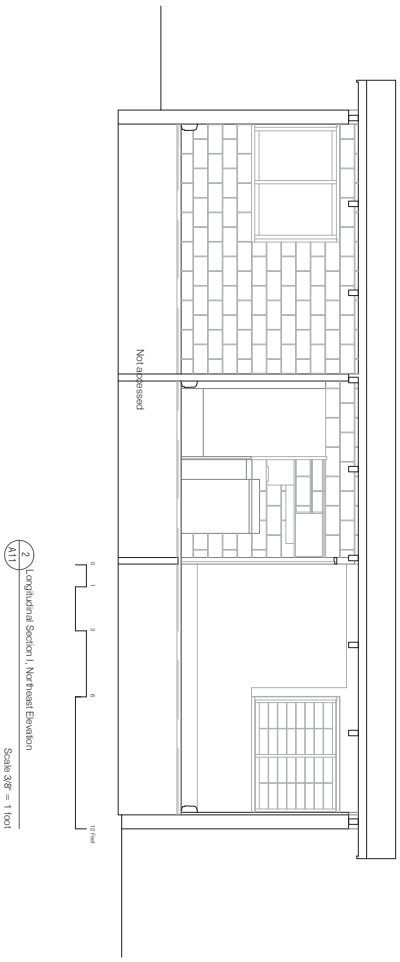
GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:
Cesar Bargues Ballester

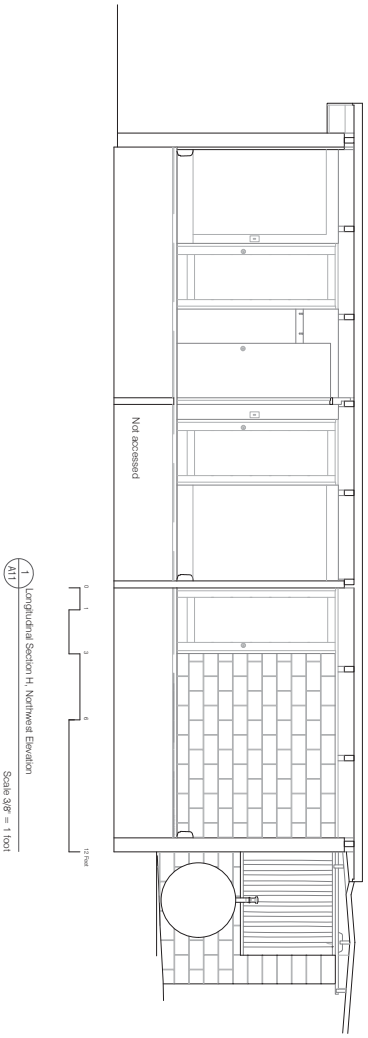
Survey Date:
September- December 2014

SHEET DESCRIPTION
THE ARTS BUILDING:
REFLECTED CEILING PLAN



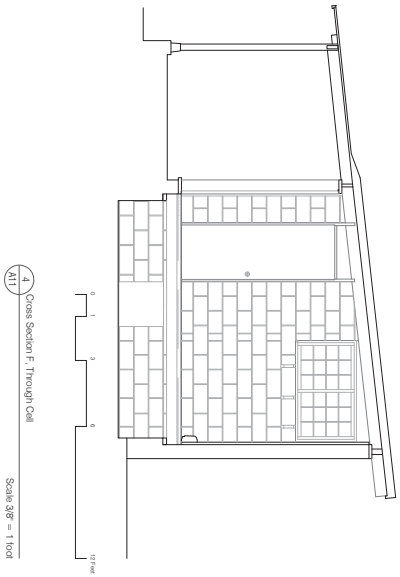
2 / A11 Longitudinal Section I, Northeast Elevation

Scale 3/8" = 1 foot



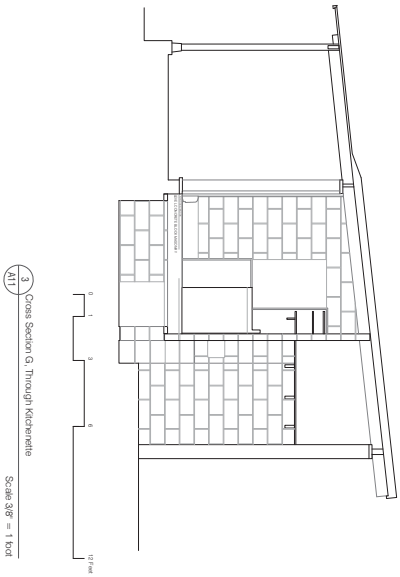
1 / A11 Longitudinal Section H, Northwest Elevation

Scale 3/8" = 1 foot



4 / A11 Cross Section F, Through Cell

Scale 3/8" = 1 foot



3 / A11 Cross Section G, Through Kitchenette

Scale 3/8" = 1 foot

THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.11

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

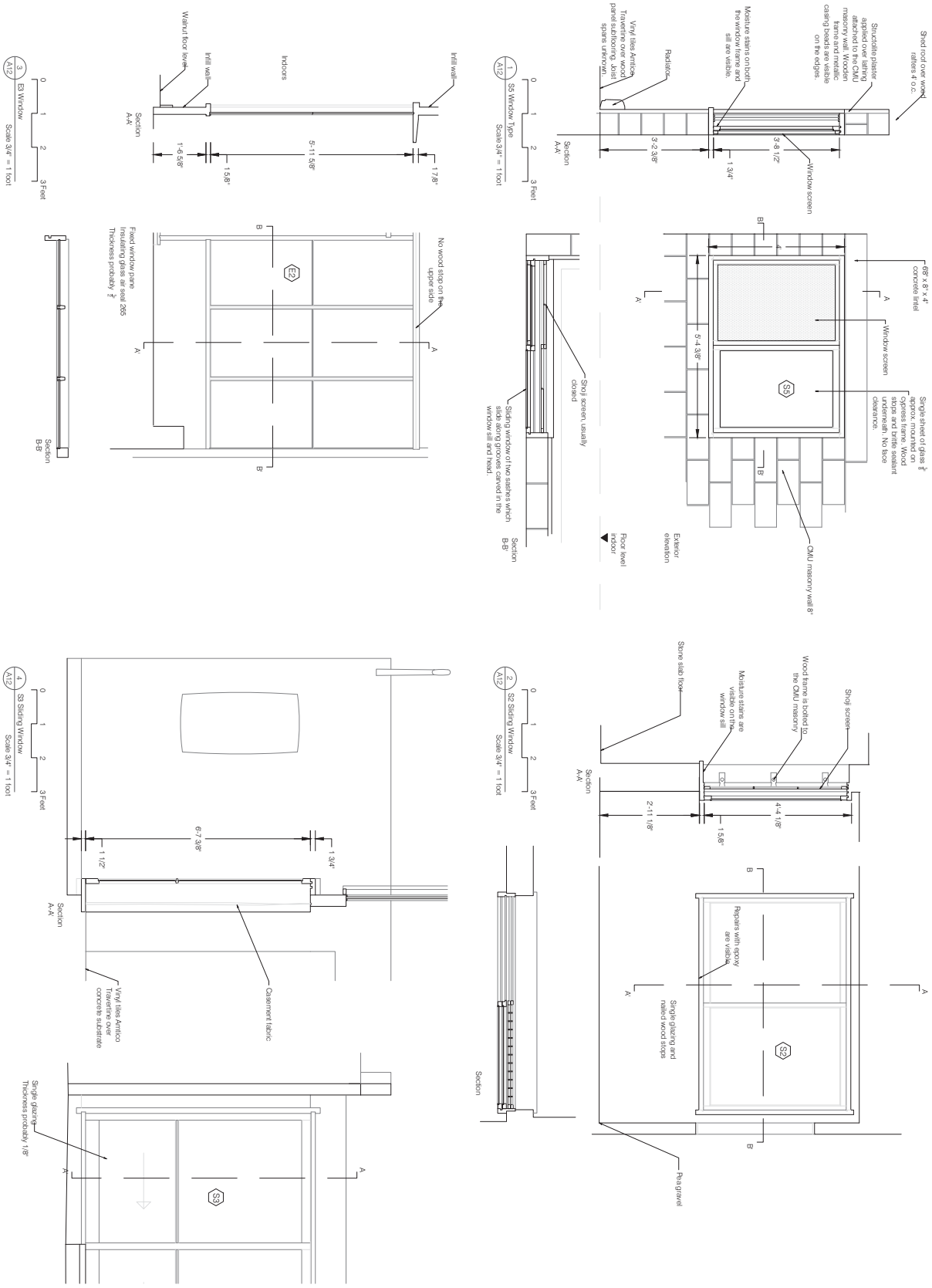
Cesar Bargues Ballester

Survey Date:

September- December 2014

SHEET DESCRIPTION

THE CLOISTER: SECTIONS



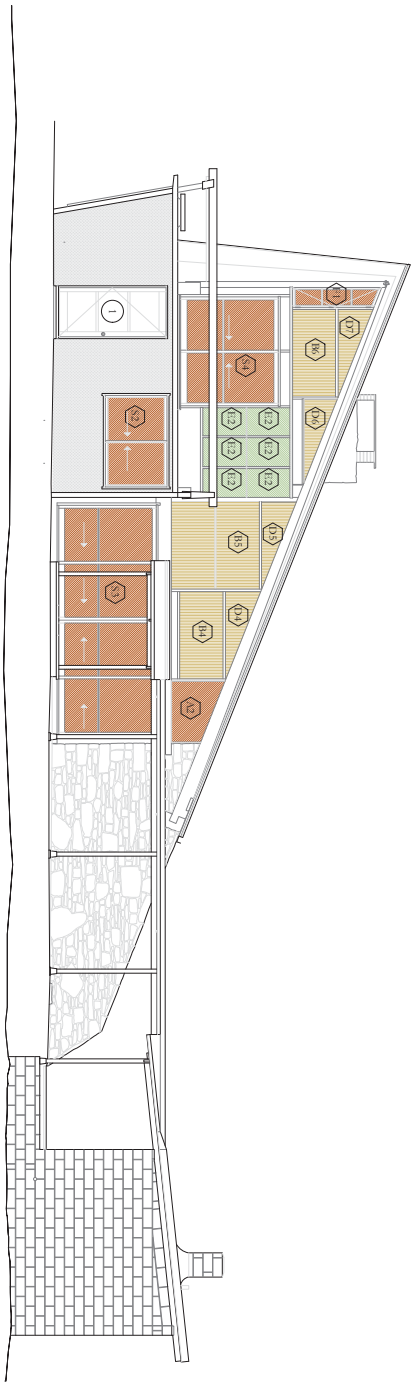
THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

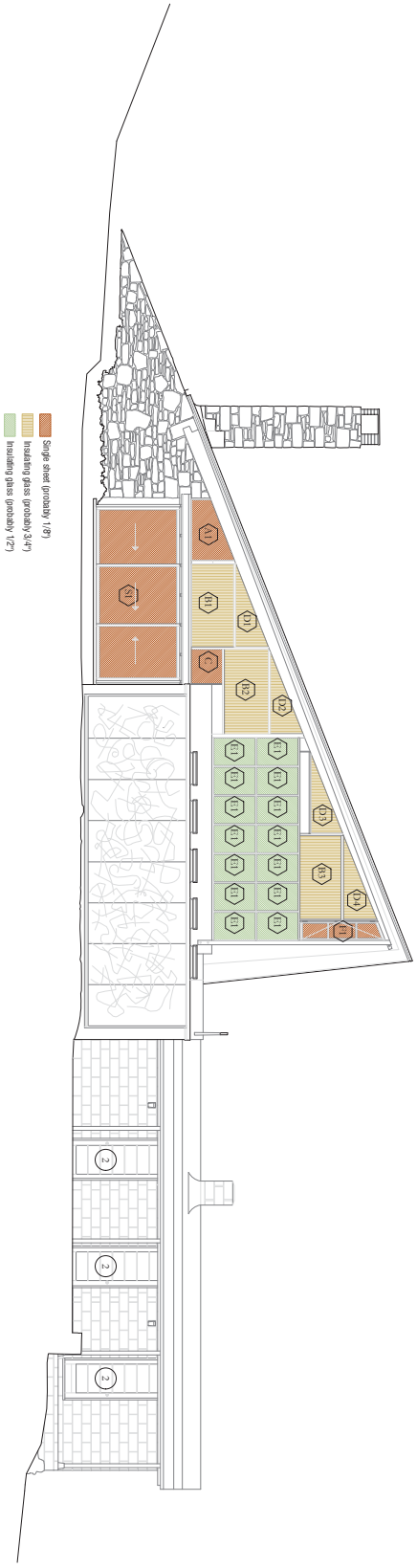
NAKA - A.12

THE ARCHITECTURAL CONSERVATION LABORATORY GRADUATE PROGRAM IN HISTORIC PRESERVATION SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA	Frank Matero - Project Director William Whitaker - Associate Director John Hinchman - Heritage Surveyor Cesar Bargues Ballester - Project Manager	Delineators: Cesar Bargues Ballester	Survey Date: September- December 2014	SHEET DESCRIPTION ARCHITECTURAL DETAILS



South elevation

Scale 1/4" = 1 foot



West elevation

Scale 1/4" = 1 foot

THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.13

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

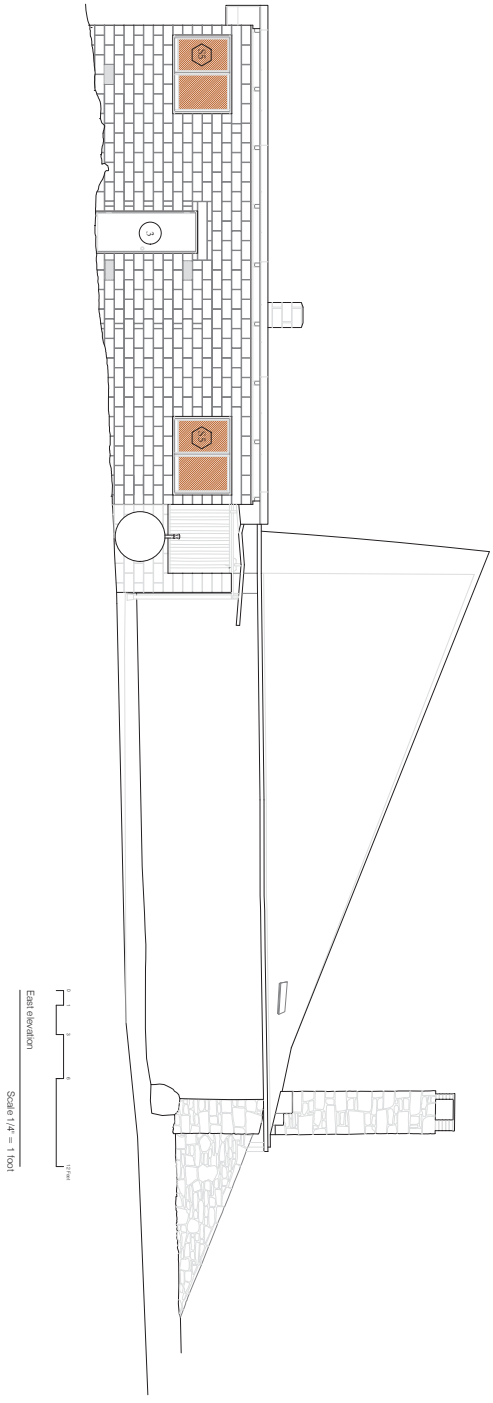
Cesar Bargues Ballester

Survey Date:

September- December 2014

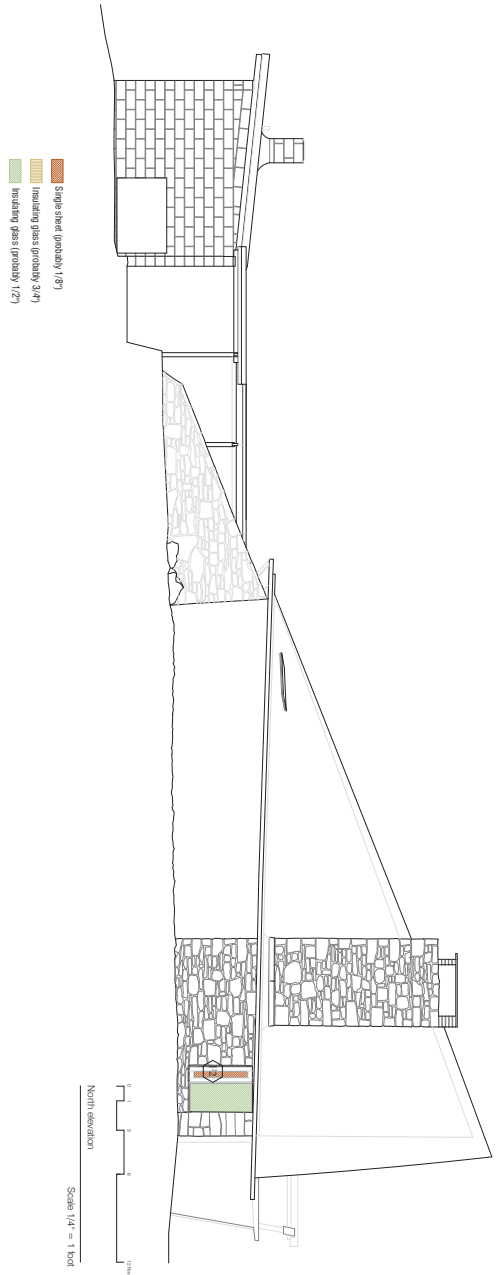
SHEET DESCRIPTION

WINDOW SCHEDULE:
SOUTHWEST AND NORTHWEST



East elevation

Scale 1/4" = 1 foot



North elevation

Scale 1/4" = 1 foot

THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - A.14

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

Cesar Bargues Ballester

Survey Date:

September- December 2014

SHEET DESCRIPTION

WINDOW SCHEDULE:
SOUTHEAST AND NORTHEAST



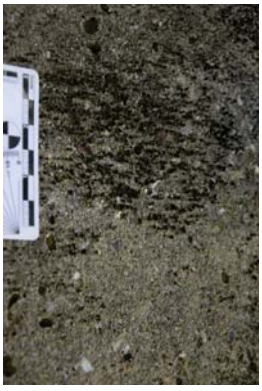
Rust stains.



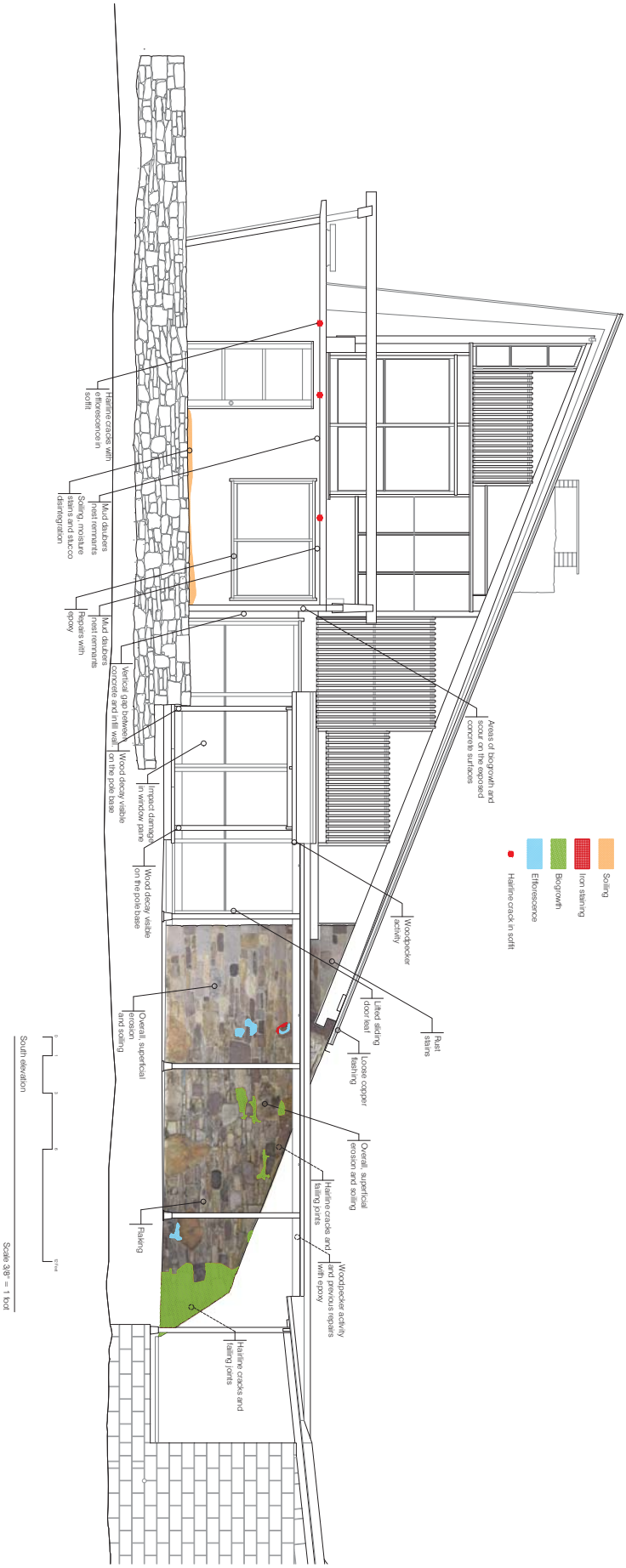
Darkened finish on the wooden elements. Note damage by squirrels



Efflorescence visible on stone masonry



Biological colonization and superficial erosion on the concrete surface



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - C.01

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:

Cesar Bargues Ballester

Condition Survey Date:

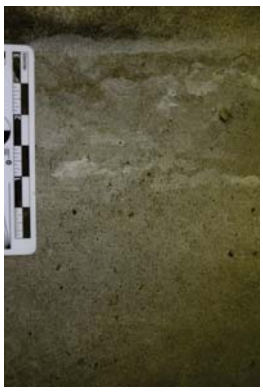
March 2015

SHEET DESCRIPTION

THE ARTS BUILDING: SOUTHWEST ELEVATION



Biological colonization and moisture stains visible on the exposed concrete surface



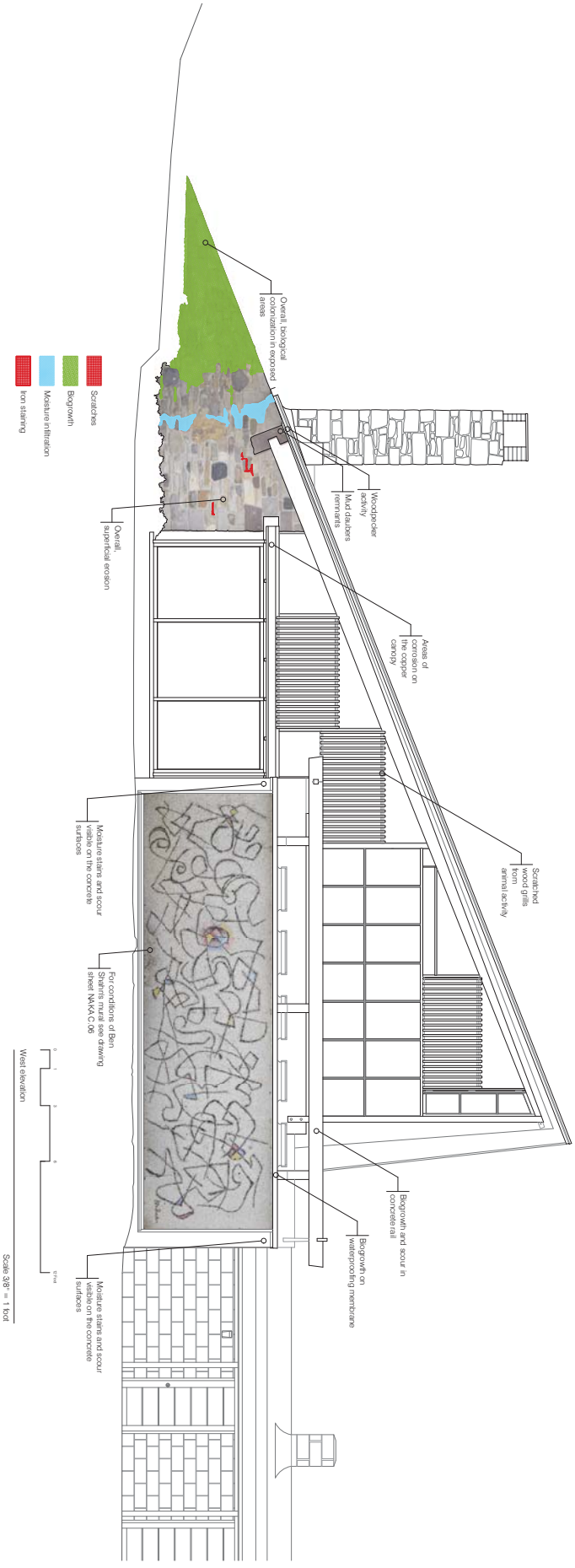
Close-up view of moisture stains on the concrete surface



Close-up view of the cypress grills on the west elevation. Note natural weathering and damage by squirrels.



Biological colonization visible on the stone masonry



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - C.02

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:
Cesar Bargues Ballester

Survey Date:
September- December 2014

SHEET DESCRIPTION

THE ARTS BUILDING: NORTHWEST ELEVATION



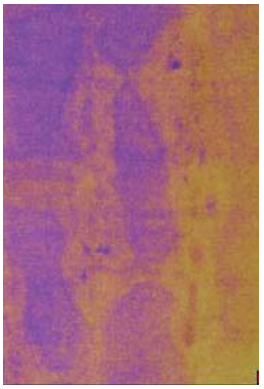
Hairline cracking and superficial erosion



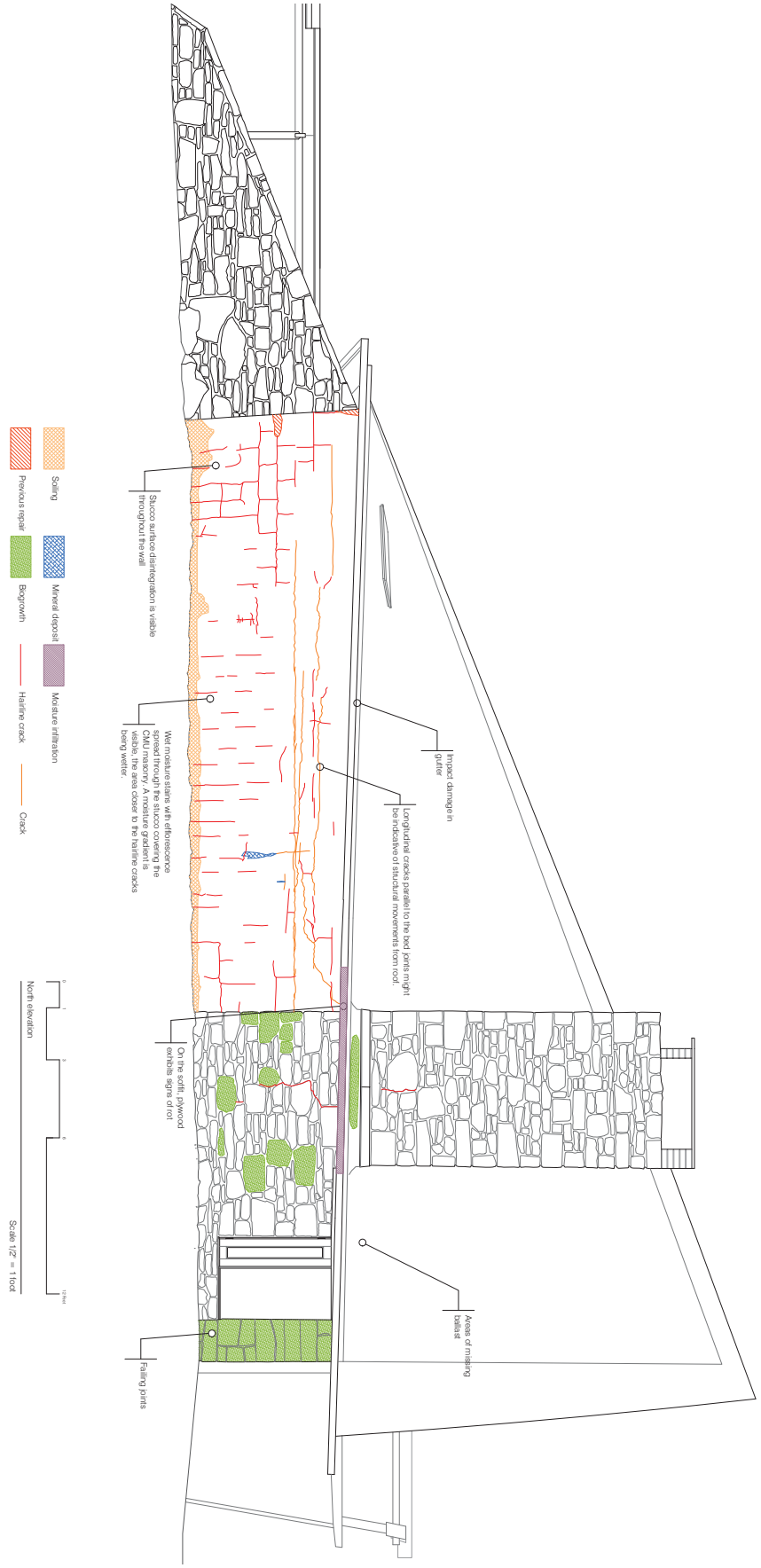
Close-up view of the stucco disintegration



Darker wet areas and hairling cracking typically reveal the Weyrite block perimeter



Overlaid infrared image on the previous photograph. Note how the darker wet areas are warmer.



THE ARTS BUILDING AND CLOISTER George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania				SHEET IDENTIFICATION NAKA - C.03
THE ARCHITECTURAL CONSERVATION LABORATORY GRADUATE PROGRAM IN HISTORIC PRESERVATION SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA	Frank Matero - Project Director William Whitaker - Associate Director John Hinchman - Heritage Surveyor Cesar Bargues Ballester - Project Manager	Delineators: Cesar Bargues Ballester	Survey Date: September- December 2014	SHEET DESCRIPTION THE ARTS BUILDING: NORTHEAST ELEVATION



Previous repair



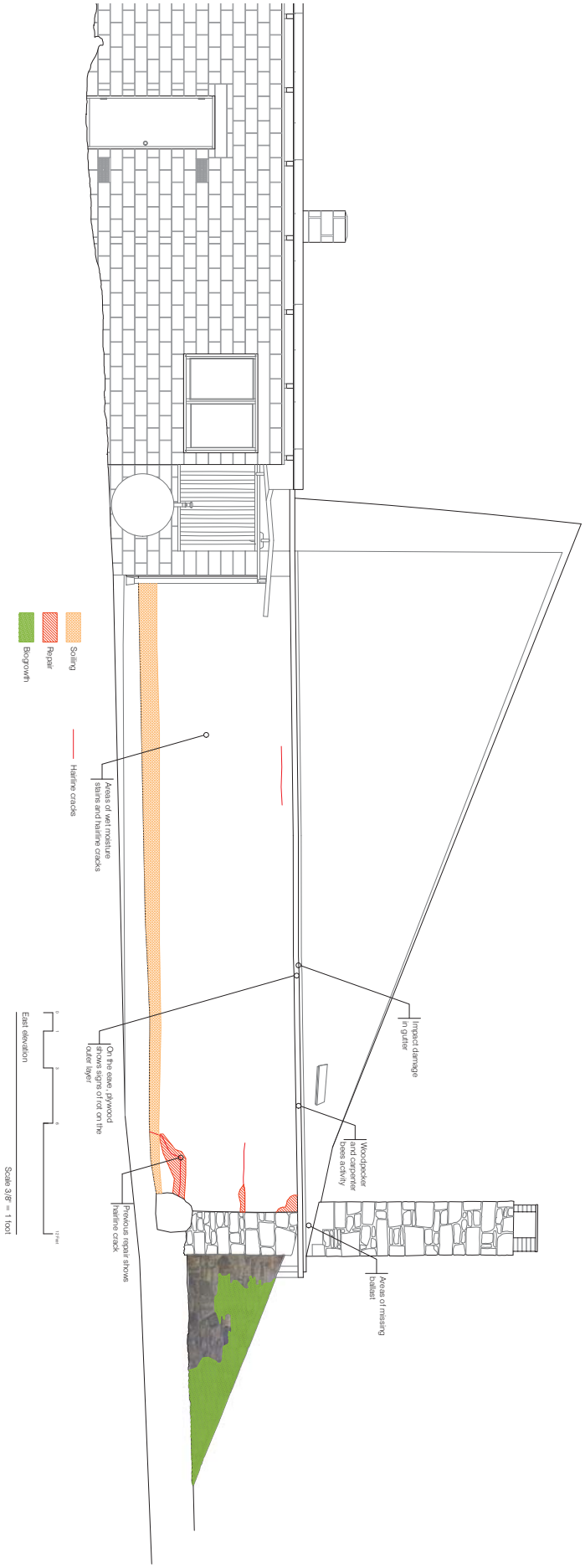
Typical hairline crack along with dark, wet areas



Typical rot visible on the plywood edge adjoining the fascia board



Typical woodpecker damage



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - C.04

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:
Cesar Bargues Ballester

Survey Date:
September- December 2014

SHEET DESCRIPTION

THE ARTS BUILDING: SOUTHEAST ELEVATION



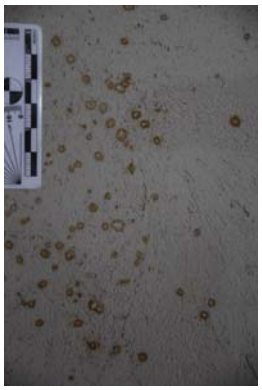
Cracking and efflorescence on the stone masonry



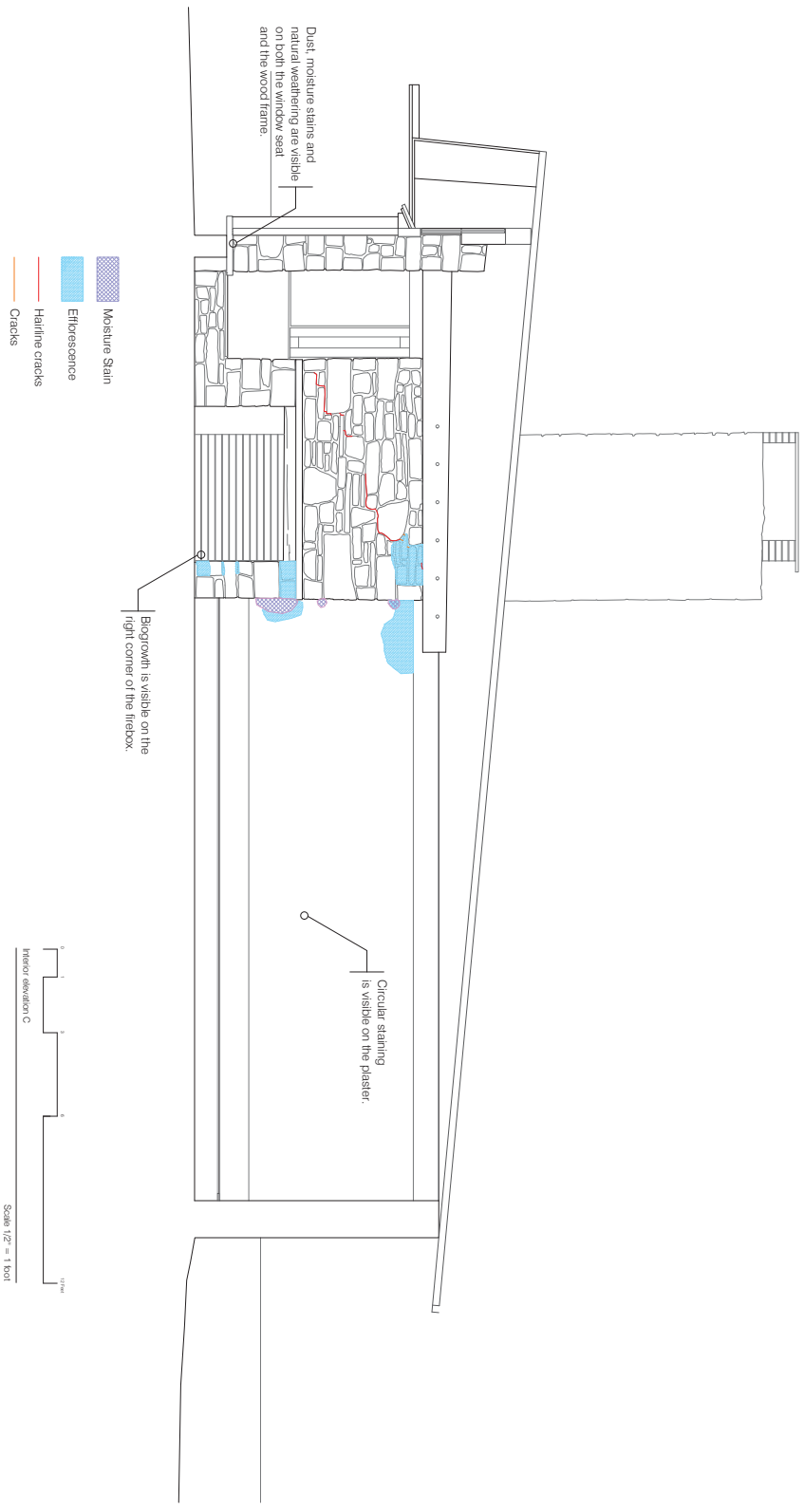
Moisture stains on the plaster and on the window seat



Scaling visible on the chimney hearth. Note minor damage by fire on the Amtico® Travertine flooring



Typical circular staining on the walls plastered with Structolite®



THE ARTS BUILDING AND CLOISTER

George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania

SHEET IDENTIFICATION

NAKA - C.05

THE ARCHITECTURAL CONSERVATION LABORATORY

GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA

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William Whitaker - Associate Director
John Hinchman - Heritage Surveyor
Cesar Bargues Ballester - Project Manager

Delineators:
Cesar Bargues Ballester

Survey Date:
September- December 2014

SHEET DESCRIPTION

THE ARTS BUILDING: INTERIORS

THE ARTS BUILDING AND CLOISTER

(George Nakashima Foundation for Peace — 1847 Aquetong Road — New Hope, Pennsylvania)

THE ARCHITECTURAL CONSERVATION LABORATORY
GRADUATE PROGRAM IN HISTORIC PRESERVATION
SCHOOL OF DESIGN - UNIVERSITY OF PENNSYLVANIA

Frank Matero - Project Director
William Whitaker - Associate Director
Cesar Barques Ballester - Project Manager

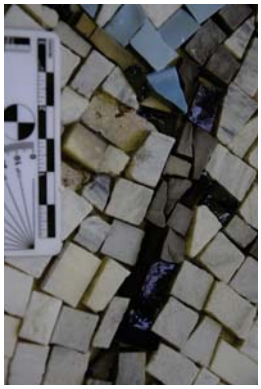
John Hinchman - Heritage Surveyor

Delineators:
Cesar Barques Ballester

Survey Date:
September- December 2014

SHEET DESCRIPTION
THE CLOISTER: ELEVATIONS

SHEET IDENTIFICATION
NAKA - C.06



Missing tesserae



Color alteration

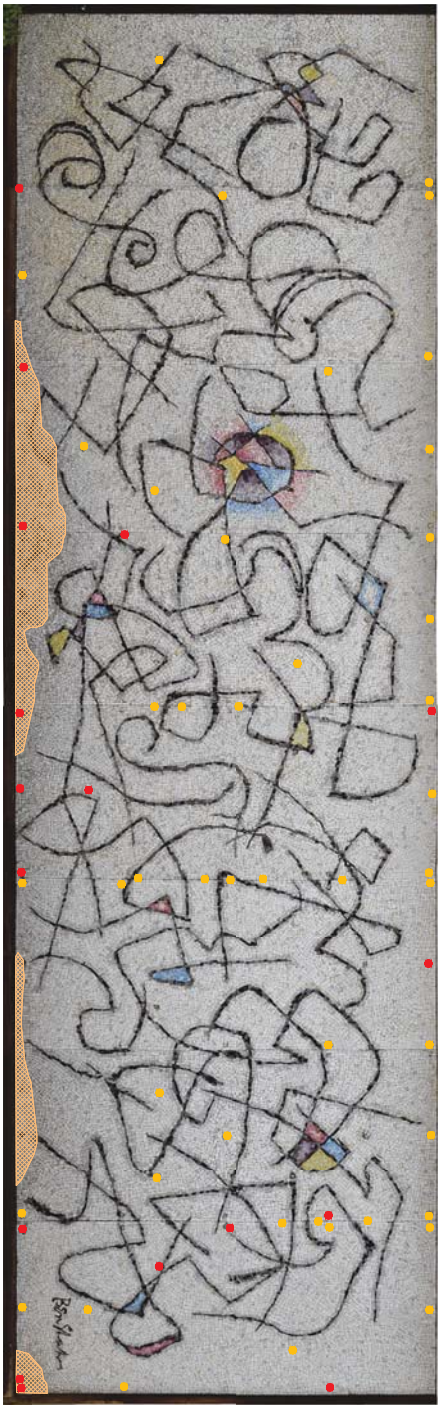


Granular disintegration



Biological colonization

Color alteration
Missing tesserae
Soiling



Ben Shahn's Mosaic

0 1 3 6

Scale 1" = 1 foot

THE ARTS BUILDING AND CLOISTER George Nakashima Foundation for Peace 1847 Aquetong Road New Hope, Pennsylvania				SHEET IDENTIFICATION NAKA - C.07
THE ARCHITECTURAL CONSERVATION LABORATORY GRADUATE PROGRAM IN HISTORIC PRESERVATION SCHOOL OF DESIGN - UNIVESRITY OF PENNSYLVANIA	Frank Matero - Project Director William Whitaker - Associate Director John Hinchman - Heritage Surveyor Cesar Bargues Ballester - Project Manager	Delineators: Cesar Bargues Ballester	Survey Date: September- December 2014	SHEET DESCRIPTION BEN SHAHN MOSAIC MURAL

Appendix H

Arts Building: C. 1980. A Reconstructed Inventory.
William Whitaker.
Curator and Collections Manager
Architectural Archives, University of Pennsylvania.

ARTS BUILDING: c. 1980

A Reconstructed Inventory

January 9, 2017
Compiled by William Whitaker

The inventory presented here is based on historic photographs taken in the mid to late 1970s through to the early 1980s – the period in which Nakashima wrote his seminal book, Soul of a Tree. That publication includes insightful statements about the building and collections, in addition to providing a number of important documentary photographs. Subsequent publicity related to the book produced additional photographic documentation making this time period a fertile one to reconstruct. However, this list would not have been possible without the discovery of a notebook entitled, “museum notes.” This item includes about 10 pages of notes about the contents of the building created by Mira Nakashima around 1977. It is an invaluable record of the contents of the building from furniture to folk art, and sculpture to wood slabs.

01. EXTERIOR – WESTERN APPROACH

[Arts Building exterior – permanent installation]



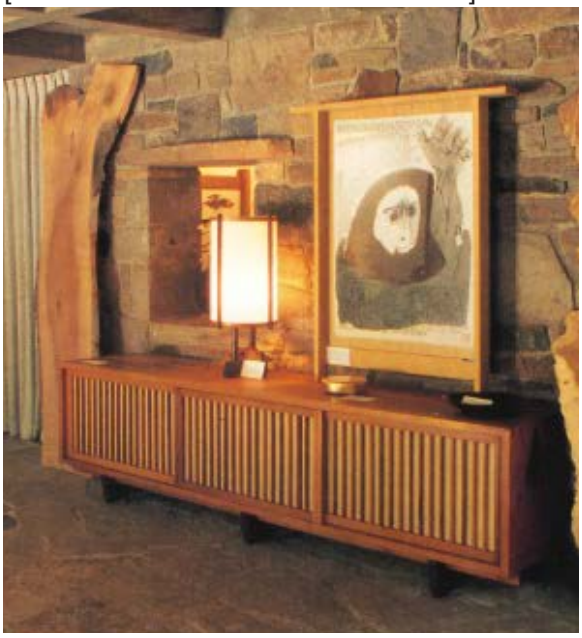
Ben Shahn
Poet's Beard (1970)
Mosaic (executed by Gabriel Loire from an original Ben Shahn gouache)

[Arts Building exterior – permanent installation]



Masayuki Nagare
Keyhole (1963-64)
Matsukage stone from Hagi, Japan

[Cabinet sold to Este Stowell in the 1980s]



8' French Walnut Cabinet with Table Lamp (lamp unlocated)

[North wall above cabinet – NOW @ Mira's]



Ben Shahn
Maximus of Tyre (1963)
Serigraph in black with hand coloring
Paper size: 36 x 26 ¼ inches
Nakashima frame size: [t.k.]
Signed, "Ben Shahn" in red with brush (lower right) – orange / red chop to left of signature

[NOW in fireplace niche]

02. INTERIOR – "CAVE," north wall



BLACK LACQUER PLATE
Note: “hand-carved, Mingei-style, from Takamatsu” on typed label affixed to underside of piece

[NOW in fireplace niche]



GOLD LACQUER PLATES IN BOX
Note: “Modern Japanese” on typed label affixed to underside of piece (box + top with 5 plates inside)

[vestibule wall opening]



Harry Bertioa
[Dandelion], 1960
[Bronze welded brass welded]
Note: “Kevin 1964 on bottom”

03. INTERIOR – “CAVE,” east & south walls

[East wall, above bench, short wall - @ Mira’s]



Ben Shahn
I Think Continually of Those Who Were Truly Great (1965)
Serigraph in brown and white with hand wash and hand coloring
Paper size: 26 ½ x 20 ¾ inches
Nakashima frame size: [t.k.]
Signed, “Ben Shahn” in black with brush lower right to the left of red chop

[NOW in Conoid Studio]



8’ American Walnut “R” Bench

[NOW in fireplace niche]



Cast Iron Skillet or pot (sitting on bench, possibly as ash tray)
Note: not found on Mira’s inventory, but in the 1967 photographs, as well as in later images.

04. INTERIOR – “CAVE,” west wall niches

[west wall, left alcove – NOW @ Mira’s]



Ben Shahn
Ecclesiastes (1966)
Serigraph in sepia with black calligraphy
(unspecified edition; 10 known)
Paper size: 22 7/8 x 17 ¾
Nakashima frame size: [t.k.]
Signed, “Ben Shahn” in black conté crayon upper left under orange-red chop

[West wall, second alcove – in Arts Building]



Ben Shahn
Gandhi (1965)
Serigraph in black
Paper size: 40 1/8 x 26 inches
Nakashima frame size: [t.k.]
Signed, “Ben Shahn” in red with brush (lower right) – orange / red chop top left
Note: inscription at lower left “For Kevin and George and Marion and Mira”
[West wall, large alcove – NOW @ Ru’s house]



Ben Shahn
Poet (1960)
Serigraph in two shades of brown
Paper size: 40 5/8 x 27 ½ inches
Nakashima frame size: [t.k.]
Signed, “Ben Shahn” in red with brush lower right

[fireplace mantle]



Jap Cast Iron Candlesticks
Note: originally installed flanking Ben Shahn’s Poet in vestibule niche

[West wall, alcove adj. closet – Now @ Kevin’s]



Ben Shahn
Branches of Water or Desire (1965)
Serigraph in black Paper size: 26 3/8 x 20 ½ inches
Nakashima frame size: [t.k.]
Signed, “Ben Shahn” in red with brush (lower right) – orange / red chop lower center right

05. LIGHT SCULPTURE



“Light Sculpture”

Note: Comprising of two book-matched slabs of English walnut (measuring 12’ tall) and one English Oak burl. The latter slab was sold in the 1980s. The English walnut slabs were reconfigured into a revised configuration for the Light Sculpture.

Note: All were shown in Cave or Gallery, the juxtaposition of wood slabs and furniture is exceptional



English walnut [10 slabs]; American maple; Persian walnut [3 slabs]; East Indian Rosewood; Carpathian elm; Black Walnut; East Indian Laurel; Buckeye Burl; Redwood Burl; Walnut burl; English Oak burl





Left: “Two walnut Conoid Chairs…stand… before an extraordinary piece of buckeye burl wood” [p. 169, Soul of a Tree]

Right: English oak burl near French Walnut Cabinet [p. 39, Soul of a Tree]

06. SLABS OF EXOTIC WOODS ACCOUNTED FOR IN MIRA’S INVENTORY

07. INTERIOR – "GALLERY"

[Arts Building, main room]



MINGUREN IV DINING TABLE (1967)
English oak burl and East Indian laurel
[dimensions t.k.]
Markings: "Museum" (in marker) / "III" / "Mira 1969"
Note: "Mate" of this table located at Ritsurin Garden's *Shoko Shoreikan* (Commerce and Industry Promotion Hall), in the *George Nakashima Room* on the second floor / link to Takamatsu

[NOW in Conoid Studio



New Chair with Arms, "Ben's Chair" (1965)
Walnut
Note: Mira's inventory states, "Ben sat here; once reserved for Ben who in the interim, passed away / SR"
Markings: "Kevin 1966" in marker on bottom of seat (1965-CH-25)
Note: many photos show this chair positioned with the Minguren IV table and in front of Ben Shahn's hand drawing from Parry Barn exhibit

[Main room, leaning against wall]



Ben Shahn
Hand (1963)
Photographic reproduction of original ink drawing given to Nakashima's created for Parly Barn exhibit in 1963 – usually close to Minguren IV table and "Ben's Chair"

[NOW in loft niche]



GRAY POTTERY BOWL
Note: "Turned but free form during stamping and glazing. Eccentricity accentuates beauty" on paper label affixed to bottom. Japan stamp on bottom.
Note: shown on Minguren IV table in a number of photographs of this period

[Arts Building, main room – NOW Mira's]



Floor lamp [generic image]
Markings: “Kevin 1967” on bottom
Note: usually near Minguren IV, towards fireplace side.

[Arts Bldg., main room]



CONOID CHAIR (1967)
Teak
Markings: “Arts Bldg” and “Kevin 1967” in marker on bottom of seat (1967 CH-22)
Note: often paired with Rosewood against East wall near end of Minguren IV table

[Arts Bldg., main room]



CONOID CHAIR (1967)
Rosewood
Markings: “Arts Bldg” and “Kevin 1967” on seat bottom in marker / partial label (1967 CH-21)

[SOLD to Connie and Tully Patrowicz]

To be located

CONOID CHAIR (date t.k.)
Oak
Markings: to be determined
Note: This one may be the Conoid chair usually paired with “Ben’s Chair” on the north side of the Minguren IV table.

[Arts Bldg., main room]



CONOID CHAIR (1967)
Walnut
Markings: “Studio” and “Mira 1967” in marker on bottom of seat (1967 CH-19-number repeated)
Note: The two walnut Conoid Chairs may have been placed at a distance from the Minguren IV table

[Arts Bldg., main room]



CONOID CHAIR (1967)
Figured Walnut
Markings: “Studio” and “Mira 1967” located on bottom of seat in marker (1967 CH-19 – number repeated)

[Arts Building, main room]



Large English Walnut Bench [extraordinary slab]



Look photos 1958 Kevin & G (photo Rothsein)

[vestibule niche]

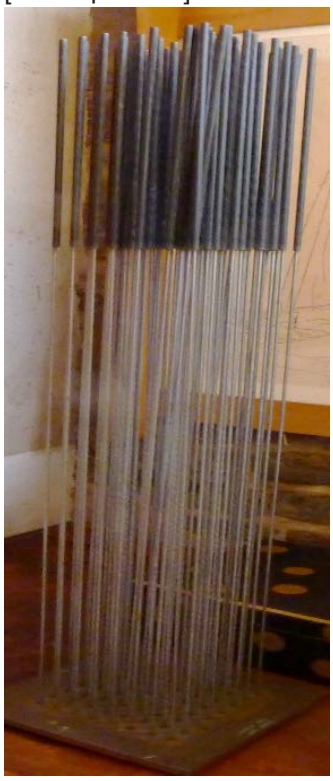


Holland Photo (George 1955)
In Mira Nakashima Frame
Note: Both this and the photo below are usually seen leaning against wood slabs in the gallery.
Framed and hung in the 1990s

[Under stair]

08. INTERIOR – GALLERY, PLATFORM AND SLIDING DOOR AREA

[corner platform]



Harry Bertioa
[Sounding Piece], 1974
[Beryllium copper, brass plate]

[NOW LOST]



Isamu Noguchi
"AKARI" LIGHT SCULPTURE
Washi paper and bamboo
Approx. 22" in diameter hung 80" off floor
Note: this image was taken in 1969 and likely shows the original paper lamp.

[Not located]



Conoid Cushon Chair with Japanse Kasuri fabric
Note: image from 1972 Smithsonian article. An example of this chair can be found in Mira's House and may be this on, but reupholstered. Note:

[Not located]



Conoid Cushon Chair with "Beige" fabric
Note: this image is reversed. It is likely that the Conoid Cushion chair was paired with a second unit, with yellow fabric (see image from Parry Barn exhibition)

09. FIREPLACE SEATING AREA

[Fireplace area]



SETTEE, NO ARMS (1956)
American black walnut, upholstery, plywood, maple (handwoven upholstery fabric by Eleanor Gordon)
52 ¼ x 49 x 35 inches
Markings: “Kevin 1956” (underside)
Note: Full Circle, p. 146-47
Note2: This example is probably the piece photographed in the Showroom and used there for a period of time.

[Fireplace area]



MINGUREN I COFFEE TABLE (1968)
English oak burl
15 7/8 x 29 ¾ x 70 inches
Markings: “Kevin 1970” (underside)
Notes: piece is not visible in 1967 photos
Note: Full Circle, p. 132-33

[Arts building, main room]



LOUNGE CHAIR WITH ARM (RIGHT)
Walnut
Markings: “George Nakashima, June 1968” / “Kevin 1968 / Arts Bldg.” in marker on underside of seat

[NOW IN SHOWROOM]



LOUNGE CHAIR WITH ARM (LEFT)
Walnut
Markings: “Kevin 1968 / Arts Bldg.” in marker on underside
Note: sap line and cavity in arm match photographs of this piece in Arts Bldg.

[Fireplace area]



LOUNGE CHAIR (no arms)
Walnut
Markings: “Mira 1966” on underside (1966-CH-27)

10. FIREPLACE AND NICHE

[NOW in Conoid Studio]





1 holy candle holder [carved by Santiago Riva of Santiago, Spain – candleholder at Martin's, New Hope / This one was rejected – had a knot hole so was retained by GKN]
Note: sat on window sill.

[Not hung, leaning in Fireplace niche]



CAST IRON POT HANGER
Antique from Takamatsu, Japan
From Soul of a Tree, p. 34: "Adjustable pothooks, called *jizai-kagi*, hang over the central hearth in many Japanese farmhouses. The motif of adjusting height in this one, which is in our Minguren Museum, is typical – a fish."

[Now in loft niches]



ANTIQUE EUROPEAN STAINED GLASS
Glass and metal
Note: "Gift of Father Peter [Sidler] Portsmouth, Rhode Island"
Note: hung in pane of casement sash in niche / artist and priest at Portsmouth Priory; designed the doors to the Church (P. Belluschi) and Nakashima the furnishings (groundbreaking on Nov. 21, 1958; finished by about 1960). This is a touchstone at the beginning of his work for the Catholic Church.

[NOW @ Mira's]



Ben Shahn
And Mine Eyes a Fountain of Tears (1965)
Serigraph in red with black Hebrew calligraphy
Paper size: 23 7/8 x 17 7/8 inches
Nakashima frame size: [t.k.]
Signed, "Ben Shahn" in black with conté crayon
Note: hung on west side of fireplace niche

[NOW @ Reception]



Ben Shahn
Wealth [date unknown]
[Iomo (orig. ink calligraphy)]
Size:
Signed: “With love for George and Marion from Bernarda & Ben”
Note: The piece was moved to the Reception House upon that buildings completion in 1977
Note: hung above fireplace



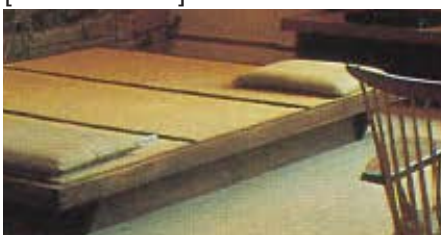
TATAMI PLATFORM (1967)
Walnut and 3 tatami mats
10 x 111 ½ x 75 ½ inches
Note: piece is movable and has been positioned askew in the room, under the skylight, for performances and special events.
Note: This piece can be moved and used in the main space of the Gallery for performances

[5 on window seat, 4 on bench in loft]



NINE CUSHONS
Cushon covers, Japanese handwoven fabric
“Kasuri” Threads are dyed before weaving

[NOT LOCATED]



LINEN COVERED CUSHIONS
Note: 1967 photographs show 6 cushions in a variety of colors. Mira recalls colors as blue and white. Two cushions are shown in the photo above.

[NOW near door]

11. UNDER FIREPLACE

[Fireplace area – movable]

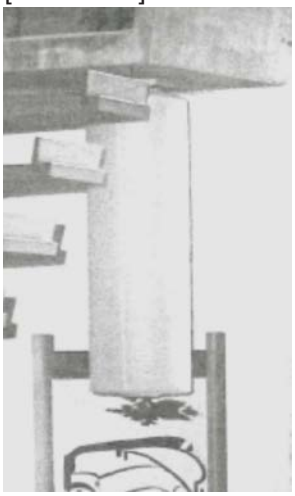


Ben Shahn
Byzantine Memory (1966)
Serigraph in black and brown with hand coloring
Paper size: 26 3/8 x 30 ½ inches
Nakashima frame size: [t.k.]
Signed, “Ben Shahn” in black conté crayon lower right and orange-red chop upper left
Note: inscribed, “Happy Birthday to George”, hung under the stair



Basket from Japan
Note: shown sitting on the built-in bench near fireplace in early photos.

[NOW LOST]



Paper lamp
Note: hung under the stair

[loft floor]

12. LOFT – BUILT-IN FURNITURE

[loft, built in]



Conoid Bench with Double Back, built-in

[loft, built in]



Slab Side Table, built-in



Desk Lamp

[Loft area, permanently installed]



Kiyoshi Konishi
Hexagonal Shoji
Port Orford Cedar (American Cypress) or “Beihi”
Takamatsu, Japan

[loft, on top of side table]

13. LOFT RAISED PLATFORM

[currently in main room]



Kent Hall Lamp [generic image], 1964

[Loft]



LONG CHAIR (1951)
Walnut, cotton webbing, sea grass
31 ¾ x 34 x 68 inches
Note: Mira noted in this inventory that it was "unfinished wal." Confirming that this is the piece on view in the Arts Building.
Note: Full Circle, p. 150-51

[vestibule]



SLAB COFFEE TABLE (original; 1949)
American black walnut
12 ¼ x 56 x 17 inches
Note: Full Circle, p. 118-19
[loft]



FITCH STOOL (1954)
Walnut with twisted grass seat
20 x 20 x 13 inches
Note: "Mira 1972" on bottom

[NOT LOCATED]



PLANK STOOL (1954)
American black walnut
Markings: "Kevin 1954" on bottom

[vestibule]



Original 4 legged chair, flat seat, cherry designed as a piano chair for Mira about 1954
Markings: “Mira 1954” on bottom (1954-CH-09)

[loft]



Left: LOW MIRA CHAIR (1950)
American black walnut, poplar
24 ¾ x 19 ¼ x 17 5/8 inches
Markings: “Mira” and signed “George Nakashima, New Hope, PA” on bottom of seat

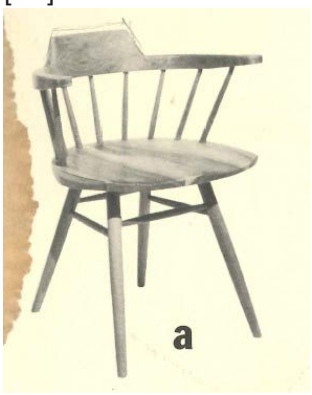
Center: MEDIUM MIRA CHAIR (1956)
American black walnut, poplar
28 ¼ x 19 ¾ x 19 ½ inches
Markings: “Kevin 1956” on bottom of seat
Note:

Right: HIGH MIRA CHAIR (1952)
American black walnut, poplar
33 x 19 ¾ x 19 inches
Markings: “Mira 1952” on seat bottom (1952-CH-02)
[loft]



STRAIGHT BACK CHAIR (1950)
[cherry?]
Markings: “Mira 1950” on bottom with “Arts” in marker

[loft]



ARM CHAIR (1958)
[material]
Markings: “Kevin 1958” on bottom (1958-CH-10)

[loft]



NEW CHAR (original)
Walnut with poplar seat and hand shaved hickory spindles
Dimensions: 16 ¼ x 18 ¼ x 35 ¾ inches
Markings: “Mira 1955” on bottom; label note “personally made by GKN” (1955-CH-12)

loft]



NEW CHAIR (1968)
[Walnut with hickory spindles]
Dimensions: 16 ¼ x 18 3/8 x 35 5/8 inches
Markings: “Kevin 1968” on bottom (195x-CH-14)

14. LOFT NICHES – WORKS TIED TO MINGUREN AND KIYOSHI KONISHI
Note: Konishi was a GKN collaborator and a Minguren member.

[loft niches]



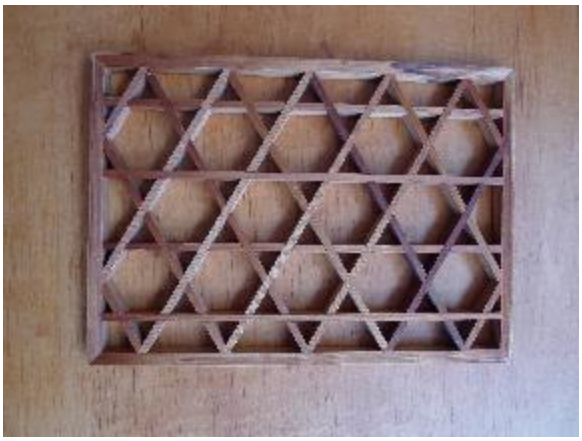
Commemorative “Getta” Wooden Clog
“Traditional Japanese footwear (minus Thongs). Signed by members of the Seisaku-sho & “Minguren” in 1965”
Japan

[Now on bedside table in Cloister]



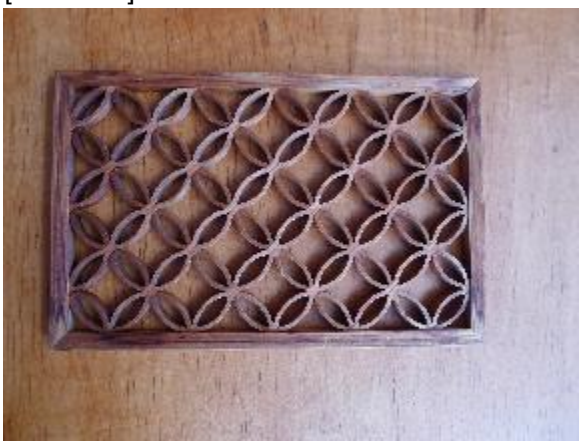
Kiyoshi Konishi
DESK LAMP
Washi paper and wood
Note: Kevin N. recalls that these were made in Japan by Konishi Mokkō. They arrived as kits, assembled and sold by GKN.

[loft niches]



Kiyoshi Konishi
Shoji Screen Sample – Hexagonal configuration
“Made of Port Orford Cedar (American Cypress) or “Beihi” in Takamatsu, Shikoku, Japan. Fine examples of a very precise art handed down for generations. Now limited by the skills of fewer people in Japan.”
Note: Mira’s notebook refers to maker as Konishi Mokkō. The latter is Company in Japanese. Kiyoshi Konishi was a collaborator with GKN and a Minguren member.

[loft niches]



Kiyoshi Konishi
Shoji Screen Sample – Round configuration

15. LOFT NICHES – JAPANESE FOLK OBJECTS AND FOLK ART

[loft niches]



Antique lumber saw
Takamatsu, Japan

[loft niches]



Metal Brands [2 items]
“A & B (For burning designs into wood)

[loft niches]



Bamboo Salt and Pepper Shakers
“An example of the skillful adaptation of Japanese technology to Western necessities”
[loft niches]



Paper Mache Folk Toys [9 items]
“These are examples of traditional folk toys of Kagawa Prefecture made by a little old lady in Takamatsu. Acquired in 1962. Her daughter carries on her work now.”
Takamatsu, Japan

[loft niches]



Wooden head rest used by Geisha [2 items]
Japan

[loft niches]



1 basket and holder for flowers
[loft niches]



"Hakosumitori" charcoal container used in the preparation room for a tea ceremony
Takamatsu, Japan
Red Pine

[loft niches]



JAPANESE BASKET SIEVE

[loft niches]



1 teapot, disposable [ceramic]
Note: top serves as cup for drinking, as shown here. 3 pieces (top, pot, and saucer)

[loft niches]



Cast Iron Tea Kettle
Japan

[loft niches]



Wood Cut Block, "An example of the delicate block-printing technique perfected in Japan. It was an entire page from a book."

[loft niche]



Turtle mold for cake (2 pieces)

[loft niche]



Crab mold for cakes (2 pieces)

[loft niche]



Flower cake mold (2 pieces)

[loft niche]



Cake mold (1 piece)
[loft niche]

[loft niches]



Wood Shaving Owl. “Example of traditional Japan Folk Art ([donated by] Ezra Stoller)
“Craft Center Japan” label Japan

16. LOFT NICHES - FOLK ART OBJECTS FROM INDIA

[NOT LOCATED – LOST]

To be located

Crude clay figure with fruit on head (folk Art from Ahmedabad) from “Hakubai”

[loft niches]



“Carved Wooden Horse”
India

[loft niches]



Wooden Printing Blocks for Textiles (9 items)
“From Ahmedabad, India”

[loft niches]



3 wooden bowls from Jain monastery Ahmedabad
Note: Period photographs show these on display in a “nested” configuration.

[loft niches]



Copper pot antique bronze

[loft niches]



Bowl from India – contributed by Gita Sarabhai
[loft niches]



Carved Wooden stand
Teak

[loft niches]



Piece of antique architectural screen from ancient part of Ahmedabad

[loft niches]



Insense basket (india)
[loft niches]



Indian Bead-pillow hanging

Notes: a Catholic Benedictine monk from Mount Saviour Monastery in Elmira, NY / very involved in interfaith groups

[loft niches]



Wood from Brother David
Note: are we sure this the small English oak burl on the mantle?

17. LOFT NICHES - GIFT FROM BROTHER DAVID STEINDL-RAST

18. LOFT NICHES - FOLK ART OBJECTS GIVEN BY BEN SHAHN

[loft niches]



Ben Shahn
Four Model Buildings made by Ben Shahn for his children's model railroad and then given to Kevin Nakashima
Note: "Sunset Hotel / Harvey House; church; wood house; stone house

[loft niches]



Pig in a Poke
Carved Hand-Painted pig in a basket given by Ben Shahn / from Southeast Asia

[loft niches]



CEREMONIAL DOLL
"Made of straw and filled with grain, it was used in a ceremony to insure good crops in Southeast Asia." Gift of Ben Shahn

[NOW LOST]

Now lost

3 Ben Shahn eggs
Painted
Note: Began rotting and had to be thrown away. Mira recalls that these were "vividly painted." one had a "face" and the other, "spots." All of the designs were on a white background.

19. LOFT NICHES - FOLK ART OBJECTS GIVEN BY NITA AND STANLEY BROGREN

Stanley Brogren and GKN went to high school together in Seattle, as well as to Univ. of Washington for architecture (both graduated with B.A.'s in 1929). Nita was a sophomore in their senior year and worked professionally as an interior designer. Nita designed the paper lamps in the Showroom as well as the frock that Mira wore for the Look Magazine photoshoot for the article "A Chair for Mira."

[loft niches]



CARVED WOODEN BIRDS MOUNTED ON WOODEN BURL (possibly by Mira Nakashima)
Gift of Stanely Brogren

[loft niches]



CARVED WOODEN DECOY DUCK
"An early American antique"
Gift from Nita and Stanley Brogren

[loft niches]



Antique Bronze Teapot (silvered) from Persia
Gift of Stanley Brogren

20. LOFT NICHES - HERILOOMS FROM OKAJIMA AND NAKASHIMA FAMILIES
Note: Given by Marion Nakashima's aunt Masa Okajima or owned by her mother.

[loft niches]



PAINTED WOODEN JAR WITH LID
"From Budapest from Aunty Masa"

[loft niches]



ANTIQUE CERAMIC CANDY DISH
"From Aunty Masa Okajima, Japan about 1900"

[loft niches]



ANTIQUE COPPER TEAPOT
Note: "From Japan about 1890. Formerly owned by Marianne Hecht Okajima, Marion's mother."

[loft niches]



TRAY FROM INDIA
Brass
Note: "A wedding gift to George and Marion from India, Feb. 14, 1941"

[Now at Mira's House]



Totem pole – Hudson Bay fan co., Seattle, WA

[loft niches]



Mask?

21. LOFT NICHES - GIFTS FROM TOM AND MARY MURAKAMI

Notes: Mira recalled that the Murakami's were "very good clients" and family friends. Tom worked for RCA and made important contributions to the creation of color TV as well as Naval radar systems. Tom and Mary lived in Kualajin from 1974 to 1978 where the Navy tested radar systems. They may have made more trips to that area. Tom (Tomomi) and Mary (nee Doi) were born in California and as Japanese Americans at the outbreak of WWI, were incarcerated at camps in Arkansas and Wyoming respectively.

[fireplace niche]



JAPANESE GLASS FLOATS
Marshall Islands, 1960
Note: "Roller float is a rare one….Gift of Dr. and Mrs. Tom Murakami"

[fireplace niche]



GLASS FISHING FLOAT
Kualajin, South Pacific
Note: "From Dr. and Mrs. T. Murakami"

[fireplace niche]



HAND WOVEN SHELL BASKET
Note: "From the Marshall Islands Gift, Dr. & Mrs. Murakami, 1979" / this is not on Mira's inventory – supporting that the list dates from c. 1976-78 / included on this list because of close connection btwn Naka's and Murakami's.

22. CLOISTER

[cloister room]



Dorothy Grotz
Bois de Boulogne (?)
Oil on canvas mounted in Nakashima frame

[East wall, Cloister room]



2 wall hangings from India – acquired in Ahmedabad, 1964

[South wall, Cloister room]



2 wall hangings from India – acquired in Ahmedabad, 1964

[Cloister room, west wall]



Isamu Noguchi
"AKARI" LIGHT SCULPTURE
Washi paper and bamboo
[size t.k.]
Note: check interior to see if it is a Noguchi Akari lamp – signature + moon in red is expected

Appendix I

National Historic Landmark nomination, February 2013

1. NAME OF PROPERTY

Historic Name: George Nakashima Woodworker Complex

Other Name/Site Number:

2. LOCATION

Street & Number: 1847 and 1858 Aquetong Road Not for publication:

City/Town: Solebury Township Vicinity:

State: Pennsylvania County: Bucks Code: 017 Zip Code: 18938

3. CLASSIFICATION

Ownership of Property		Category of Property	
Private:	X	Building(s):	X
Public-Local:	___	District:	___
Public-State:	___	Site:	___
Public-Federal:	___	Structure:	___
		Object:	___

Number of Resources within Property

Contributing	Noncontributing	
17	2	buildings
___	___	sites
2	___	structures
___	___	objects
19	2	Total

Number of Contributing Resources Previously Listed in the National Register: 19

Name of Related Multiple Property Listing: Nakashima, George, House, Studio & Workshop

4. STATE/FEDERAL AGENCY CERTIFICATION

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this ____ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ____ meets ____ does not meet the National Register Criteria.

Signature of Certifying Official Date

State or Federal Agency and Bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria.

Signature of Commenting or Other Official Date

State or Federal Agency and Bureau

5. NATIONAL PARK SERVICE CERTIFICATION

I hereby certify that this property is:

__ Entered in the National Register
___ Determined eligible for the National Register
___ Determined not eligible for the National Register
___ Removed from the National Register
___ Other (explain):

Signature of Keeper Date of Action

6. FUNCTION OR USE

Historic:	Domestic-single dwelling Commercial/Trade-professional Industrial/Processing/Extraction-manufacturing facility Recreation and Culture-museum	Sub:
Current:	same	Sub:

7. DESCRIPTION

ARCHITECTURAL CLASSIFICATION: Modern Movement (Japanese-influenced International Style)

MATERIALS:

Foundation:	concrete
Walls:	concrete, concrete block, stucco, stone, wood, glass
Roof:	wood, transite, reinforced concrete, warped plywood shells
Other:	

Summary
George Nakashima is one of America's most eminent furniture designer-craftsmen and a significant force within the American Craft movement of the mid-twentieth century, a seminal period for woodworking in the United States. Nakashima and others within the new movement rejected the mass-production brought on by the machine age and industrialization while at the same time embracing Modern stylistic influences and ideas that were international in scope. Often defined as "organic naturalism," his timeless pieces defy stylistic categorization. Believing in the spiritual qualities of wood, Nakashima's signature features incorporated techniques intended to enhance the impact of the wood's natural beauty, such as the "free-edge" and the use of butterfly inlays. His success as an artisan propelled him briefly into the arena of mass-production; from 1945 to 1954 internationally recognized modern furniture manufacturers Hans and Florence Knoll produced a selection of Nakashima's designs, which appeared alongside other noted modernists including: Franco Albini, Harry Bertoia, Pierre Jeanneret, Ludwig Mies van der Rohe, Isamu Noguchi, Eero Saarinen, and Florence Knoll herself. However, Nakashima saw furniture making more as a spiritual journey, crafting unique pieces that responded to the natural form of each piece of wood. His work expresses a worldview that is based upon a unique set of circumstances including his formal education in architecture, his exposure to European Modernism, eastern religious philosophy, and traditional Japanese craft traditions, including instruction from Issei carpenter Gentaro Hikogawa while confined to a Japanese-American Internment Camp. He began his professional career as an architect, working at the vanguard of International Modernism in Japan before turning to furniture design. Thus, Nakashima is also responsible for the design and construction of the structures that comprise the Nakashima Woodworker complex, erected between 1946 and 1982. Designed in the International Style intermingled with elements of traditional Japanese architecture and featuring the innovative use of concrete, the buildings and structures in the complex are treasures of Nakashima's unique legacy of craftsmanship and design excellence.

Describe Present and Historic Physical Appearance

The George Nakashima Woodworker site is located at 1847 and 1858 Aquetong Road, Solebury Township, Bucks County, Pennsylvania. The property consists of a complex of buildings on both sides of Aquetong Road on two tax parcels. On the south side is a nine-acre, partially wooded, parcel that contains eighteen resources including the George Nakashima House (1946), the Workshop (1946), the Showroom (1954), the Finishing Department (1955), the Main Lumber Storage Building (1956; 1968), the Chair Department (1957), the Lanai (1958), the Pool Storage House (1958), the Pool House (1960), the Swimming Pool (1960), the Conoid Studio (1957-60), the Arts Building and the Cloister (1964-67), the George Nakashima Garage (1967), the Reception House (1975-77), the Heating House (1977), the New Lumber Storage Building (1982), and the Pole Barn (1990). On the north side of Aquetong Road on a partially wooded three-acre parcel are the Mira Nakashima House (1970), the Mira Nakashima Guest House (1971), and Mira Nakashima Garage (1985). There are twenty-one resources total on the property, nineteen of which were designed and constructed by George Nakashima and are contributing; only the Pole Barn and the Mira Nakashima Garage are noncontributing. The buildings and structures generally reflect the International Style with some also possessing traditional Japanese influences. All of the buildings (on both tax parcels) were designed by George Nakashima, who also had a hands-on role in the construction of most of the buildings. Materials used include stone, cement block, concrete, glass, stucco and wood. Some of the roof types also constitute unique and unusual engineering systems. These include a conoid shell roof which is a shape generated from a section of a cone; a hyperbolic paraboloid which is a saddle-shaped surface, and a scissors truss, which is a truss that is asymmetrical resembling a partially open pair of scissors. The buildings and the setting retain physical integrity and continue to be used for a variety of

purposes including residences, education, production, storage and administration related to the legacy of internationally known furniture craftsman George Nakashima.

The Site

The setting for the property consists of sparsely wooded areas with intermittent open mown areas; approximately 50 percent of the property is open space. A gravel driveway and footpaths are the primary means of vehicular and pedestrian circulation within the complex of buildings. Generally, there is not signage for pathways or on buildings. After entering the complex, there is a small parking area to the right (west) for workers and visitors. Many of the buildings are built along a south facing ridge and have large windows on the south facing side allowing natural light and heat into the buildings and providing a view of open mown areas, scattered trees, and densely wooded areas. Buildings are spaced relatively far apart but in a linear cluster on the northern half of the property along the ridge not far from Aquetong Road. Buildings used for processes and workshops are clustered closest to Aquetong Road, lumber storage buildings are along the northern boundary of the property and buildings with residential and administrative uses are toward the center and east parts of the property. The buildings with administrative and residential functions including the Reception House, George Nakashima House, Showroom, and Conoid Studio, are entered from the rear or north side with the front or south side facing onto the open areas. The buildings are not physically or visually separated from each other. For example, the main storage building is immediately adjacent to the Reception House. There are small ponds, boulders, stone walls, patios and paths dispersed among the buildings. George Nakashima and his father planted trees from the Pacific Northwest on the property to remind him of his homeland. The driveway for the property crosses Aquetong Road and connects to the Mira Nakashima property, which also has scattered trees, wooded areas and a small pond.

Arts Building (contributing building; map #1)

The Arts Building was completed in 1967 in the International Style and was constructed as an art gallery and museum to display works by Ben Shahn. It continues to serve as a museum that also displays artifacts associated with George Nakashima. The building is about two-and-a-half stories tall and measures approximately 36' x 40'. Its roof is a hyperbolic paraboloid constructed of plywood covered with asphalt. Walls are constructed of concrete block, stone and poured concrete. Large sections of the west and south sides are glass windows. Along the west wall on the first floor of the building is a tile mosaic designed by artist Ben Shahn. The south side of the building has two entrance doors, one near the southwest corner and the other large sliding doors leading out to the covered walkway. The interior of the building features a cantilevered floating staircase that leads to a mezzanine. The staircase has no outside rail and no risers, and the ends of the steps are secured deeply into a thick stone wall. Many examples of Nakashima's work are in the building.

Cloister (contributing building; map #1B)

Connected to the arts building by a covered walkway, the Cloister is a small, one story, rectangular-shaped building. It has a shed-type roof covered with asphalt. Walls are constructed of cement block. There are three wood entrance doors with horizontal glass panels. The interior features rice paper screens over windows, exposed beam ceilings, and plaster walls. The Cloister contains a bedroom, bathroom, kitchen, and storage room. The International Style Cloister was planned and constructed more-or-less simultaneously with the Arts Building (1964-67).

Conoid Studio (contributing building; map #2)

With a distinctively designed reinforced concrete conoidal shell roof, the Conoid Studio provides work areas for the design of furniture as well as space for education and training. The concrete roof is approximately 2-½" thick and has sinusoidal waves beginning on the northern side of the building that flatten towards the southern

side of the building. The sinusoidal waves are not only aesthetically pleasing, but are key to the support and structural engineering of the building. There is an arched buttress that supports the roof along the southern façade. The building is constructed into a south facing hillside and cantilevered from a basement wall. It measures approximately 40' x 40'. Materials used on the walls of the studio include cement block, stone, stucco, and glass. The roof of the building is constructed of poured concrete with reinforcing rods and wire lath. The non-weight-bearing upper walls are constructed of light frame. The interior of the building includes a large open area with kitchen, bathroom and a design office area. The south-facing windows allow for a maximum amount of natural light partially filtered through rice paper screens. Floors are wood and the ceiling exposes the same sinusoidal curves of the exterior. There is a *tatami*, or raised platform with grass mats, located in a rectangular bay that cantilevers outward from the building on the south side. A large rice paper "Akari" lighting sphere by Isamu Noguchi is suspended from the ceiling. Numerous Nakashima designed chairs and tables are used in the room. Construction of the Conoid Studio began in 1957 and was completed in 1960. It is International Style. It is counted as a contributing resource to the property.

Chair Department (contributing building; map #3)
The Chair Department was originally built as a clubhouse for workers. However, soon after it was built it was converted to space for assembling chairs. The building, the same form as the Conoid Studio, has a conoidal shell roof made of plywood. The Chair Department was built in 1956 as a smaller prototype for the larger Conoid Studio built the following year. The Chair Department, however, does not have the sinusoidal waves in the roof. Overall the building measures approximately 25' x 20' and is nearly two stories high at the south side. Since the building is cantilevered into the hillside, it is one story on the north side. Materials of the walls include stucco, concrete block, wood, and glass. It is a contributing building.

Finishing Department (contributing building; map #4)
Originally built for lumber storage, the Finishing Department was quickly converted for use as a building where finish is applied to the furniture. It was built in 1955 and is also International in style. The building is counted as a contributing resource. The roof over the main part of the building is a slightly sloped gable, covered with plywood and asphalt. There is also a shed roof over a wing that is covered with corrugated Transite, which is a composite of asbestos and concrete. The walls are constructed of cement block and wood. The south side consists almost entirely of large glass windows.

Showroom (contributing building; map #5)
The Showroom was constructed in 1954, specifically for use as an area to put examples of the furniture on display and as the business office. The building has a gently sloped gable roof supported by recycled barn beams that is covered with corrugated Transite. Wall materials include stone, wood and stucco. The building is trapezoidal in shape and has a covered wood deck and patio. Sliding rice paper screens lead to the wood deck and to an entryway that leads to the patio. The interior features a *tatami* platform, cherry wood floors, a small fireplace, a hanging cabinet, and wall lights designed by Nakashima. In addition to the open showroom area there is also a bathroom, office and kitchen area now used as office space.

Workshop (contributing building; map #6)
The Workshop is where the furniture is manufactured. The original section of the Workshop was constructed in 1946 with additions made to the building in 1959, 1970 and 1988. The original 1946 section of the Workshop is contained in the eastern most part of the building. In 1959 the original section of the Workshop was expanded by an addition on the west side. In 1970 the northern part of the Workshop was added and the carport to the east, later modified to shop space. The Workshop has a gable roof with a projecting clerestory added in

1985. The roof is covered with corrugated Transite and asphalt. Wall materials are wood, stucco, Transite, glass and cement block. It is irregular in shape measuring roughly 65' x 60'.

George Nakashima House (contributing building; map #7)
Built in 1946, the George Nakashima House served as the primary residence for the Nakashima family and is currently used as a residence by Kevin Nakashima, George's son. A small addition was built onto the house in 1954 for a bedroom. The house has a gable roof covered with wood shingles built in 1982 over the original poured concrete tile roof, expanding the house three feet to the south. Walls are stucco, stone and wood. It measures roughly 55' x 15' and is one story in height. The interior of the house features natural un-milled support posts, large recycled beams and hardwood floors. The living room has a fireplace and rice paper sliding doors that lead to a balcony that overlooks the open space areas of the property.

Heating House (contributing building; map #8)
The Heating House is a contributing building, measuring 17' x 9'. It was built in 1977 and is constructed of concrete block and wood. It housed the fuel and the wood-fired boiler for heating the George Nakashima House; the boiler has since been converted to oil.

Lanai (contributing structure; map #9)
The Lanai is a small structure designed for the Simpson Redwood Company to serve as outdoor living space. It was constructed in 1958 of California redwood with a cantilevered design and anchored in concrete. A stone barbecue is built into the structure. The roof is now covered with cedar shake shingles. It is counted as a contributing structure.

George Nakashima Garage (contributing building; map #10)
The garage is a small rectangular concrete block building with a gable roof covered with corrugated Transite. The walls are covered with stucco and it has a foundation of stone. It is a one-car garage with an overhead door and a round window. It also includes a laundry room and storage. The garage was constructed in 1967 and is a contributing building.

New Lumber Storage Building (contributing building; map #11)
The new lumber storage building was completed in 1982. The walls are constructed of cement block and it has a plywood and asphalt covered shed type roof. It is a contributing building.

Main Lumber Storage Building (contributing building; map #12)
Built in 1956, the main lumber storage building had an addition in 1968 and a small electric kiln addition in 1999. The main Lumber Storage Building features two hyperbolic paraboloid roofs made of plywood and covered with plywood and asphalt. Walls are constructed of cement block. It is a contributing building.

Reception House (contributing building; map #13)
The Reception House was built from 1975 to 1977 to serve as a guesthouse featuring a tea room and Japanese-style sunken bath; it continues to be used as a guest house and as a location for meetings. The roof of the house is covered with cedar shake shingles. The support system for the roof is a unique scissor truss design. Wall material includes stone, stucco and cement block. The interior features a living area with a fireplace, a dining area with a kitchen cleverly hidden behind sliding wood and rice paper screens and a tea room with a *tatami* floor. There is also a large, amoeba-shaped, sunken Japanese bath heated by a Japanese wood-burning boiler.

Pole Barn (non-contributing building; map #14)
Although designed by family members with an architect's background, due to its recent vintage, the pole barn is a noncontributing resource; it was constructed in 1990 with additions in 1995 and 2006. It is a very large building measuring roughly 45' x 180' and serves as a lumber storage building, containing the huge slabs of wood from which the Nakashima furniture is fashioned.

Pool Storage House (contributing building; map #15)
The Pool Storage House is used to store chemicals and equipment for the nearby Swimming Pool but was built primarily to serve as a prototype for the Pool House. It was built in 1958 and has a canted barrel vault roof made of plywood that rests on a cement block base. It is a contributing resource.

Pool House (contributing building; map #16)
The Pool House is a large building measuring 33' x 30' and is open at both ends. It was constructed in 1960 with a distinctively canted barrel vaulted roof design. The roof is constructed of plywood and covered with a thin layer of asphalt and edged with copper. The base of the Pool House is constructed of stone and concrete block. It is a contributing resource to the historic property.

Swimming Pool (contributing structure; map #17)
The Swimming Pool was built about the same time as the Pool house, in 1960, and won a prize for its amoeba shape with cantilevered overhang. It is constructed of reinforced concrete and is counted as a contributing structure.

Mira Nakashima House (contributing building; map #18)
The Mira Nakashima House was constructed in 1970 and is a contributing resource to the historic property. The building was designed and built by George Nakashima for his daughter Mira. It has a distinctive scissor truss roof design that is covered with cedar shake shingles. Wall materials include cement block, wood, and stucco. It has a concrete and wood deck across the main façade, accessed by a wood ramp. Large sliding doors lead from the deck to the house. The interior features an open floor plan, hardwood floors, with rice paper screened windows and a corner fireplace in the living area. The hardwood and linoleum floors are laid directly over the 3" x 8" structural members laid flatwise and project outside to form the porch. It has a kitchen, bath and four bedrooms.

Mira Nakashima Guest House (contributing building; map #19)
Built in 1971, the Mira Nakashima Guest House is a small building, the distinctive feature of which is its scissor truss roof design. The roof is covered with cedar shake shingles. Wall materials include stucco and cement block. It is a contributing building, but was restored and slightly reconfigured in 2008 by Mira.

Mira Nakashima Garage (non-contributing building; map #20)
The Mira Nakashima Garage was built in 1985. It was not designed or built by George Nakashima and is therefore a noncontributing building. It has a cedar shake roof and vertical wood siding.

Statement of Integrity

The George Nakashima House, Studio, and Workshop complex retains a high degree of historic integrity. Very few noncontributing resources are located on the property; with few exceptions most of the buildings remain unaltered and the setting and overall landscape of the property is outstanding. The noncontributing buildings on the property have designs that fit with the existing buildings. For example, the pole barn, while a very large storage building, is covered with naturally weathered boards and exposed rafter tails that mimic other buildings on the property. The Workshop is one building that has been altered due to the growth of the manufacturing operation. However, many of the changes that have occurred to the building fall within the period of significance and were executed by Nakashima; therefore, the changes are similar to and fit in with the buildings on the property. The setting for the property includes many small landscape elements that add considerably to historic value of the property. These landscape elements include small ponds, scattered trees some of which are unique specimens to the area, clusters of boulders and stone walls. Overall the property retains all aspects of historic integrity including its location, setting, materials, design, workmanship, feeling and association.

8. STATEMENT OF SIGNIFICANCE

Certifying official has considered the significance of this property in relation to other properties:
Nationally: X Statewide:__ Locally:

Applicable National Register Criteria: A__ B X C X D

Criteria Considerations (Exceptions): A__ B__ C__ D__ E__ F__ G

NHL Criteria: 2 and 4

NHL Exceptions: 8

NHL Theme(s): III. Expressing Cultural Values
5. architecture, landscape architecture, and urban design;
6. popular and traditional culture.

V. Developing the American Economy
1. extraction and production
2. distribution and consumption

Areas of Significance: Architecture
Art (American Craft movement)
Commerce
Engineering
Ethnic Heritage, Japanese
Industry
Landscape History

Period(s) of Significance: 1946-1982

Significant Dates:

Significant Person(s): George Nakashima

Cultural Affiliation:

Architect/Builder: George Nakashima

Historic Contexts: XVI. Architecture
International Style

State Significance of Property, and Justify Criteria, Criteria Considerations, and Areas and Periods of Significance Noted Above.

Introduction

The George Nakashima Woodworker complex is significant under NHL Criterion 2 for its association with internationally renowned furniture designer and woodworker George Nakashima, and under Criterion 4 for its innovative Japanese influenced International Style structures designed by Nakashima and built under his direct supervision. Criterion Exception 8 with regard to the fifty-year rule is applicable since six of the seventeen contributing resources on the property post-date 1963, although all but one was designed by Nakashima, who lived, worked, and played a role in the furniture business on the property until his death in 1990. These more recent buildings also played integral roles in the operation of the company and the relationship of his family, which were interwoven. The property includes his former residence, studios, showroom, production workshops, reception house, lumber storage buildings, and other resources associated with his family and career from 1946 through 1990. Construction began on the first building in 1946; the last building George Nakashima designed and built was completed in 1975. Mira Nakashima-Yarnall continues to produce furniture based on her father's archive of designs, as well as her own original work, which is in keeping with his design philosophy. She and other family members, including her brother Kevin and some of her children and their families are also involved in the business.

George Nakashima is recognized as one of America's most eminent furniture designer-craftsman, and a significant force within the American Craft movement of the mid-twentieth century, a seminal period for woodworking in the United States.[1] As a self-proclaimed "woodworker," Nakashima became an important voice for the artist craftsmen, helping to create a new paradigm for studio furniture production in the postwar period.[2] While revered as a master craftsman, Nakashima preferred the moniker "woodworker," reflecting his life-long commitment to the subjugation of the ego as a means to developing his creative force. Nakashima's exposure to eastern religion and Japanese craft traditions taught him not only the value of humility, but of seeking peace, beauty, and harmony through one's work. As was true with the previous Arts & Crafts period of furniture making, Nakashima and others within the new movement rejected the mass-production brought on by the machine age. At the same time, they embraced Modern stylistic influences and ideas that were international in scope. Reflecting the European Modernist tradition, Nakashima espoused a minimalist, utopian vision of design for the common man. Often defined as "organic naturalism," his timeless pieces defy stylistic categorization, although some designs harken back to American classics such as the Windsor chair and the Shaker "plain style."[3] Believing in the spiritual qualities of wood, Nakashima's signature features incorporated techniques intended to enhance the impact of the wood's natural beauty, such as the "free-edge" and the use of butterfly inlays. The wood was cut along the grain to form large, monolithic slabs and elements generally viewed as imperfections such as knots and splits were celebrated. Nakashima's veneration for wood as his

[1] David L. Barquist, "Druids and Dropouts: Working Wood, 1945-1969," in *Crafting Modernism: Midcentury American Art and Design,* ed. Jean Falino (New York: Abrams, in association with Museum of Arts and Design, 2012), 226-245.

[2] Janet Koplos and Bruce Metcalf, *A History of American Studio Craft* (Chapel Hill: The University of North Carolina Press, 2010), 249-250. According to the authors, Nakashima received quite a bit of publicity and his opinions became influential. He and a few others represent a new paradigm for studio furniture: the woodworker. As they explained, Nakashima defined woodworker as "one who makes things in wood, adopting an approach that seeks to integrate both art and craft," taken from George Nakashima, *Soul of a Tree*, 219. Nakashima outlined his "woodworker" philosophy is his address at a path-breaking conference held in New York in 1953 on the topic of the influence of design on modern living.

[3] Steven Beyer, *George Nakashima and the Modernist Moment* (Doylestown, Pennsylvania: James A. Michener Art Museum, 2001), 12. Nakashima's designs for chairs in particular are reminiscent of traditional American designs such as the Windsor chair or chairs crafted by Shaker craftsmen.

medium is expressed in his seminal work *The Soul of a Tree,* where he speaks of his desire to "offer the tree a second life of dignity and strength." The book has provided inspiration for many craftsmen.[4]

His success as an artisan propelled him briefly into the arena of mass-production; between 1945 and 1954 internationally recognized modern furniture manufacturers Hans and Florence Knoll produced a selection of Nakashima's designs, which appeared alongside other noted modernists including: Franco Albini, Harry Bertoia, Pierre Jeanneret, Ludwig Mies van der Rohe, Isamu Noguchi, Eero Saarinen, and Florence Knoll herself. High-end furniture manufacturer Widdicomb-Mueller of Grand Rapids, Michigan likewise produced suites of Nakashima furniture, between 1957 and 1961. According to Steven Beyer, "By the early 1950s, less than ten years after the establishment of his studio, Nakashima had distinguished himself as one of the most important [furniture] designers practicing in America." His foray into mass-production exposed Nakashima to a much broader audience, elevating his national standing as a designer and leading to comparisons with other noted American furniture designers of the era such as Charles & Ray Eames. However, Nakashima saw furniture making more as a spiritual journey, crafting unique pieces that responded to the natural form of each piece of wood.[5] Thus he soon returned to his workshops as his sole means of production and, with the help of a handful of skilled individuals (which later included daughter Mira), was able to maintain his high standards for quality and integrity. In this regard, Nakashima is more appropriately compared with prominent craftsman such as Wharton Esherick and Sam Maloof. Still, Nakashima's work expresses a worldview that is based upon a unique set of circumstances including his formal education in architecture, his exposure to European Modernism, eastern religious philosophy, and traditional Japanese craft traditions, including instruction from Issei carpenter Gentaro Hikogawa while both men were confined in a Japanese-American Internment Camp. As a testimony to George Nakashima's skill and national prominence, he was awarded the American Institute of Architect's Craftsmanship Medal in 1952. Nakashima's work has also been included in some of the most celebrated national exhibitions of handcrafted Modern furniture of the twentieth century, and he appears in every noted publication on the craft movement and fine woodworking in America.[6]

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[4] George Nakashima, "The Soul of a Tree," in *The Craft Reader,* ed. Glenn Adamson (Oxford and New York: Berg Publishers, 2010), 222. Originally published as George Nakashima, *The Soul of a Tree: A Master Woodworker's Reflections* (Tokyo/New York: Kodansha, 1981).

[5] Todd Merrill and Julie V. Lovine, *Modern Americana: Studio Furniture from High Craft to High Glam* (New York: Rizzoli International Publications, Inc., 2008), 125. According to the authors, "George Nakashima was surely one of the most recognized of the so-called studio furniture makers emerging from the postwar period. His name was constantly linked with the likes of Charles Eames and Eero Saarinen. However, while those designers were dedicated to the cause of mass production, Nakashima remained adamantly a craftsman, ever suspicious of the dehumanizing effects of the machine made."

[6] Exhibits include: the Museum of Modern Art's first exhibition of American design titled, *Design for Use, USA* (1951); the Renwick Gallery of the Smithsonian Institution's *Woodenworks* (1972); and Boston's Museum of Fine Arts's *The Maker's Hand: American Studio Furniture, 1940-1990* (2003). Nakashima's work has also been the focus of exclusive showings, such as: New York's American Craft Museum's *Full Circle*, a fifty year retrospective (1989) and the James A. Michener Museum's *George Nakashima and the Modernist Moment* (2001).

Publications in which George Nakashima is the sole subject include: and Derek E. Ostergard, *George Nakashima: Full Circle* (1989); Steven Beyer, *George Nakashima and the Modernist Moment* (2001); Mira Nakashima, *Nature, Form & Spirit: The Life and Legacy of George Nakashima* (2003). He was also included in an influential study organized by the Committee on Design and Craftsmanship titled "A Study of Design and Craftsmanship in Today's Products" presented by the Walker Art Center in Minneapolis, which included an exhibition and conference. George Nakashima is featured in the most authoritative texts on American craft, Modernism, and studio furniture, including: Edward S. Cook et al, *The Maker's Hand: American Studio Furniture, 1940-1990*; Glenn Adamson, ed., *The Craft Reader* (2010), the first comprehensive anthology of writings on modern craft; Todd Merrill and Julie V. Lovine, *Modern Americana: Studio Furniture from High Craft to High Glam* (2008); Jeannine Falino and Jennifer Scanlan, *Crafting Modernism: Midcentury American Art and Design* (2011), in-depth examination of the American studio craft movement in the decades following World War II (featuring the greatest artisans within the major mediums); Janet Koplos and Bruce Metcalf, *A History of American Studio Craft* (2010). The Woodenworks exhibition was also accompanied by a publication: *Woodenworks; Furniture Objects by Five Contemporary Craftsmen: George Nakashima, Sam Maloof, Wharton Esherick, Arthur*

George Nakashima began his professional career as an architect, working at the vanguard of International Modernism in Japan before turning to furniture design. Thus as a trained architect, George Nakashima is also responsible for the design and construction of the structures that comprise the Nakashima Woodworker complex, erected between 1946 and 1982. Designed in the International Style intermingled with elements of traditional Japanese architecture and featuring the innovative use of concrete, these structures are to be considered among the treasures of Nakashima's unique legacy of craftsmanship. Pure examples of the International Style are fairly rare, and these structures reflect Nakashima's exposure to some of the early pioneers of the style that gave birth to the Modern movement in architecture. Most notably, Nakashima worked in Japan with Antonin Raymond who was a protégé of Frank Lloyd Wright and is generally considered to be a father of Modern architecture in Japan.[7] While Nakashima's skillful and innovative approach to architecture is manifested in the buildings that he designed for his New Hope complex, examples of his work in the United States are extremely limited. In fact, his transformation from architect to furniture designer was primarily a reaction to American architectural practice in the mid-twentieth century, which he found antithetical to his earlier experiences in Europe and Asia. Nakashima embraced the hallmarks of the new International Style, such as its simple forms and clean lines, open plan, and expansive glass—elements often made possible through the plasticity of concrete construction. To this he added authentic elements of traditional Japanese building craft. In addition, well known structural engineers Paul Weidlinger, Matthys Levy and Mario Salvadori worked with George Nakashima on the Conoid Studio, Chair Department, and the (first) lumber storage building to create unique, experimental roof forms using concrete construction.

George Nakashima's Early History and Influences

George Nakashima was born May 24, 1905 in Spokane, Washington. He grew up in the forested mountains of the Pacific Northwest that surrounded his family home in Seattle. His education consisted of the study of forestry—perhaps initiating his reverence for trees—and then architecture at the University of Washington. In 1928 he was given a one-year scholarship to study architecture in Paris at the Ecole Americaine des Beaux-Arts in Fountainebleu. After graduating from the University of Washington in 1929 he received a scholarship to attend the Graduate School of Design at Harvard University. Preferring a better grounding in engineering, he soon transferred to the Massachusetts Institute of Technology (MIT) and received a Masters degree in architecture in 1930. While Nakashima believed that architecture must transcend engineering, he felt that an understanding of engineering principles and the nature of building materials was essential in order "to satisfy an architect's obligation to truth."[8] After MIT he was hired by the Richard Brooks Studio in New York to paint

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Espenet Carpenter, Wendell Castle (1972). George Nakashima was the cover feature in *Fine Woodworking* magazine, a publication considered to be the first comprehensive periodical for technical information on hand skills, new technologies, machine tools, and woods. See: John Kelsey, "George Nakashima: For Each Plank There's One Perfect Use," *Fine Woodworking* 14 (Jan.-Feb. 1979): 40-46.

George Nakashima's house has also been featured in three publications: Tina Skinner, *Esherick, Maloof, and Nakashima: Homes of the Master Wood Artisans* (2009); and Leslie Williamson, *Handcrafted Modern: At Home with Mid-century Designers* (2010), which includes the most significant interiors created by the designers themselves as their own residence, including those of: Russel Wright, George Nakashima, Harry Bertoia, Charles and Ray Eames, Walter Gropius, Eva Zeisel, and Albert Frey; Michael Gotkin, *Artist's Handmade Houses* (2011), featuring the homes of Henry Chapman Mercer, Paolo Soleri, Russel Wright, Henry V. Poor, Raoul Hague, George Nakashima, Ralph R. Whitehead and Jane B. McCall, Sam Maloof, Frederick E. Church, Constantino and Ruth Nivola, Ruth and Robert Hatch, and Michael Kahn and Leda Livant.

[7] Kurt G. F. Helfrich and William Whitaker, eds., *Crafting a Modern World: The Architecture and Design of Antonin and Noemi Raymond* (New York: Princeton Architectural Press, 2006), 25.

According to Mira Nakashima, at Harvard, "he soon discovered that Harvard's program was based on the theoretical design approach of Walter Gropius and the Bauhaus School. So, after only a few weeks at Harvard, his quest for a solid grounding in engineering propelled him to . . . MIT." Mira Nakashima. *Nature, Form & Spirit: the Life and Legacy of George Nakashima* (New York: Abrams, 2003), 13.

murals for the New York capitol building in Albany and a year later was hired by the Long Island State Park Commission to paint murals and design buildings. He worked on projects at Jones Beach, Sunken Meadow Park, and Montauk Point. He lost the job in 1933 due to the depression and traveled across the country to Seattle to see his parents. From Seattle he traveled back to New York and then via steamship across the Atlantic Ocean eventually making his way once again to Paris.

Near Nakashima's apartment in Paris, renowned Modernist architect Le Corbusier's "Pavillion Suisse" was under construction. According to his autobiography *The Soul of a Tree*, Nakashima made weekly visits to observe the process.[9] The Pavillion Suisse is considered a landmark Modern design. It signaled the application of the International Style to structures other than those intended for industrial purposes, moving beyond functionalism to incorporate curvilinear forms and aesthetic details. Nakashima was greatly impacted by this structure. According to Mira Nakashima,

> While Nakashima had surely been introduced to the design philosophy of Le Corbusier during his years of studying architecture in the United States and at Fontainebleau, seeing the Pavillion being built allowed him to observe the Swiss master's work at very close hand. As he watched the structure grow week by week, he was filled with excitement to learn Le Corbusier's techniques and methods of building, his innovative use of concrete, and his new forms. Nakashima's vigilant observation allowed him to carry an intimate knowledge of the procedure and construction methods of reinforced concrete—not to mention a love for the expanded possibilities of the medium—throughout his life.[10]

Nakashima appreciated, and later applied to his own designs in New Hope, Le Corbusier's use of concrete, open-space planning, simple, clean lines, and horizontal courses of windows (intended to admit as much light as possible). Le Corbusier also calibrated his proportions based on the height of a man, which, he believed, assured a sense of harmony throughout the work, and promoted a feeling of peace and well-being. According to Mira, "All of these principles were, in fact, shared by the traditional architecture of Japan, and they resonated deeply with Nakashima."[11]

After a year in Paris, Nakashima traveled to Japan. He visited his mother's ancestral home in Kamata and was immersed for the first time in the traditional lifestyle of the Japanese. As Nakashima described his time in Japan, "It was a great experience to savor the life of my forebears after having spent my youth in America. The sensitive environment, the expressive language, the excellence of the architecture and crafts, the traditions and the personal relationships—all touched me to the depths of my being."[12] In 1934 he took a job with architect Antonin Raymond, who is recognized as the father of Modern architecture in Japan.[13] Raymond came to Japan to work with Frank Lloyd Wright on the Imperial Hotel, and decided to stay and set up an architectural office in Tokyo after the project was completed. Raymond was interested in integrating modern Western building technology with traditional Japanese architectural forms. In so doing, he worked closely with Japanese craftsmen and absorbed their traditions in a manner that had apparently eluded Wright. Likely as part of their personal interest and professional study of Japanese building traditions, Nakashima traveled with coworker Junzo Yoshimura to visit various architectural monuments, including the shrines and temples of the ancient capital of Kyoto. According to Nakashima, these were "fabulously built wooden structures expressing the

[9] George Nakashima, *The Soul of a Tree: A Woodworker's Reflections* (New York: Kodansha International, 1981), 10.
[10] Mira Nakashima, *Nature, Form & Spirit*, 16-17.
[11] Ibid., 18.
[12] George Nakashima, *Soul of a Tree*, 59.
[13] Helfrich and Whitaker, *Crafting a Modern World*, 25.

beauty and serene quality of the island people of Japan, and the deep reverence these people have for nature."[14] They also attended tea ceremonies and festivals. The cumulative effect of these experiences was the development within Nakashima of a deep appreciation of Japanese cultural and architectural traditions. In addition, Sakakura and their other coworker, Kunio Maekawa, had worked with Le Corbusier in Paris and so Nakashima was able to learn more about the master's work and to exchange ideas.[15]

Around 1936 the Raymond office received a commission to design a building for the ashram of Sri Aurobindo in Pondicherry, India. George Nakashima was interested in working in India and agreed to oversee the design and construction of the building. While working on the project, he became a disciple of Sri Aurobindo and partner Mira Alfassa, and donated his salary for the project to the monastery. They had developed a spiritual philosophy known as Integral Yoga, which taught that beauty is the expression of divine truth, that freedom fosters creativity, and that focus develops discipline. These ideas deeply affected Nakashima such that "when he established his own studio in Bucks County, he wanted it to be a center for the evolution of a life moved by a higher consciousness, a life of the spirit." Thus according to his daughter Mira, "He always spoke of his work as a spiritual adventure, as an attempt to bring forward his psychic being, but rejecting all that comes from the ego, vital desire, and the mind's presumptuous, reasoning incompetence."[16] The building, named Golconde, was constructed in the International style of reinforced concrete with a roof made of 5' x 3' pre-cast concrete barrel vaulted sections. The experience underpinned Nakashima's passion for, and increased his knowledge of, reinforced concrete construction that he would later realize in his designs for the New Hope compound.

George Nakashima completed his work in India and traveled back to Tokyo in 1939. At this time the world was on the verge of war and Antonin Raymond closed his office in Tokyo and moved to New York City, later purchasing a farm outside of New Hope, Pennsylvania. While he was in Tokyo George Nakashima met Marion Okajima, a Japanese American working as a private English tutor, and they were engaged. When he returned to the United States, Marion joined him and they were married in Los Angeles in 1941. Settling in Seattle, Nakashima worked as an architect for Ray Morin while beginning to make furniture part time. Father Leopold Tibesar of the Maryknoll Boy's Club gave Nakashima permission to use their basement workshop in exchange for teaching the boys woodworking. He set up a small furniture shop and it was there that he produced his first privately commissioned collection of handcrafted furniture, for cosmetics executive Andre Ligne. The commission allowed Nakashima to devote himself full-time to furniture making and he made the decision to reject his architecture career. He had become increasingly disillusioned by American architectural design and practice, particularly that of Frank Lloyd Wright, whose work, although beautifully designed and spectacularly celebrated, was poorly engineered. Nakashima believed, however, that furniture making was a natural extension of architecture at a smaller scale, and that his experience as an architect could inform his furniture design. While in Seattle, he also developed a friendship with artist Morris Graves who shared his interest in Indian philosophy and who gave him a book on Shaker furniture, a now well-worn volume within his still extant reference library.

On December 7, 1941 the Japanese attacked Pearl Harbor and shortly thereafter those of Japanese ancestry living on the West Coast were forced into internment camps away from the Pacific Coast. The Nakashimas, including their newborn daughter Mira, were relocated to Camp Minidoka in Idaho. In George Nakashima's autobiography *The Soul of a Tree,* he describes the mass incarceration in the internment camps as "a stupid and insensitive act, one by which my country could only hurt itself. It was a policy of unthinking racism."[17]

[14] George Nakashima, *Soul of a Tree*, 58.
[15] Mira Nakashima, *Nature, Form & Spirit*, 18.
[16] Ibid., 34.
[17] George Nakashima, *Soul of a Tree*, 69.

Despite the horrendous circumstances, Nakashima made the best of his situation. As luck would have it, Japanese carpenter Gentaro Hikogawa was also incarcerated at the camp; Hikogawa was well trained in the use of traditional Japanese hand tools and had an intimate knowledge of Japanese wood joinery. Hikogawa taught his skills to Nakashima, thus enhancing Nakashima's already considerable furniture making ability. They used scraps of wood and bitter-brush scavenged from the desert to make pieces of furniture that could enhance their primitive living conditions. While Nakashima claimed to bear no scars from the interment experience, it certainly strengthened his beliefs. As Mira explains, "Fortunately, he was able to transform anger and negativity into the positive passion of conviction, the passionate creativity of his work, and the passion for beauty and perfection, which served him well."[18] Rather than building animosity because of his heritage, Mira points out that "My father's insistence that he was a citizen of the world not limited by national or racial boundaries, enabled him to rise above prejudice and persecution, to embrace, rather than reject the Japanese culture and aesthetics as few, if any, of his fellow internees dared."[19] In fact, the experience eventually led to the conception of the globe-encircling Altars for Peace that he would erect in his later years.

In 1943, one of George Nakashima's professors at MIT contacted his former employer Antonin Raymond to petition for the release of the Nakashima family which was granted with the provision that Nakashima work for Raymond. Since many of Antonin Raymond's jobs at the time were government related, Nakashima could not work as an architect, but as a worker on his New Hope farm, primarily tending to the chickens. However, he was able to set up a small workshop in the Raymond's milk house, designing what became known as the "milk house" stool and table, which, among other designs, were a regular part of his furniture line. While living in the New Hope area, George Nakashima also became enamored with the building traditions of the early Quaker settlers. In fact, in *The Soul of a Tree*, he includes sketches of the nearby Thompson-Neely house and barn.[20] In 1945, after the war was over, George Nakashima moved into a small house near Meetinghouse Road and continued to design and build furniture. In 1946, he approached a Quaker farmer and asked him if he could have three acres of his land along Aquetong Road in exchange for carpentry work. The farmer agreed and George Nakashima began to construct his Workshop while he and his family lived in a tent on the property. The parcel was expanded through the years to 8.7367 acres, 12.2 acres including Mira's property.

The Development of the George Nakashima Woodworker Complex

Soon after he acquired the land George Nakashima built his Workshop, immediately followed by the design and construction of a house for himself and his family. Thus began a tradition of combining family residential buildings with workshops, storage buildings, and studios; and mixing family life with the manufacture, design, and marketing of furniture. As the business grew Nakashima hired workers to assist him, who often became like family members themselves. George Nakashima was the creative talent, while his wife Marion acted as the business manager. Children Mira and Kevin Nakashima would eventually become a part of the business, with Mira playing a major role in the design and manufacturing of the furniture, including the execution of designs from the archive left by her father as well as the introduction of her own design in the same spirit. The house the family lived in was small, just one story high and relatively simple in design, reflecting his signature blend of Modern architecture and Japanese building traditions. In addition to designing these buildings, George Nakashima also took a hands-on approach to their actual construction. He was his own general contractor on each project and directly supervised the work, if not actually performing the work himself. He also rarely made blue prints of his designs. Instead he drew his plans by hand with pencil on paper, which was also true of his furniture designs. Although Nakashima was capable of producing high-quality architectural renderings, the fact

[18] Mira Nakashima, *Nature, Form & Spirit*, 43.
[19] Ibid., 41.
[20] George Nakashima, *Soul of a Tree*, 69, 71.

that none were produced for these structures reflects Nakashima's insistence on being an active participant in the construction as well as the design process.

The first structure to be erected was the Workshop, in 1946. It is a simply constructed building made of cement block with large windows in the southern exposure for natural lighting and war surplus Transite roofing. It has been expanded over the years to include additions made in 1959, 1970, and 1988. While the Workshop is an unassuming structure, it has been in continuous use as the site for the production of Nakashima furniture since its inception in 1946. It is where most of the furniture was created, the woodworkers trained, and where Nakashima worked through the creative process to realize new designs.

George Nakashima next turned to building a house, which he did largely on his own using both traditional and/or indigenous and experimental materials. According to daughter Mira,

> The house was of stone, with oak framing, and some experimental materials such as concrete roof tiles. I remember watching my father hand-pouring and setting the concrete tiles on the roof, and we used to pick up fieldstone along the highway and put them in the car if they looked to be the right size and shape for the wall he was constructing. Dad would often send me to the rock-pile to find small stones to fit into a particular spot; it was my first lesson in architecture.[21]

In the tradition of the International Style, the George Nakashima House combines natural materials including local stone, white stucco walls, and simple wood trim to create an asymmetrical design that also features exposed framing, ribbon windows, glass walls in the living area, and an open floor plan. Elements indicative of Japanese architecture include rice paper Shoji screens used as dividers, and rafters and support posts (or parent posts) consisting of un-milled trees simply stripped of their bark. The living room ceiling is made of wide cedar panels held by clips to allow for expansion. The alternating use of materials, the lack of symmetry, and exposed structural elements create architectural interest, the result of which is that no two elevations resemble one another. The street front features local stone with an entrance almost hidden in a recessed area to one end. In the opposing elevation, the stone is carried out in the retaining wall while the section of wall above is faced in stucco. One end of the house is covered with natural wood planks laid vertically while the other is of plain stucco. As with all the Nakashima structures, the attention to detail is striking. Dark stained rafters extend under the eaves and in the gable ends, with the rafter ends painted white to highlight them; similar exposed framing appears in the ceiling of the recessed entry porch, and various structural elements appear on the exterior where the roof supports meet the walls. And as in the Japanese tradition whereby houses are to be in harmony with nature, transition between the indoors and outdoors is created by means of wide doorways entering onto patios and decks. There is no railing on the deck to obstruct the view and large stones are used as they were found in nature as steps leading from the deck to the yard, which is covered in pebble-sized stone. Stone retaining walls help to level the house and yard, which is banked within the hillside.

For a considerable length of time (1946 to 1954) the Workshop and house were the only buildings on the property. A series of events occurring during this period greatly increased Nakashima's recognition, providing both the demand and capital needed to expand his business. The result was the design and construction of additional structures to the new Hope complex. In 1946 Nakashima established a relationship with H.G. Knoll Associates, a furniture manufacturer in New York City, and with Widdicomb-Mueller Company of Grand Rapids, Michigan, in 1957. While short-lived, these relationships presented significant opportunities for Nakashima. In 1951 examples of George Nakashima's furniture were included in a well traveled, ground-

[21] Mira Nakashima, *Nature, Form & Spirit*, 46.

breaking exhibition of Modern design initiated by the Museum of Modern Art in New York City. From 1951 to 1961, the Jamaican resort, Frenchman's Cove, commissioned George Nakashima to build a collection of furniture for the resort. Two dining tables designed for the Frenchman's Cove project became part of Nakashima's regular line of furniture and were sold at after 1958 at the new Showroom.

In 1955 a building was constructed for lumber storage, which was quickly converted to a furniture Finishing Department. Thus began a significant period of construction at the New Hope property. Mira describes her father's work during this period:

> As the furniture business prospered, it afforded him the financial capability to consider building again, and indeed, demanded more space for his operations. He also continued to design and build elsewhere as opportunities arose. Although he had not done any architectural work since he had put up his first house and workshop on the New Hope property, 1954 marked the beginning of a flurry of building, which would include new space to work, to show pieces to clients, and to store the expanding inventory of lumber, and even in 1960, to build a kidney-shaped swimming pool and barrel-vaulted pool house. The most important of these new buildings was the Conoid Studio, which would be a combination design studio, conference room, and a place to keep some of his finest pieces of wood.[22]

Along with the Finishing Department, George Nakashima designed and built the Showroom in 1954. Like the Nakashima house, the Showroom is a finely crafted structure that blends inside with out, and Modernism with traditional Japanese motifs. It is a one-story rectangular building with a large open interior space to display furniture, with ample room for conducting business. Also like the Nakashima house, it includes character defining elements such as exposed framing members highlighted against white drywall ceilings, stone walls visible both inside and out and including a stone fireplace with custom-designed metal hood, large expanses of glass, and the use of shoji screens. Again, in keeping with the Japanese philosophy of harmonizing the structure with its natural environment, sliding glass doors lead to a wood deck that overlooks a small pond, situated at the gable end. The surrounding landscape includes stone retaining walls and pebble walks.

In 1954, Kevin Nakashima was also born to George and Marion Nakashima. As a result, the house had to be expanded by an addition to include another bedroom.

Building continued on the property and by 1956 George Nakashima began the use of experimental warped shell roof designs, particularly the conoidal and hyperbolic paraboloid. Simplistically speaking, a conoid is a modified cone shape, while a hyperbolic paraboloid is a saddle-shaped curve. Both are innovative and economical methods of covering a large area with a relatively thin and lightweight roof surface. In experimenting with the conoid shell roof type, Nakashima designed and built a clubhouse or lounge for his workers in 1956. The building's roof was made of a layered plywood shell. The clubhouse was soon converted for use as a chair assembly shop, or the Chair Department as it is now known. It was followed in 1960 with the construction of the most remarkably engineered and designed building on the property, the Conoid Studio. To construct the Chair Department (1957), Conoid Studio (1957-60) and the main lumber storage building (1956) George Nakashima hired engineers Paul Weidlinger, Mario Salvadori, and Matthys Levy of Weidlinger Associates. Paul Weidlinger was the founder of Weidlinger Associates Incorporated in New York City, which

[22] Ibid., 136.

continues to be one of the most outstanding engineering consulting firms in the world, specializing in the analysis and effect of seismic activity on buildings and structures.[23] As Mira explains,

> During the 1950s he [George Nakashima] became fascinated by the capabilities of warped thin-shell or "form-resistant" structures. He especially admired the work of Mario Salvadori, Paulo Luigi Nervi, and Felix Candela, and had a correspondingly low opinion of some of Eero Saarinen's concrete structures, which he called 'unwilling' shells, because of their thickness. He determined to build his own shells, based on sound engineering principles that would permit both an economical use of materials and 'organic' forms. Behind this idea lay a belief that sound engineering was an expression of the laws of nature, and that a beautiful structure was a manifestation of those laws.[24]

The studio measures 40' x 40' and so the idea of the curved or conoid shape was to support the roof and allow it to cover a large open space. While an ordinary conoid has a doubly curved surface, the team decided to add a series of small sine curves to increase the strength of the roof, resulting in its unusual scallop-shell-like appearance. The roof is supported and further strengthened by a reinforced concrete arch located at the overhanging front of the building, with a concrete lintel atop the wall supporting the rear and stiffeners inserted in alternate corrugations. According to an article appearing in *Engineering* magazine at the time of its construction, "The resulting shell has an entirely new form and represents a new application of the conoidal shell." As the article also states, while conoidal shells are frequently used in monitored industrial buildings in Europe, they are rare in the United States. Thus, this represents a "departure in the design philosophy of reinforced concrete shells"[25] and a truly unique structure. The roof of the Conoid Studio is not only unique for its shape, but also for its poured reinforced concrete construction, which measures only 2-½" in thickness.

The interior of the Conoid Studio is a masterful blend of Modern design with Japanese elements such as shoji screens to modulate the light emanating from the completely glazed front wall. The conoid roof was highly successful in creating the desired effect. As Mira describes it:

> The overall effect of the interior of the Conoid Studio is that of a soaring, freely undulating, but organically disciplined space, something like a gigantic, organically formed seashell, transiting in graduated waves from a flat sine curve to an open arch facing the sun. The walls of this structure would be largely glass, as they did not have to carry the weight of the roof.[26]

A finely crafted wood partition separates the studio space from the domestic uses, such as the kitchen, bathroom, storage, and design office space.

Interleaved with George Nakashima's building and architectural work on his New Hope property, the furniture manufacturing business was thriving. Construction of the Conoid Studio inspired George Nakashima to design

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[23] Mario Salvadori was an engineer and architect who worked on the Manhattan Project during World War II. In 1956, Matthys Levy was a recent graduate in structural engineering from Columbia University. He went on to design and engineer landmark structures including the Georgia Dome in Atlanta and La Plata Stadium in Argentina. He also was a consulting engineer on the investigation into the collapse of the World Trade Center buildings in New York City on September 11, 2001. He currently is chairman of Weidlinger and Associates, Inc. in New York City.

[24] Mira Nakashima, *Nature, Form & Spirit*, 136.

[25] "Adventure in Structure, Sea Shell Roof," *Architectural Record* 122 (November 1957); and Matthys P. Levy and Paul Weidlinger, "Conoid with Corrugations Makes an Unusual Roof," *Engineering News-Record* 159 (December 5, 1957).

[26] Mira Nakashima, *Nature, Form & Spirit*, 136.

an entire line of furniture that he sold at his New Hope showroom including the Conoid chair, bench, coffee table, end tables, and dining table. The Conoid furniture differed from much of Nakashima's earlier work by including daring architectural elements such as "rigorously architectonic bases" cantilevered seats, angled back supports, and thin floor runners. As biographer Derek Ostergard points out, Nakashima used for the first time the "fully developed cantilevered seat, a powerful statement, perhaps reflecting confidence after completion of the Conoid Studio."[27]

Like the Arts Building, the main lumber storage building constructed in 1956 of cement block has two thin hyperbolic paraboloid roofs built with three layers of 3/8" plywood in order to cover a large open space of thirty-one square feet. Noted for its economy and ease of construction, Nakashima called his new method of constructing a hyperbolic paraboloid, "perhaps the easiest and cheapest way to roof a clear span of this size."[28]

In 1958, George Nakashima was commissioned to design an outdoor living room by the Simpson Lumber Company of Arcata, CA. The living space was designed as a cantilevered lean-to anchored in a concrete base and included a stone barbecue. The "Lanai," as it came to be known, was designed to be built of redwood. The lumber company advertised the outdoor family room in various popular magazines of the time, offering copies of the plans for the structure at no charge. This was a marketing tool by the Simpson Lumber Company to entice customers to purchase its redwood lumber products. In the July 1958 issue of *The Woodworker* Nakashima is quoted as saying the project was intended to "bring the East to the West." As it was explained, "This 'lanai' features two cantilevered piers of reinforced concrete around which Nakashima has used California redwood to produce an aura of pure beauty as well as practicality. The graceful shingled roof imparts a light and serene feeling and the entire structure is airy, yet strong; protective, yet unobtrusive, and the design reflects the manner in which wood can be worked with the best styling of both the Orient and the West."[29] The prototype for the Lanai is on the Nakashima property near the Reception House, and includes a stone beehive barbecue.

In 1959, the small and somewhat inconspicuous Pool Storage House was constructed. Its significance is that it was a prototype for the much larger Pool House that was built nearby in 1960. Mira Nakashima, a high school senior at the time, assisted with the design and construction of the Pool Storage House. Both the pool storage building and the Pool House have plywood barrel vaulted roofs set on solid stone or cement block foundations. The Pool House was also designed to have a passive solar heating system that provides hot water for showers in the building. The Swimming Pool is also uniquely designed and engineered with a cantilevered concrete extension on the south side and won a design award in 1960.

By now, the Nakashima complex had grown considerably and in a manner that was well integrated with the natural environment. In his furniture catalog Nakashima described himself as an architect for the whole environment, able to produce "an integrated concept of architecture, furnishings and landscape."[30]

The next building to be constructed on the property was the Arts Building, in 1967. The building has a hyperbolic paraboloid roof design and was specifically constructed to display the works of Ben Shahn, the well-known mural painter, photographer, and social activist. George Nakashima and Ben Shahn became friends in the 1950s. George Nakashima designed an addition on Ben Shahn's house in the New Deal community of

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[27] Derek E. Ostergard, *George Nakashima: Full Circle* (New York: Wiedenfeld & Nicolson, 1989), 77.

[28] "A Lumber Storehouse, New Hope, Pennsylvania," *Architectural Record* 126 (July 1959).

[29] Kenneth R. McDonald, "Pennsylvania Designer Uses California Redwood to Fashion this 'Lanai'," *The Woodworker* (July 1958): 31.

[30] Ostergard, *George Nakashima*, 80.

Roosevelt, New Jersey, and Ben Shahn purchased furniture from George Nakashima. From 1967 to 1969, Ben Shahn's art was sold at the Nakashima studio in New Hope and in the Arts Building following its construction. Ben Shahn sketched a tile mosaic that he proposed for installation on the west wall of the Arts Building. Unfortunately Shahn passed away in 1969, prior to its execution by the Gabriel Loire stained glass studio in France. The tile mosaic was built in eight sections and transported back to New Hope for installation on the west wall in 1972. Among the extraordinary features of the Arts Building is its cantilevered stairway, handcrafted by Nakashima, with steps resembling the edges of the milk house table embedded into the stone wall; its soaring roofline with exposed beams, its open space interior, and expansive glass walls. Perpendicular to the Arts Building is "the Cloister," a series of rooms—bedroom, bathroom, and service kitchen—that Nakashima intended to house visiting craftsmen from Japan (although that goal was never realized).

In 1970 Nakashima's daughter Mira and her family were in need of a place to live in the New Hope area and so he purchased a parcel of land across Aquetong Road from the main complex in 1968 and began the construction of her house. In the design and construction of Mira's house and an adjacent guesthouse, he employed a scissors truss roof, which is basically an asymmetrical gable resembling a partially open pair of scissors. It is an economical means of supporting a roof that with the addition of natural tree support posts on the interior and exposed support structure makes the roof both aesthetically pleasing and well engineered. It shares many of the same qualities of the George Nakashima House in its styling, use of materials and architectural elements, and blending of indoors and outdoors. It combines stucco and wood with concrete block, and has an open plan with sliding doors that lead out to a deck. The site also includes a small guesthouse of the same materials and also has the character defining scissor-truss roof.

Another building on the property that employs the use of a scissors truss roof is the Reception House or "Sanso Villa." Built in 1975-77, it was the last building on the complex to be designed and built by George Nakashima and is arguably his finest example of freely translated traditional Japanese domestic architecture. In addition to its demure scale and simplicity, it includes many other modern translations of defining characteristics of Japanese domestic architecture, including: its open space; exposed structural elements; three *nakabashira*, or internal posts, and a *daikokubashira*, also referred to as *oyabashira*, a parent or mother post; glass walls; *tatami* mat covered floors; and *shoji* screens. It begins with the *genkan* or welcoming entrance with storage for shoes, behind which is located a modern version of a *mizuya* or small kitchen with a cupboard and wash-up for tea utensils. The kitchen can be hidden behind shoji screens that open on to the dining area. On the other side of the room is the living area with a stone fireplace and built-in features including a window seat, *ji-bukuro* or low storage compartment (actually a casing for the heating elements) with cabinets above, and a *tsuke shoin* or built-in desk. The most distinguishing features are perhaps the attached Japanese tearoom, entered through an expanded *nijuri guchi* or a small doorway through which guests must enter on their hands and knees, and the *horiburo*, a sunken tiled but heated by convection from a Japanese wood-burning boiler.

The Reception House is furnished with many of Nakashima's signature pieces to complete the integrity of its design and jewel-box-like perfection. Like the other residential structures, the Reception House has sliding glass doors and a deck that looks out over the hillside from its terraced site. It reflects Nakashima's whole environment approach; the integration of architecture, furnishings, and landscape. With the completion of the Reception House in 1977, major architectural design and engineering work by George Nakashima on the site essentially, although he remained involved in the furniture design business continued until his death in 1990.

The International Style and Traditional Japanese Architectural Forms

As outlined, the structures that comprise the Nakashima complex were designed by George Nakashima in the International Style intermingled with elements of traditional Japanese architecture. While the combination may

sound peculiar at first blush, as Nakashima has proven, the two are eminently compatible. Both styles seek simplicity of form, celebration of the natural beauty of the materials, and the conspicuous display of structural components. As already discussed, Nakashima's background provided him with a very distinctive set of ideas and experiences brought together to create this site. These experiences included his architectural education, personal observations on the work of Modernist master LeCorbusier, his own work in Japan and India for Antonin Raymond, eastern religious philosophy, and his exposure to traditional Japanese craftsmanship. Although Nakashima eventually abandoned architectural practice in favor of woodworking, he continued to design and build structures for his business and for himself and his family, and to bring an architect's understanding to the production of furniture. His keen perception of the philosophical and design principles that underpin both the International Style and traditional Japanese building practices are uniquely and expertly manifested at the Nakashima complex.

The International style first emerged in Europe in the 1920s and 1930s, and was formally introduced to America through a 1932 exhibition held at the Museum of Modern Art (MoMA). In a 1963 publication Henry Russell Hitchcock, one of the very same individuals responsible for that exhibition, announced that the International Style was now over.[31] The style had been deemed by many to be stark, cold, and elitist. And when compared to the revival styles of architecture then popular in the United States, perhaps their assessments were correct. The International style has always been considered a radical diversion from popular architectural practice, and in that regard it has been imminently successful; what early proponents of the International Style indeed intended was a break from the architectural conventions of the past. While pure examples of the International Style, particularly for residential architecture, are fairly rare, many mid-century Modern buildings reflect its influence. This is true most specifically with regard to the utilization of a set of basic design principles (outlined below) and the introduction of open floor plans.

Rather than slavishly copying the architectural styles of the bygone eras with all its fussy ornament, the International style sought beauty in the true character of construction. This notion has been popularly summarized by adages such as "less is more" and "form follows function." The three defining principles of the International Style—volume, regularity (rather than symmetry), and the avoidance of applied decoration—certainly reflect these ideals. If in fact the International Style is dead, it is certainly not forgotten, owing to the tremendous impact that it had on the profession worldwide. Before it was so named, the International style marked the emergence in Europe of the Modernist movement. It was nothing short of a revolution in architectural design that would reverberate across the globe. As one architectural historian explains, "The International Style served a vital purpose. By establishing a pattern and a method this movement provided the necessary backbone of the development of a new architecture, which might otherwise have floundered without certain shape or purpose. The International Style consciously defined a formula by which any architect could design a good building."[32] Thus the emergence of the International Style and the subsequent rejection of historical precedent in architectural design had a profound effect on architectural practice and education in the United States that continues to the present day.

The term "International Style" was coined by three individuals, Henry Russell Hitchcock, Phillip Johnson, and Albert H. Barr, Jr., who worked together in 1932 to create the MoMA exhibition of this emergent, largely European style in order to provide its U.S. début. Barr was the first director of MoMA; Johnson, an architect by training, was the founder of the museum's Department of Architecture and Design; and Hitchcock, a respected architectural historian. While attendance to the exhibition was not overwhelming, it traveled throughout the

[31] Henry Russell Hitchcock and Philip Johnson, *The International Style* (originally published under the title: *The International Style: Architecture Since 1922*) (New York: W. W. Norton, 1995), 20.
[32] Mary Mix Foley, *The American House* (New York: Harper & Row, 1980), 241.

country and was outlined in an associated publication entitled, *The International Style*. The publication served to disseminate early ideas about the style, but also provided a lasting tribute. The moniker that they chose, "International Style," reflected the global distribution and perspective of its early practitioners—and perhaps due to aspirations held by Hitchcock and Johnson—for its future proliferation. The roots of the International Style can be traced to earlier movements occurring largely in Holland, France, and Germany, such as the Bauhaus, De Stijl, and the aesthetics of cubism and constructivism. Also influential was experimentation in reinforced concrete lead by Adolf Loos and Le Corbusier, as were the use of steel and glass and the standardization of building components pioneered by individuals such as Walter Gropius and Adolph Meyer.[33] As *The International Style* publication announced, "Today a single style has come into existence. The aesthetic conceptions on which its disciplines are based derive from the experimentation of the individualists. . . . This contemporary style, which exists throughout the world, is unified and inclusive, not fragmentary and contradictory like so much of the production of the first generation of modern architects."[34]

The book outlines the three principles of International Style, beginning with volume. The concept of volume relates to structure. In the past structural support was provided by the walls of a building. The International Style utilized the skeleton or framework of the building, usually constructed in metal or concrete, to provide support. These supports appear as a grid of vertical and horizontal members, exposing the true character of the construction. The beauty of this system was that it freed the structure of its load-bearing walls and thus allowed open interior floor plans and the realization of large sections of wall in glass. Sections of glass were countered by solid walls, generally covered in white stucco formed to provide a continuous overlay, becoming a hallmark of the style. According to Hitchcock and Johnson, "This concession to the principle of achieving a smooth continuous surface is an important instance of the exaggeration of the functionalist's anti-aesthetic claims."[35] Windows became the most visible character defining detail feature, punctuating the otherwise bare walls and defining a rhythm, which leads to the second principle, regularity.

Free of many of the interior walls that were necessary to the support of traditionally constructed buildings, International styled structures were not tied to the symmetry that had defined earlier buildings. On the contrary, if form was to follow function, maintaining symmetry would prove difficult. According to our authors, "The natural expression of the various functions grouped in one building is *not* symmetrical."[36] Thus, as they further noted, "technically the prime architectural problem of distribution is to adjust the irregular and unequal demands of function to regular construction and the use of standardized parts."[37] Moreover, symmetry was considered synonymous with monotony. Instead, buildings were to follow a certain regularity that would create aesthetic interest. Because rooms are generally broader than they are tall, a horizontal orientation became another character defining feature of the style. The horizontal nature of the structures was further emphasized by banding or broad expanses of windows and/or glass walls.

The third principle of the International Style is the avoidance of applied decoration. As an alternative, decoration was defined as all the "incidental features" of the design that provide interest.[38] The authors further argued against applied ornament by claiming that the quality of the execution of such details had declined significantly since the mid-eighteenth century. Perhaps this was true also because construction technology had evolved in a manner such that ornament had lost its functional quality and the aesthetic associated with its

[33] Ibid., 241.
[34] Hitchcock and Johnson, *International Style,* 35.
[35] Ibid., 65.
[36] Ibid., 72.
[37] Ibid., 71.
[38] Ibid., 82.

production (as indicated by the term "applied decoration"). Instead the contrast needed to provide architectural interest was obtained through the use of varying materials presented in their natural form. White walls were thought to create a less striking contrast with the natural environment, while at the same time highlighting complimentary materials such as wood, metal, and glass. Traditional ornament was replaced by more subtle designs focused on window style and arrangement, and on horizontal axis. Window style included clean-cut, flush mounting and ribbon banding. A horizontal axis was further accentuated by utilizing a flat and/or parapet roofline. Porches and terraces that melded the interiors with the out-of-doors also helped the International Style building to blend with its environment.

Focusing on the nature of the building materials and stripping away the applied ornament lends an element of simplicity to the International Style that is in harmony with the precepts of traditional Japanese architecture. As noted Bauhaus-trained German architect Bruno Taut commented after a visit to Japan in 1933, "Japanese architecture has always been modern."[39] Indeed, the Japanese obsession with simplicity in the design of domestic architecture was first introduced in the fourteenth century by influential Zen Buddhist priests (known as the Muromachi and Momoyama periods). The movement "sought to eliminate the inessential and seek the beauty in unembellished humble things. It sought spaciousness in deliberately small spaces, and a feeling of eternity in fragile and temporary [wood] materials. A house's interior was not to be just protected from nature, but to be integrated with nature in harmony."[40] Removing unnecessary décor provided for a flexible use of space. Built-in cabinets provided storage and eliminated the need for freestanding furniture. Bedrolls could be brought out at night, allowing room for work and play during the day. Space was defined by the size of a standard tatami mat of 90 x 180 centimeters, which is considered adequate sleeping room for the average person. And in fact, every dimension of the Japanese house is relative to that of a *tatami* mat and thus based on the scale of the human body. Japanese traditionally favor wood as a building material, reflecting a deep-seated respect for nature. Thus, Japanese carpenters are noted for having perfected techniques for drawing out the intrinsic beauty of wood, often left in a rustic condition.[41] Integration with nature is facilitated through elements such as *shoji* screens and sliding doors "fusuma" that allow whole walls of the house to open onto it.

The Japanese Shoin style that developed during the Muromachi period (1336-1572) included distinct elements: a *tokonoma* or honored decorative alcove for hanging scrolls and other special objects; a *chigaidana*, staggered shelves located near the *tokonoma*; *chodaigamae* or decorative doors; a *tsuke shoin*, hanging shelf or built in desk; *shoji* screens; *tatami* mats; and *nakabashira* or interior supporting posts and *daikokubashira*, also referred to as *oyabashira*, a parent or mother post.[42] Other features appearing in Japanese houses are a *genkan* or entrance for welcoming guests that included a built-in cabinet for storing shoes; a *ji-bukuro* or low storage compartments appearing in the recesses between *tokonomas*; a *mizuya* or small kitchen with a cupboard and wash-up for tea utensils, and a *goemon-buro* or metal tubs heated from below by a wood stove. It was also during the Muromachi and Momoyama periods that the tea ceremony became more popular and that spaces within houses designed to facilitate such activities emerged. Tea rooms are entered through a *nijuri guchi* or a small doorway through which guests must enter on their hands and knees, thus requiring them to leave behind their (Samurai) swords and their egos in the pursuit of a pure and humble state of mind.[43]

Eventually the formal Shoin style gave way to a more relaxed Sukiya style, avoiding symmetry and repetition in favor of rustic simplicity. Along with it, the Sado or Chado "Way of Tea" sought to extend the "meditative

[39] Geeta Nehta and Kimie Tada, *Japan Style* (North Clarendon, VT: Tuttle Publishing, 2005), 9.
[40] Ibid., 9.
[41] Ibid., 9.
[42] Ibid., 15.
[43] Ibid., 23-31.

simplicity" of the tea ceremony or *chanoyu* into every aspect of life to create harmony with nature and a retreat from the cares of the world.[44] These ideals strongly influenced arts and architecture in Japan. As one author describes it, "Contrary to Le Corbusier's adage of modern architecture, a traditional Japanese house is not simply a "machine to live in," but a home for the soul."[45] In fact, the traditional Japanese farmhouse or *minka* utilizes natural materials and building techniques that span hundreds of years.[46] *Minkas* are characterized by the use of a heavy wooden structural frame and thatched roof. Since their builders generally did not have access to the finest quality milled wood, *minkas* often incorporate large uncut or uneven timbers in their natural form, joined by mortise and tenon rather than metal fittings. The use of such materials and conditions helped to instill a reverence for joinery within the Japanese culture, as did their admiration for nature. Heavy thatched roofs were also an important part of Japanese aesthetic, and their deep overhangs provide protection from frequent rains and damp climate. Japanese roofs, now more likely tiled than thatched, generally do not include drains, using rain chains and gravel channels in the ground to carry run-off from the roof.

The relationship between the house and garden was also very important to the Sukiya style and thus great emphasis was placed on the landscape. Traditional Japanese house sites include a tea garden to mediate between the house and the outside world, separated by shoji screens. Shoji doors and windows are generally situated to take advantage of garden views or natural light. The garden plantings are intended to be a microcosm of nature, with thick moss carpets, larger evergreens, and low shrubs. Elements of the garden are accessed or joined by meandering paths or stepping stones referred to as a "rojo."

With the precepts of the International Style and elements of traditional Japanese architecture in mind, the influences that inspired the design and construction of the Nakashima complex speak directly to the Nakashima complex. Beginning with the Nakashima family house in 1946, followed by the Showroom in 1954, Conoid Studio in 1960, Arts Building in 1967 (and its associated Cloister in 1965), culminating with the jewel box Reception House in 1977, Nakashima combined these characteristic design elements. And in the case of the Conoid Studio in particular, Nakashima's designs also incorporated the innovative use of structural concrete. As with other proponents of the Modern Movement, Nakashima rejected the notion of style. According to Nakashima, "There is actually no 'modern' and no 'traditional,' but rather honesty and dishonesty of concept. When we speak of 'modern' it is again a style, and often as sentimental and 'traditional' as Cape Cod. Whatever styles and forms we have should evolve from the methods and materials used."[47]

George Nakashima and the American Craft Movement, 1945-1970

George Nakashima is recognized as one of America's preeminent furniture designer-craftsman, and a significant force within the American Craft movement of the mid-twentieth century. The post-war period from 1945 to 1969 is considered to be one of the seminal periods for woodworking in the United States, sometimes referred to as the "golden age," and Nakashima was one of its foremost contributors.[48] According the curator of American decorative arts at the Philadelphia Museum of Art, David Barquist,

[44] Ibid., 20. As the authors relay, "In architecture chanoyu has generated a special style called the Sukiya style, known for its minimalism, simplicity, rusticity, understatement and restrained playfulness."

[45] Ibid., 18.

[46] The word *minka* originally meant a home of a common person who was not an aristocrat or a samurai; however, it is now primarily used to describe farmhouse with heavy wooden structure and thatched roofs. Nehta and Tada, 108.

[47] George Nakashima, "How We Treat Wood," *Journal of the American Institute of Architects* 18 (July 1952): 10.

[48] Glenn Adamson, "Gatherings: Creating the Studio Craft Movement," in Jean Falino, ed. *Crafting Modernism: Midcentury American Art and Design* (New York: Abrams in association with Museum of Arts and Design, 2012), 32.

> The postwar generation, seeking an alternative to the austerity of the Depression and war years, embraced wood as a more natural and traditional medium. A dazzling sequence of iconic landmarks in the history of American craft followed, beginning with Rude Osolnik's irregular wood turnings of about 1945 and George Nakashima's natural-edge slab-top coffee table of 1946, through the elegant lines of Sam Maloof's trademark rocking chair of 1963 and Wendell Castle's music stand of 1964. These craftsmen celebrated wood with a passion that became the identifying characteristic of makers of handmade furniture and turnings in the decades after the war." [49]

During the war and the Depression years that preceded it, both the demand for luxury and handmade goods and the supply of needed materials collapsed. The return to prosperity that followed the war brought both new possibilities *and* new building materials; developed for use during the war, materials such as plywood and plastics, and methods such as lamination and synthetic-bonding elements enabled the affordable mass production of furniture and other objects, quickly meeting rising demand for consumer goods.[50] Designers such as Charles and Ray Eames gained distinction with prefabricated designs now considered iconic. Many, however, saw the rise in mass production as a sign of a soulless society. As synthetic materials entered the home furnishings market during the 1950s and 1960s, Nakashima was among the few who continued to use traditional materials and production methods, and to reflect back to vernacular forms, albeit with a modern spin.[51] According to Glenn Adamson of the Victoria and Albert Museum in London, "Put simply, there was a sense of crisis about the future of the handmade." As with the previous Arts and Crafts period, craftsmen were determined to restore valued traditions. As Holly Hotchner, Director of the Museum of Arts and Design summed it up: "In the period immediately after World War II, the crafted object, and the process of making things by hand, became an invigorating counterbalance to wartime experiences and privations, the homogeneity of mass-production, and the creeping alienation of suburban and corporate life."[52]

Many of the craftsmen of the post-war period worked alone to create unique objects, and were motivated not by the promise of fame and fortune, but by their search for self expression within an increasingly alienating society. Nakashima referred to himself as a "woodworker" rather than a furniture designer or craftsman. This notion resonated with many others working in the field, most of whom were self-taught or minimally trained (although the GI Bill did provide training opportunities and colleges now created fine arts programs that offered such coursework).[53] Nakashima was among the exceptions, having been trained in architecture. The "woodworker" moniker reflected Nakashima's life-long commitment to the subjugation of the ego as a means to developing his creative force. Nakashima's exposure to eastern religion and Japanese craft traditions taught him not only the value of rejecting one's ego, but of seeking peace, beauty, and harmony through one's work. As Nakashima explains it, "The key to fine workmanship lies in the drive for perfection and the development of skills to achieve it. Perhaps as a backlash to industrialism and commercialism, a new concept seems to be taking hold."[54]

It was perhaps Nakashima's all-encompassing approach to his life and work that resonated with craftsman of the post-war era and that made him so revered. In an interview with *Life* magazine in 1970 he urged his fellow

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[49] David L. Barquist, "Druids and Dropouts: Working Wood, 1945-1969," in *Crafting Modernism*, 226-245.

[50] Tastemakers, Mary and Russel Wright's 1950 *Guide to Easier Living* (1950) emphasized the convenience and economy of mass-produced goods as the best solution to meeting the demands of modern life.

[51] Ostergard, 64-65.

[52] Holly Hotchner, "Foreword," in *Crafting Modernism*, 14.

[53] Barquist, "Druids and Dropouts," 227.

[54] George Nakashima, "The Soul of a Tree" in *The Craft Reader*, 224.

craftsmen to get away from the trappings of civilization and "enjoy the nature and the life of the spirit." According to Nakashima, "I think there are times when one should go underground when he can't stand what is going on in the outside world."[55] As with the Arts and Crafts movement, those working in the post-war era felt that industrialization needed to be counter-balanced with handicrafts and thus there was a growing discussion about the role of the craftsman in an era of mass production. According to Matilda McQuaid, Associate Curator of Architecture and Design at MoMA, "this intensity of mass production during the 1940s and the infusion of new materials created if not a backlash then a yeaning by both consumer and craftsman for natural materials and the irregularities of handcrafted objects during the postwar period."[56]

The furniture designs employed by George Nakashima reflect a variety of influences. Often defined as "organic naturalism," his timeless pieces really defy stylistic categorization. At the same time, some designs hark back to American classics such as the Windsor chair and the (also timeless) Shaker "plain style," both of which are known for their economy of design and the conspicuous use of elements such as tenons and dovetail joints.[57] Likewise, much of Nakashima's design work reflects the Arts and Crafts Movement ideal of combining beauty with functionality. Believing in the spiritual qualities of wood, Nakashima's signature features incorporated techniques intended to diminish human impact upon wood's natural beauty, by use of the "free-edge" and the butterfly inlay. The wood was cut along the grain to form large, monolithic slabs and elements generally viewed as imperfections such as knots and splits were celebrated. His signature butterfly joints were also often used to connect two mirrored segments of a tree to create large pieces such as dining tables. Nakashima believed that the beauty of the natural wood spoke for itself; his role was to utilize it in a way that highlighted that fact. As he explained it in an interview with *Life* magazine,

> The direction of cut, the thickness of cut, all these things are very important. The growth lines of winter, when a tree is growing slowly, give the grain its bands of darker, harder wood. The summer growth is wider, lighter, softer. And because of all the strange twists inside even trees that look very straight, all these differences became exaggerated and beautiful in the cutting. In root wood and crotch wood, those places where a tree changes direction, you find a different grain, a shimmering burl-like grain. But every board is unique and there are always surprises.[58]

Thus, Nakashima is typically known for using wood as close to its natural state as possible; retaining the free edge of the tree in order to capture its natural elements and configuration was a major component of that philosophy. According to Nakashima, cutting the wood " is like cutting a diamond."[59] This tendency is a reflection of Nakashima's Japanese heritage; as he explains, "To leave a piece of wood alone, simply for its own value, is rather Japanese. In Japan there is a reverence for wood and a gentleness toward nature that we don't have here in the west."[60]

At the same time Nakashima and others of the post-war era embraced Modern stylistic influences and ideas that were international in scope. Modernism originated in Europe through movements such as the Bauhaus and

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[55] "The Craftsman: Fulfilling our Need and Nostalgia for Wood," *Life* 68 (June 12, 1970): 78.

[56] "Matilda McQuaid, "George Nakashima and the Mass Production of Craftsmanship," in James A. Michener Art Museum, *George Nakashima and the Modernist Movement* (Doylestown, PA: James A. Michener Art Museum, 2001), 16.

[57] Steven Beyer, *George Nakashima and the Modernist Moment* (Doylestown, Pennsylvania: James A. Michener Art Museum, 2001), 12. Nakashima's designs for chairs in particular are reminiscent of traditional American designs such as the Windsor chair or chairs crafted by Shaker craftsmen.

[58] "The Craftsman: Fulfilling our Need and Nostalgia for Wood," 78.

[59] Ibid.

[60] Ibid.

many of its artisans and architects immigrated to America in the post-war period. Imported Danish modern, for example, became a touchstone of modern design by the 1950s.[61] As in the European Modernist tradition, Nakashima espoused a minimalist, utopian vision of design for the common man. As Ostergard characterizes it,

> Nakashima's work may owe a debt to both East and West, but in fact, his designs of the last half-century have been international in scope, timeless in quality. Balanced on the cusp of two cultures, the disparate methodologies of craftsmanship and mechanization, and the differing personal motivation of a lover of nature and a trained architect, Nakashima and his aesthetic have retained its vivid validity and consistency. Ultimately it has been the mixture of all these factors that has made his work unique, despite his professed lack of interest in individual statements.[62]

In his seminal work, *The Soul of a Tree* and in other venues Nakashima helped to outline a new paradigm for studio furniture design and production. In her essay for the James A. Michener Art Museum's publication *George Nakashima and the Modernist Moment,* McQuaid discusses three particularly significant events that helped define George Nakashima's role in the movement. The first was his participation in MoMA's path-breaking 1951exhibition *Design for Use, USA*, which traveled throughout the United States and in Europe. It was extremely influential in part because it was the first MoMA exhibition about American design that placed emphasis on those items "that were typically, even particularly, American."[63] The exhibition was also intended to deliver an important message about the designer-craftsman as both "an aid to manufacturing and a corrective to its dehumanizing effects, a message that drew equally from the legacies of the Bauhaus and the Arts and Crafts movement."[64] It was a message that Nakashima also espoused and for which he would continue to advocate. The exhibition included three of Nakashima's best known pieces: the "High Mira" three-legged stool, which was one of the earliest designs produced in his New Hope studio and was inspired by the classic American Windsor chair; and two of his pieces from his first major commission in 1941 for Andre Ligne, a walnut chair with cushions, and a walnut occasional chair with a grass seat. Nakashima's adherence to tradition and his independent studio production set him apart from many of his contemporaries who were also included in the exhibition yet designed for mass production.

Next, Nakashima was included in a landmark study undertaken by Walker Art Center in Minneapolis in cooperation other major museums, which in a similar mode to the MoMA exhibition, focused on how product design could be substantially improved by craftsman and industry working together. As both a proponent and successful model for the role of the craftsman in the world of industrial production, Nakashima was among the prominent American designers examined by the Committee on Design and Craftsmanship. The study culminated in a publication entitled *A study of Design and Craftsmanship in Today's Products*, and included an accompanying film and a conference. Among the objectives of the study was to discover "the ways in which individual designer-craftsman contribute to the production of well-done things by perpetuating the traditions of craftsmanship and by exploring new directions in form and technique."[65] Nakashima's work was used to illustrate ideas about the artist-craftsman as successful designer-producer. While dedicated to craftsmanship, Nakashima understood the role that mechanized processes could play in handcrafted work. He was very willing

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[61] Todd Merrill and Julie V. Lovine, *Modern Americana: Studio Furniture from High Craft to High Glam* (New York: Rizzoli, 2008), 19.

[62] Ostergard, *George Nakashima*, 86.

[63] McQuaid, "George Nakashima," 20.

[64] Glen Adamson, *The Craft* Reader (Oxford and New York: Berg Publishers, 2010), 36.

[65] Unpublished prospectus titled "Design and Craftsmanship," sponsored by the Committee on Design and Craftsmanship, 3-4, Museum of Modern Art Library, New York, NY, as cited in McQuaid, "George Nakashima," 22.

to utilize machine tools in his furniture production "as long as the intrinsic qualities of the material were not compromised by the lack of individual wood selection, hand detailing, sanding, and finishing."[66]

According to McQuaid, George Nakashima's impact was also recognized by his participation in an important and well attended conference held in New York in 1953 on the influence of design on better living. Nakashima gave an address, entitled "One Man's Answer," which was followed by a panel discussion about the roles of art and design. Along with Nakashima, the panel included preeminent industrial designer Henry Dreyfuss; president of Steuben Glass, Inc. Arthur Houghton, Jr., and California architect Paul Williams. In his address, Nakashima expressed the view that "American civilization was spiritually deprived and motivated primarily by its materialism" and made an appeal for "a more integrated approach, not only to design and the manufacturing process, but to life itself."[67] Nakashima advocated for a balance between art and design, culminating his talk with the following statement:

> We must adapt to our experiences and our technology. To accomplish this, as I see it, a whole new environment has to be created, an environment not based on the sentiments of the spinning wheel but also not based on sentiments and tyrannies of the production line. Rather an environment which provides a synthesis of what is good for us as human beings, who are in control of their environment, not victims of it.[68]

Numerous other important events helped to shape and define Nakashima's career as a national significant designer-craftsman. In 1946 Nakashima established a relationship with H.G. Knoll Associates, a furniture manufacturer in New York City. Knoll mass-produced some of Nakashima's designs, although custom production and sales of his furniture continued at the New Hope workshop. H.G. Knoll had a similar relationship with a number of highly regarded Modern furniture designers of the mid-twentieth century.[69] In addition to Nakashima, these included Isamu Noguchi, Eero Saarinen, Robert Venturi, and Ludwig Mies van der Rohe, to name a few of the best known. As Mira Nakashima informs us, "Shu [Florence] Knoll was the driving force behind the Knoll planning unit. She wanted serious quality in everything that the company made, and she recruited artists of the highest caliber to design for it, among them the architect Alvar Aalto, the sculptors Harry Bertoia and Isamu Noguchi, and my father."[70] Although Nakashima eventually decided to end his relationship with Knoll and return to independent work, it was an important experience; it both presented his work to a broad and discriminating audience and provided important lessons about furniture manufacturing and marketing. As Mira explains it, "Nakashima's collaboration with Knoll ended in 1954, but his association with Knoll was a fruitful one. It gave my father the opportunity to see how craftsmanship and industry could work together, and how a serious designer could produce pieces of genuine quality for the mass market."[71]

Perhaps a factor of the lessons learned during his venture with Knoll, it was also about this same time that Nakashima developed furniture catalogs. The first in 1945 was a small, six-fold blueprint design. In 1951 Nakashima issued a book-form catalog that featured ten new items, and the next catalog, issued in 1955,

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[66] McQuaid, "George Nakashima," 23.

[67] Ibid., 25.

[68] "Nakashima's Solution: His Own Woodworking," *New York Herald Tribune*, October 25, 1953, as cited in McQuaid, "George Nakashima," 24.

[69] The corporate headquarters for Knoll, located in East Greenville, Pennsylvania, was contacted in an attempt to retrieve sales and production data regarding the relative success of Nakashima's designs versus other designers at Knoll; however, this data was not available. Elizabeth Needle and Linda F. Kasper to David Kimmerly, electronic correspondence, 2008.

[70] Mira Nakashima, *Nature, Form & Spirit*, 76.

[71] Ibid., 77.

introduced twenty-one new designs. Interestingly, the delicate line drawings used in the 1955 catalog reflect the fact that the character of the final product was subject to the selection of the wood and the needs of the client rather than being rigidly fixed.[72] Also running counter to the "mass-production" of Nakashima pieces for Knoll was his development during this period of one of the most important designs of his career, the Slab Coffee Table. As Ostergard commented, "it was his expanded use of the free edge that revealed his most important artistic growth at this stage."[73] Likewise his use of the butterfly joint as both a functional and decorative element had become an integral component of his designs. According to Ostergard, "although Nakashima was not the first designer to employ it, he developed it more fully than anyone else."[74]

By the early 1950s, Nakashima had distinguished himself as one of the most important furniture designers in the country. This was accomplished through the high quality of his work and by the model that he provided as an individual dedicated to his craft—qualities that Nakashima would surely argue must go hand-in-hand. As McQuaid states, Nakashima became the silent voice of the artist-craftsman—frequently referred to as such in publications and often depicted as the artist in creative isolation who desired distance from activities that took him away from work and family."[75] While Nakashima's recognition by the public was not as great as designers such as the Eameses or Saarinen, considering that his pieces were individually crafted while their designs were mass-produced, his influence was remarkably far-reaching. More so then many of his contemporaries, Nakashima's "presence and his commitment to his ideals came to be regarded by many as a seminal influence on studio craft after the war."[76] Nakashima's acclaim can also be attributed to his involvement with Knoll, which constituted an endorsement of his work at the highest levels of Modern furniture design. Working with Knoll also provided Nakashima an opportunity to prove that industry and craft could be integrated in a manner that contributed to the quality of both. Another such opportunity was soon to present itself.

In 1957, George Nakashima was approached by Widdicomb-Mueller Company of Grand Rapids, Michigan and asked to design a line of furniture, also intended for mass production, similar to the arrangement he had previously negotiated with H.G. Knoll. As with that venture, Nakashima was able to test and to refine his own beliefs about craftsmanship and industry. Incorporated in 1873, the Widdicomb Furniture Company was located in what was historically the center for furniture manufacturing in the United States. By the late nineteenth century, it claimed to be the largest manufacturer of bedroom furniture in the world. Although the operation was largely mechanization by the early twentieth century, the decorating and finishing was still done by hand in order to create high-end pieces. In the 1920s they began producing some Modern designs and within a decade were producing them exclusively. The company contemplated using thirty-five different designers before selecting George Nakashima. The resulting *Origins* line, which included full suites of furniture, was introduced on June 12, 1958 at the Furniture Fair in Grand Rapids.[77] It was also featured on the cover of the October 1958 issue of *House Beautiful*. Although clearly modern, the *Origins* line, like all of Nakashima's work, was considered timeless; the company referred to it as "a new 'American look' that despite its traditional inspiration was 'a boldly modern approach'" to design. As with Knoll, the relationship with Widdicomb-Mueller was constructive for Nakashima "allowing him to broaden his base of support among consumers and

[72] Ostergard, *George Nakashima*, 69.

[73] Ibid., 63, 69.

[74] Ibid., 70. As Ostergard also points out, in the past the butterfly joint was used primarily as a remedial joint to repair a split piece of wood; rarely was it used as a primary joint in the construction of furniture.

[75] McQuaid, "George Nakashima," 25.

[76] Ostergard, *George Nakashima*, 58.

[77] There is little to no sales or production data available to verify the relative success of the line in the Widdicomb Furniture Company archives, which are located at the Grand Rapids Public Library in Michigan. Ruth Van Stee, Grand Rapids Public Library, to David Kimmerly, electronic correspondence, 2008.

critics" alike.[78] Moreover, as Matilda McQuaid described it, "his work for Widdicomb-Mueller seemed to go beyond just a financial benefit and became a test of his beliefs about the craftsman's maintaining control over the machine and ultimately assuming the responsibility for the final product. As McQuid concludes, "Ultimately, Nakashima always saw himself as a woodworker."[79] He soon returned to studio production and the *Origins* line was discontinued. As Ostergard points out, "Nakashima's dual role as designer and producer may have kept his operations vital. This may be why Nakashima also limited the scale of his operations. By so doing, he has been able to retain a strong degree of control over the output of his firm."[80]

Among the other significant indications of Nakashima's achievement in the field was his inclusion in an exhibition by the Renwick Gallery of the Smithsonian Institution in 1972 entitled *Woodenworks.* The Renwick Gallery is devoted to the study and presentation of American design and crafts and significantly *Woodenworks* was its inaugural exhibition. It featured the work of five preeminent craftsmen, all working in wood and all of whom were noted for combining modern forms with traditional materials and skills; they included: Wendell Castle, Arthur Espenet Carpenter, Wharton Esherick, Sam Maloof, and George Nakashima. According to the accompanying publication, the Renwick curators were responding to the "new awareness" about the role of the professional craftsman in society. They stated that "Today, when plastics so often take the place of wood and ape its appearance in commercially produced furniture, it seems fitting to take a fresh look at the familiar traditional material as handled by master craftsmen to recover some sense of that special quality generated from a mating of individual creativity with fine natural material." Also important indicators of Nakashima's acclaim were two exclusive exhibitions of his work, one just before and the other following his death in 1990. The first was New York's American Craft Museum's *Full Circle*, a fifty year retrospective (1989); and secondly, the James A. Michener Museum's *George Nakashima and the Modernist Moment* (2001). Nakashima was also included post-mortem in the Boston's Museum of Fine Arts *The Maker's Hand: American Studio Furniture, 1940-1990*, in 2003. *The Maker's Hand* exhibition also appeared in book form and has been called the most authoritative publication to date about the Studio Furniture movement. It states "To connoisseurs of modern furniture, names such as Wendell Castle, Wharton Esherick, Sam Maloof and George Nakashima are signposts to a revolution in the decorative arts that remains one of the most vital of our time."

In addition to exhibitions, George Nakashima has been the subject of numerous publications, and has in fact been featured in every noted publication on the craft movement and fine woodworking in America. Publications which featured George Nakashima as the sole subject include: Steven Beyer, *George Nakashima and the Modernist Moment;* Mira Nakashima, *Nature, Form & Spirit: The Life and Legacy of George Nakashima;* and Derek E. Ostergard, *George Nakashima: Full Circle*. As already mentioned, he was also involved in an influential study organized by the Committee on Design and Craftsmanship titled "A Study of Design and Craftsmanship in Today's Products" presented by the Walker Art Center in Minneapolis. Nakashima is also celebrated in numerous compendiums of the studio craft movement in addition to the ones mentioned above, including: *The Craft Reader*; *Crafting Modernism: Mid Century American Art and Design*; and *Modern Americana: Studio Furniture from High Craft to High Glam.* In addition, the George Nakashima House, as part of his craft legacy, has also been featured in: *Esherick, Maloof, Nakashima: Homes of the Master Wood Artisans* (2009); *Handcrafted Modern: At Home with Mid-Century Designers (2010); and Artists' Handmade Houses* (2011).

[78] Ostergard, *George Nakashima*, 72.
[79] McQuaid, "George Nakashima," 29.
[80] Ostergard, *George Nakashima*, 64.

Finally, among the most significant recognitions that George Nakashima has received for his work as a master American craftsman is the American Institute of Architect's Craftsmanship Medal, which he received in 1952. As stated in the citation: "You have perpetuated in your work in the design and making of furniture the high standards of past ages of handcrafts, and that respect for good materials and honest labor . . . that will in any age distinguish great craftsmanship."[81] George Nakashima won many other awards for both his furniture design and for his architecture. Among these are the Silver Medal of Honor in Design and Craftsmanship given by the Architectural League of New York, 1960; Catholic Art Association Medal, 1969; listing in *Who's Who in America*, 1975; Gold Medal and title of Japanese American of the Biennium in the Field of Arts, San Francisco, 1980; Honor Award for Inspired Creativity Outstanding Sensitivity in Design, The Pennsylvania Society of Architects of the American Institute of Architects, 1981; Bucks County Distinguished Service Award, 1985; and the University of Washington Alumnus Summa Laude Dignatus, 1990.

As a collectible item, Nakashima's work is highly prized and valued today, despite his insistence that his furniture first be useful. As Mira Nakashima explains, "My father said that his furniture should not be considered overly precious and that it was meant to be lived with. . . . Ironically, some of Nakashima pieces today are now considered works of art, at least for insurance purposes. . . . There are many stories of how this piece or that piece created a peaceful atmosphere in a client's home or office (except when squabbles later arose over who would inherit it)."[82] A check of David Rago's auction house web site located in nearby Lambertville, New Jersey, which handles Arts and Crafts and Modern furniture, reveals just how valuable Nakashima furniture is in today's collectible market: walnut floor lamp with white paper, $25,000; set of four high Mira walnut chairs, $17,000; walnut double chest of drawers, $14,000; and English walnut side table with free edge, $14,000. Furniture made by Nakashima became popular among the progressive upper and middle class, including doctors and lawyers, as well as other artists. For example, in the estate of Andy Warhol there was a Nakashima coffee table, and artist Ben Shahn owned several Nakashima pieces. One of George Nakashima's more notable commissions was for Nelson Rockefeller who hired him in 1974 to design furniture for the New York governor's Japanese style house in Pocantico Hills, New York.

Due to George Nakashima's spiritual and religious nature he designed altar rails, benches, pews and tabernacles for several churches in Bucks County. In the mid 1980s he embarked on a mission to make six altars of peace, one for each of the world's continents. The first of these altars was crafted in 1986. It measured slightly over 10' x 10' and was made of two matching sections of a walnut tree that were connected by butterfly joints. The altar was installed in the Cathedral of St. John the Divine in New York City. The mission of constructing the altars has continued through the efforts of his children Mira and Kevin Nakashima. Mira, an architect and designer, also has continued to produce George Nakashima's furniture at the New Hope studio as well as executing and selling some new designs based on her father's philosophies.

Comparisons with Other Designer Craftsman

According to Ostergard, writing in *George Nakashima; Full Circle*, "While there were aesthetic corollaries between Nakashima's work and that of his contemporaries who evolved as designers, only a few noted craftsman produced work on the same individual, handcrafted basis during this period."[83] As already discussed, many of the furniture designers of Nakashima's era used the new materials that became available during the mid-20th century. Charles Eames, for example, used plastic and stainless steel, and designed furniture with simple shapes such as squares and rectangles. Eero Saarinen also used plastic but favored space-age lines such

[81] "The Craftsmanship Medal for 1952 to George Nakashima," *Journal of the American Institute of Architects* 18 (July 1952): 4.
[82] Mira Nakashima, *Nature, Form & Spirit*, 116.
[83] Ostergard, *George Nakashima*, 53.

as curves and circles; his tulip chair, which he designed for the H.G. Knoll Company, is an example. Jere Osgood, who, like Nakashima trained in architecture, attained recognition using lamination to create curvilinear forms. Ostergard rightly identifies Wharton Esherick as the closest comparison to Nakashima as a designer craftsman. And another designer-craftsman with whom Nakashima has been compared is Sam Maloof. In fact, Tina Skinner aligns the three in her publication *Esherick, Maloof, Nakashima: Homes of the Master Wood Artisans*, recognizing that the influential trio turned to traditional craft and woodworking at the same time that the United States was deeply embracing mass consumerism.[84] The three were likewise featured in *Woodenworks*, the Renwick Gallery's debut exhibition (and in various publications and compendiums of the craft), along with Wendell Castle and Arthur Espenet Carpenter.[85] George Nakashima, however, distinguished himself from even these designers by executing designs that are clearly modern with very simple streamlined shapes or a natural free edge wood shape, reflected in his unique experiences and worldview.[86] In addition, Esherick, Maloof, Carperter, and Castle are generally categorized as "studio artisans" while Nakashima is considered a "designer craftsman" due to foray into contract production and the size of his operation.[87] For the purposes of this nomination, moreover, there are limited numbers of craftsmen that also designed and built their own home and studio complexes. The most notable example, which has already been designated a NHL, is the Wharton Esherick Home and Studio (although the Eames House is also a NHL).

Wharton Esherick was an artist, furniture maker, and interior designer, and as the elder among this group, is said to have "pioneered the archetype of the self-taught woodworker."[88] Ostergard identifies numerous differences between Esherick and Nakashima, one of the most important perhaps being that Esherick had a "distinctly personal element to design" whereas Nakashima was more interested in anonymity (initially refusing to even sign his pieces). Esherick created one-of-a-kind pieces; while Nakashima worked from set prototypes, his pieces were made distinctive by the idiosyncrasies of wood with which he worked. In addition, Ostergard claims that Nakashima's work was "often veiled by vernacular or natural forms and the use of fundamental materials."[89] Esherick attended the Pennsylvania Academy of Fine arts and began his career as a graphic artist and painter. He first used carving tools to craft frames that would compliment his artwork, turning then to woodcuts and eventually to furniture design. While sharing Nakashima's respect for wood, Esherick's pieces

[84] See: Tina Skinner, *Esherick, Maloof, Nakashima: Homes of the Master Wood Artisans* (Atglen, PA: Schiffer Publishing, 2009).

[85] Wendell Castle, like other craftsman who came of age in the 1960s, did not share the earlier generations reverence for wood. As he once stated, "It is important not to be subservient to a material. The significant thing about my work is not what it is made of but what it is." Lee Nordness, *Objects: USA—Works by Artist-Craftsmen in Ceramic, Enamel, Glass, Metal, Plastic, Wood and Fiber* (1970), 265, as cited in Barquist, "Druids and Dropouts," 231. Castle's work was regarded more for its artistic or sculptural qualities then for its functionality, as with Nakashima's furniture designs. As a result, Castle's pieces appealed to a smaller, more elite audience, designing what has been called "art furniture." Arthur Espenet Carpenter was a self-taught furniture maker who began his woodworking career turning wood bowls with a lathe in the San Francisco area. His signature style, known as the "California Roundover" incorporated curved lines and rounded edges. After about a decade of maintaining a successful business, in 1957 he bought a farm in Bolinas and began making furniture full-time. Claiming inspiration from Esherick and Maloof, Carpenter's designs were consider spare and practical, yet at the same time sleek and often artistic in nature. He too crafted his own home and workshop. The latter is a circular edifice with the kitchen at its core, encircled by contemporary, open-space rooms.

[86] Rude Osolnik is also recognized as a "pioneer in retaining feature of individual pieces of wood," but he was a wood turner and not a furniture maker. Barquist, "Druids and Dropouts," 227.

[87] Merrill and Lovine, 20. Other "designer-craftsman" discussed in this publication along with Nakashima include: Vladimir Kagan, Silas Seandel Paul Evans, and Phillip Lloyd Powell (the latter two worked together), although the authors comment that Nakashima was the most recognized among them. Also working in the New Hope area were Evans and Powell— the former was a metal sculptor and the latter a woodworker who combined their talents. Silas Seandel was also primarily a metal sculptor. Valdimir Kagan's style was sleek, organic and very modern, with an affinity toward the Danish modern designs then very much in vogue.

[88] Barquist, "Druids and Dropouts," 228.

[89] Ostergard, *George Nakashima*, 55.

often included ornamental carving in the Art Nouveau, Art Deco, and Cubist idioms, revealing a sculptor's sensitivity to form. In fact, Esherick considered himself foremost a sculptor.[90] Esherick's home, like his furniture, is almost sculptural and each component is handcrafted. Organic in form, it evolved slowly over a forty-five year time span. Esherick's home shares a fairly diminutive scale and simplicity with Nakashima's, but little else beyond the use of indigenous materials such as native stone. The adjoining Esherick workshop is, however, more aligned with the Modernist movement than the rest of the structure, having been designed with the help of Louis Kahn, albeit modeled after a stone barn. The Esherick complex is also far less extensive than Nakashima's; Esherick combined his residence and studio/gallery in one structure (also on site is a wood shed, out house, and log garage, now a visitor's center).

Sam Maloof worked during the same time period as Nakashima, beginning in 1945 until his death in 2009, and was also largely self-taught. Both received extensive press coverage, beginning in the late 1940s, in magazines such as *House Beautiful*, *Life*, *Look*, and *Newsweek*, as well as in art and architecture periodicals such as *Craft Horizons* and *Fine Woodworking*.[91] Likewise, both took advantage of machine tools and employed assistants in their workshops, created prototypical designs that have endured over time. Maloof too worked in his own home-based studio to create handcrafted designs in the modernist idiom, and was known for his innovative joinery. Unlike Nakashima who worked more in isolation, Maloof was part of a very active academic and artisan community that grew up around Claremont (California), encompassing Claremont and Scripps colleges, where many local artists taught and/or studied. Maloof entertained and had access to a broad range of artists, architects and designers. Maloof's home and studio is very different from Nakashima's; it is a sprawling California style contemporary that grew from a bungalow to a twenty-six-room timber frame house. Maloof added each room as he could afford it, now totaling 7,000 square feet, to house his extensive art collections as well as examples of his own furniture. In this regard, the Maloof House is very different for the sparse house that George Nakashima built for himself and his family. While Nakashima welcomed other artisans to his property, his compound includes numerous discrete buildings for family, guests, furniture display, and furniture manufacture.

Two other NHL sites are connected with modern designers: the (Charles and Ray) Eames House; and Manitoga, the Russel Wright Home & Studio. At the Eames House, located in the Pacific Palisades of Los Angeles, California, the "living component" or residence and the "working component" or studio are joined by an open court, unlike the complex of structures erected by George Nakashima that separates family, workshop, and studio space. The Eames House is significant architecturally as the most intact of the famed Case Study houses; the Case Study program was part of an effort undertaken by a number of noted architecture and design professions to promote modern architecture in the post war era by basically designing and building model homes. It is considered one of the most significant attempts to create experimental or demonstration homes in our nation's history.[92] The house, built in 1949, consists of a modular design with an exposed steel frame painted black with colorful infill in one of several materials; include plaster, plywood, asbestos, glass, and Pylon (translucent laminate similar to fiberglass). The interior has an open plan with living spaces on the first floor and bedrooms on the second. Comparisons between the Eames and Nakashima as furniture designers have already been discussed. Wright's Manitoga is also intended as an experimental house to demonstrate how American families could live better by utilizing basic principles of domestic economy and modern design. Wright was a highly influential mid-twentieth century industrial and interior designer best known for his

[90] Carolyn Pitts, National Historic Landmark nomination for the "Wharton Esherick Studio," National Park Service, U.S. Department of the Interior, 1992, 13.

[91] Barquist, "Druids and Dropouts," 230.

[92] Elaine Jackson-Retondo, National Historic Landmark nomination for the "Eames House," National Park Service, U.S. Department of the Interior, 2006.

inexpensive, mass-produced household items and furnishings, and for his conviction that "good design is for everyone."[93] In that regard, Wright was more aligned with the Eames's approach to production than that of George Nakashima. With regard to the structure, a main block is connected by a wood pergola to a wing that serves as both master bedroom and workroom. Completed in 1960, the house is built into an abandoned quarry and has been described as "part cave, part forest pavilion, [a] rough hewn house that hugs the brow of a cliff over a secluded quarry pool [sheltering] nobly dramatic spaces which join the panorama of nature, change with the seasons."[94]

Working as solitary craftsmen in an isolated environment of their own making appears to have been a part of the persona of the designer-craftsmen of the post-war era, as indicated by the home and studio complexes of Wharton Esherick, Sam Maloof, and George Nakashima. The Eames and Wright houses, while personal residences, were intended to also serve as models for modern design and living. The Nakashima complex is unique in its International and Japanese influenced styling and its use of experimental concrete, but also by the fact that it includes numerous individual structures for living, working, studying, wood storage, and furniture display. The Nakashima site is also distinguished by the fact that it is not a museum—as are all of the other sites discussed—but a working operation. Mira Nakashima, a talented designer-craftsperson in her own right, has worked tirelessly to continue her father's unique legacy and to maintain the spirit with which Nakashima Woodworker was established. Moreover, all of these sites reflect the design philosophy and aesthetic of its maker and thus each is a fiercely individualistic, even idiosyncratic, set of structures that are one-of-a-kind and beyond comparison.

[93] Kathleen LaFrank, National Historic Landmark nomination for "Manitoga (Russel Wright Home)," National Park Service, U.S. Department of the Interior, 2005, 12.
[94] Ibid., 4.

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Previous documentation on file (NPS):

__ Preliminary Determination of Individual Listing (36 CFR 67) has been requested.
_X_ Previously Listed in the National Register.
__ Previously Determined Eligible by the National Register.
__ Designated a National Historic Landmark.
_X_ Recorded by Historic American Buildings Survey: HABS No. PA-6783
__ Recorded by Historic American Engineering Record: #

Primary Location of Additional Data:

_X_ State Historic Preservation Office
__ Other State Agency
__ Federal Agency
_X_ Local Government
__ University
__ Other (Specify Repository):

10. GEOGRAPHICAL DATA

Acreage of Property: 12.2 acres

UTM References: Lambertville (NJ, PA) Quadrangle

Zone	Easting	Northing
1. 18	503541	4465576
2. 18	503885	4465781
3. 18	504056	4465459
4. 18	503707	4465269

Verbal Boundary Description:

The boundary for the proposed property includes all of Bucks County Tax Map Parcel numbers (TMP#) 41-36-77 and 41-36-87-13. Bucks County Tax Maps are available at Bucks County Courthouse, Board of Assessment, 3rd floor, 55 E. Court Street, Doylestown, PA 18901.

Boundary Justification:

The proposed boundary contains all of the resources historically associated with George Nakashima. Both tax parcels contain buildings designed by or associated with Nakashima and his family. No buildings with association to Nakashima were excluded. The boundary also includes natural and cultural landscape features that are integral parts of the setting which are part of the properties overall historic integrity.

11. FORM PREPARED BY

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Date: November 2007 (NR documentation); October 2012

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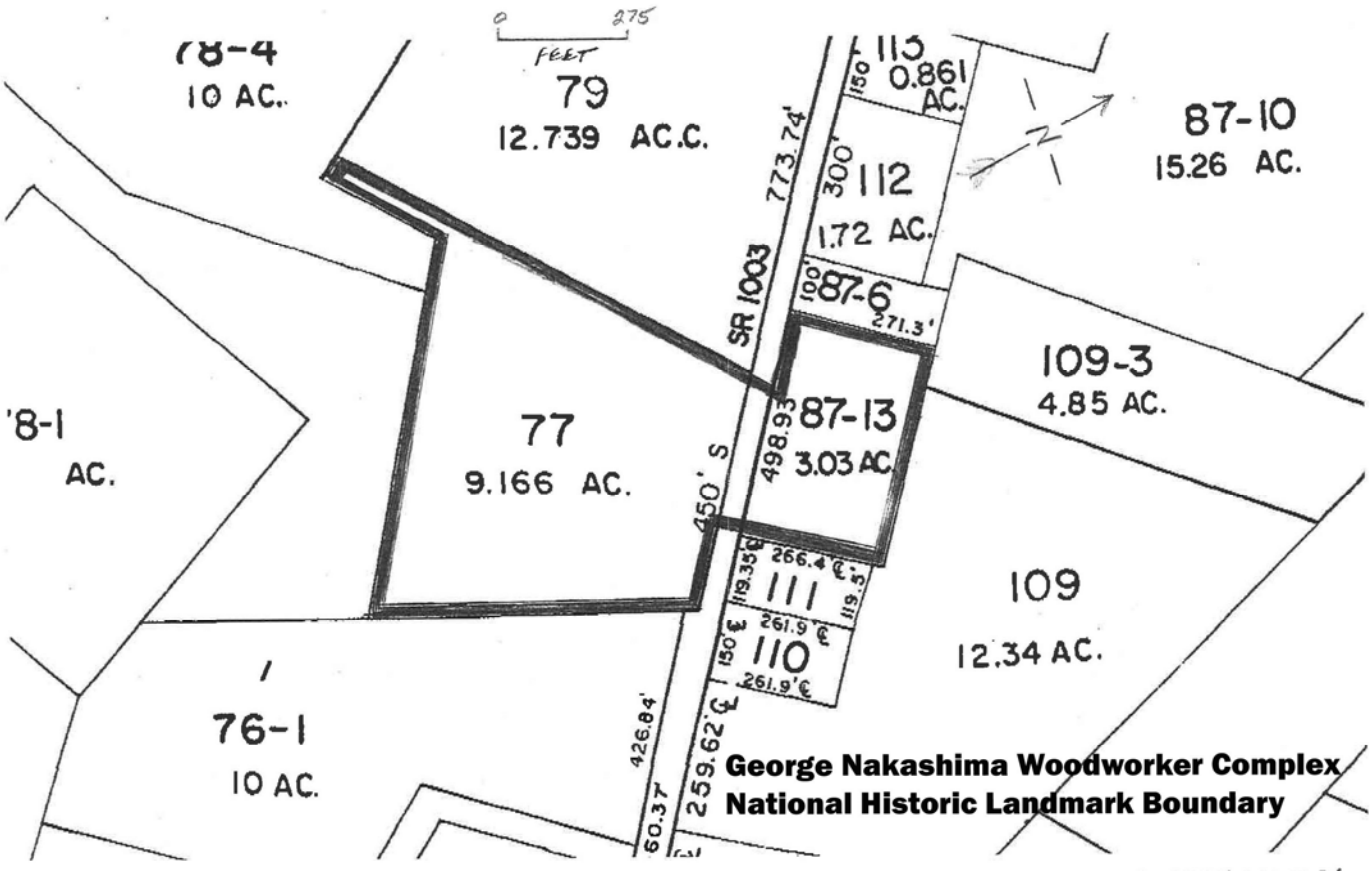
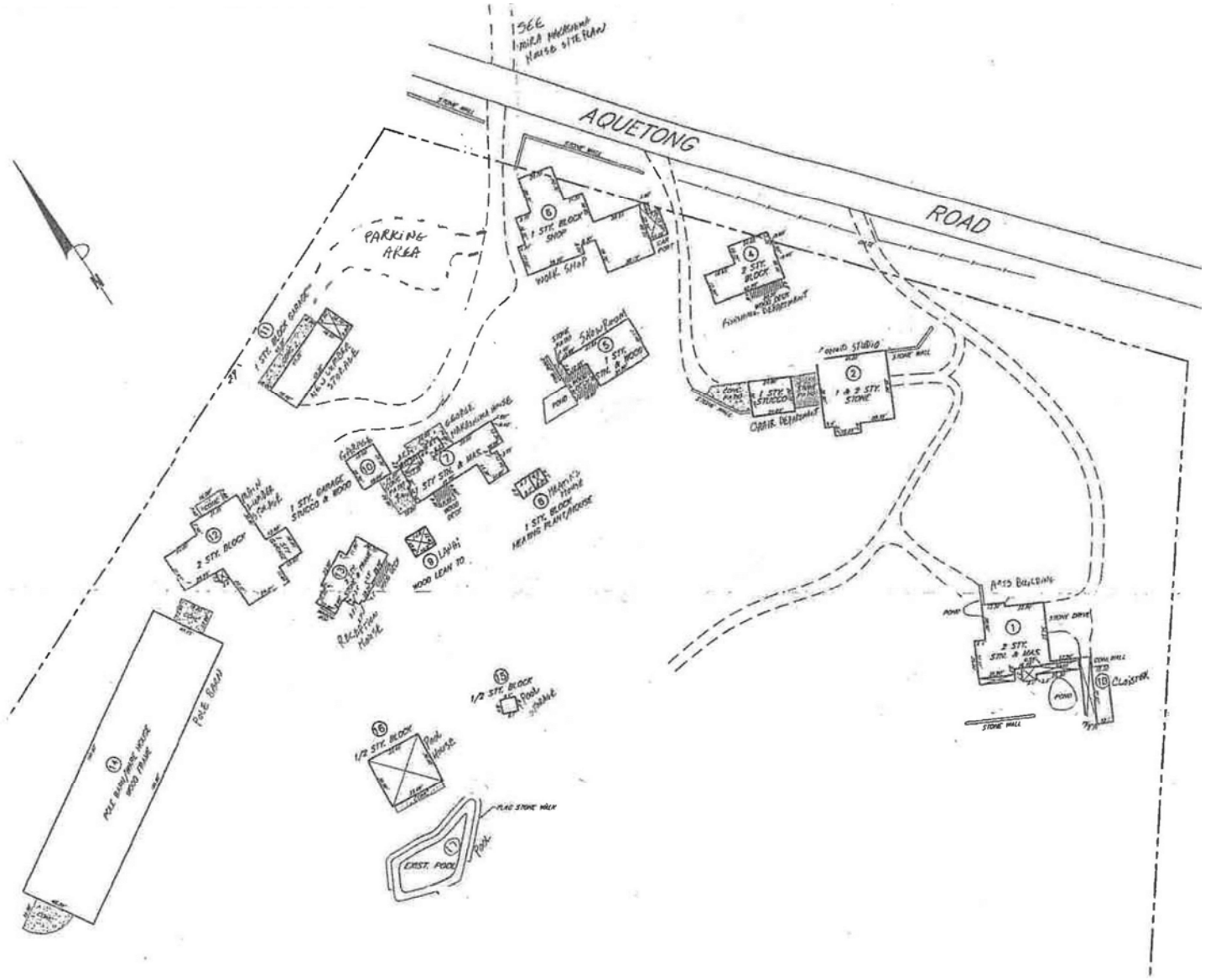
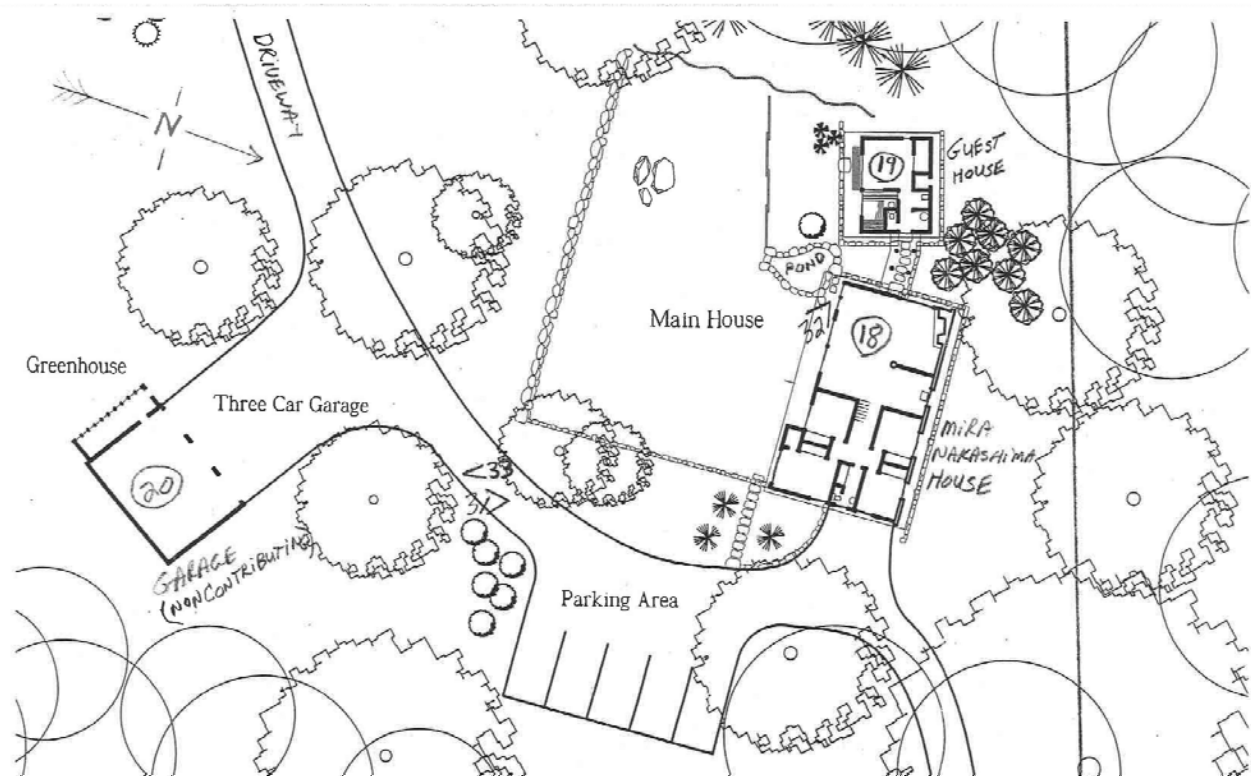
NATIONAL HISTORIC LANDMARKS PROGRAM
February 7, 2013



George Nakashima Woodworker Complex, Proposed NHL boundary, 2007, 2013



George Nakashima house and studio buildings, site plan, 2007



Mira Nakashima house, site plan, 2007



George Nakashima House, looking southeast
James Rosenthal, HABS, photographer, 2012

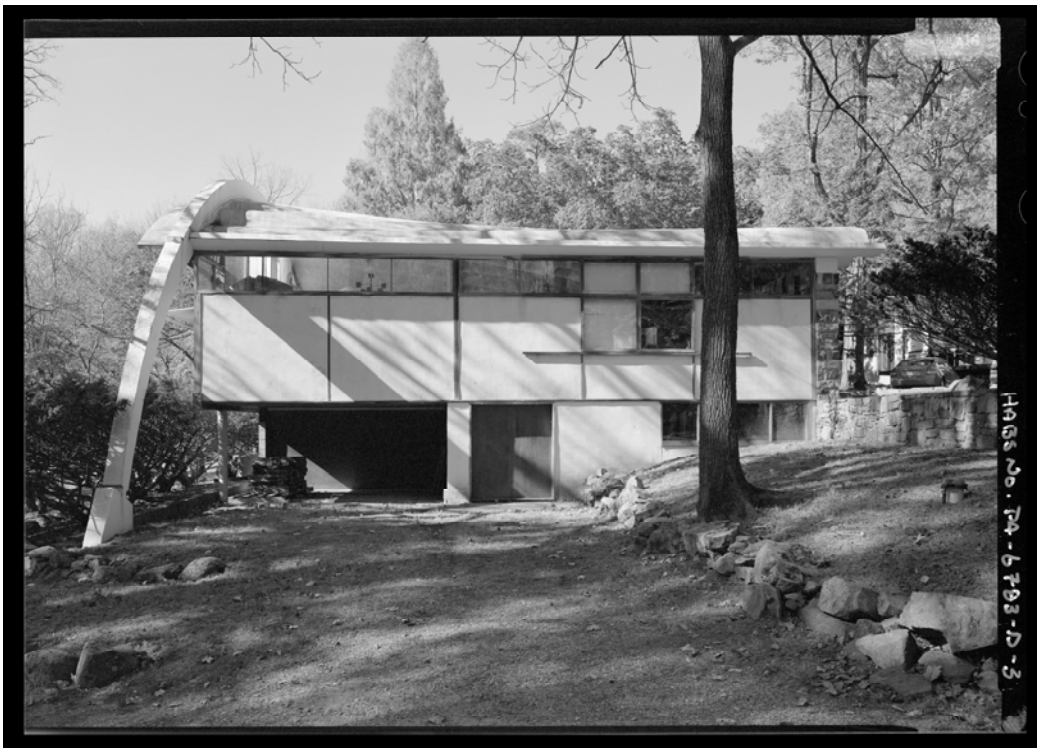


Workshop, looking north-northeast (above)
Detail view, Workshop interior, craftsman inserting butterfly joint (below)
James Rosenthal, HABS, photographer, 2012





Interior view, Showroom, looking west
James Rosenthal, HABS, photographer, 2012



Conoid Studio, side elevation looking west-northwest (above)
Interior view, Conoid Studio, looking southeast (below)
James Rosenthal, HABS, photographer, 2012





Arts Building viewed from the Cloister, looking north (above)
Interior view, Arts Building, looking west (below)
James Rosenthal, HABS, photographer, 2012





Reception House, looking west (above)
Interior view, Reception House, looking northwest (below)
James Rosenthal, HABS, photographer, 2012



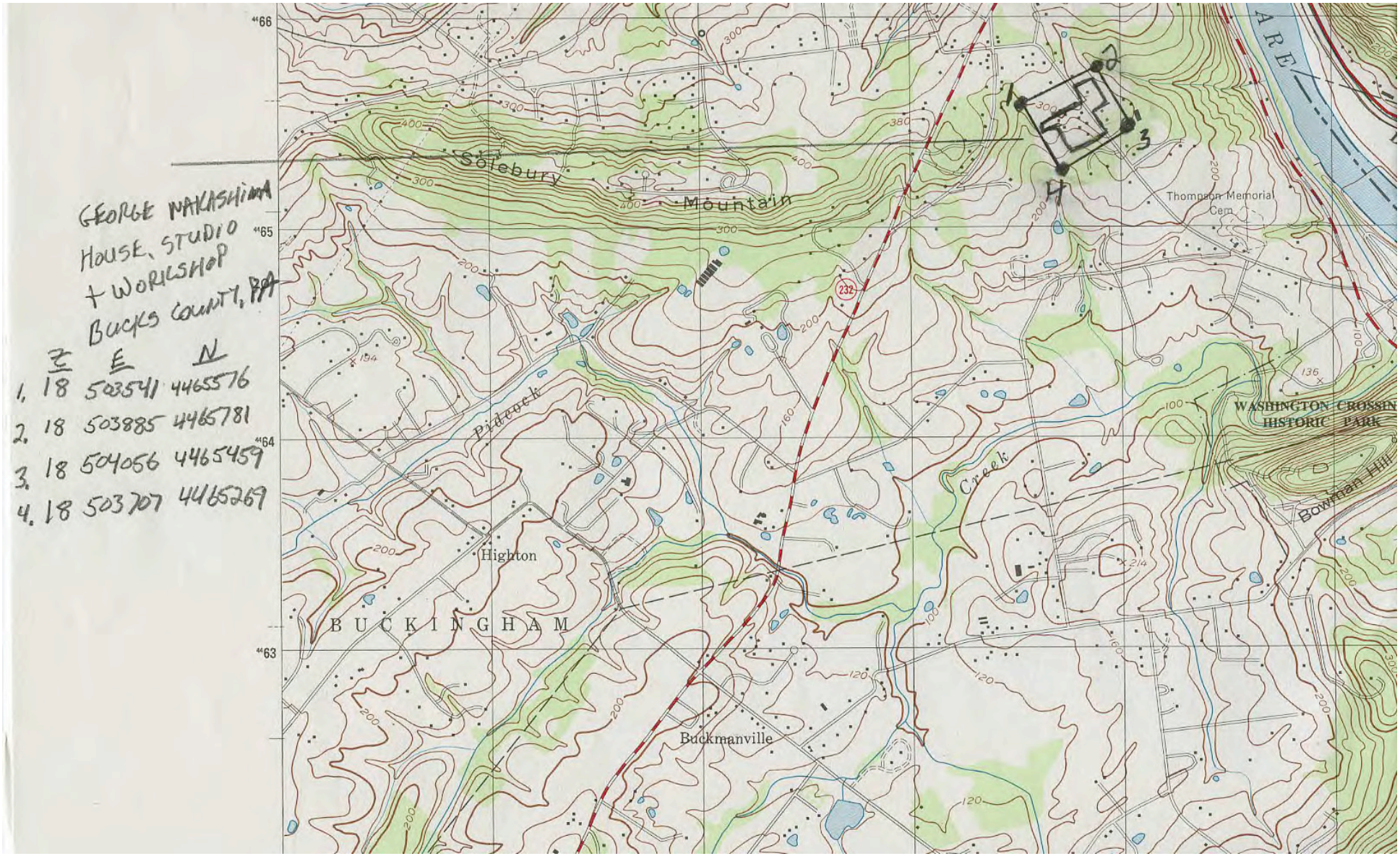


A Scottish Wych Elm Burl Conoid Bench with back (above)
The first Peace Altar in the Arts Building before shipment to the Cathedral of St. John the Divine in New York City, 1986 (below)
Courtesy of Mira Nakashima, George Nakashima Woodworker, S.A.





The iconic Conoid chair first designed ca. 1960.
Courtesy of Mira Nakashima, George Nakashima Woodworker, S.A.


GEORGE NAKASHIMA
HOUSE, STUDIO
+ WORKSHOP
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Pidcock
Creek
Highton
BUCKINGHAM
Buckmanville
WASHINGTON CROSSING
HISTORIC PARK
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All construction photographs (CMP Vol. I, p. 26-27, 67, 77, 78, 80, 83)	George Nakashima Woodworker	Unknown author. Courtesy of George Nakashima Woodworker.
Gorge Nakashima leaning on the Loft's rail in the Arts Building. (CMP Vol. I, p. 28)	Unknown	Unknown author. Courtesy of George Nakashima Woodworker.
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Rendering of the Golconde dormitory for Sri Aurobindo's Ashram. (CMP Vol. I, p. 32)	Architectural Archives of the University of Pennsylvania	Courtesy of Architectural Archives of the University of Pennsylvania
Aerial view of George Nakashima Woodworker's Complex. (CMP Vol. I, p. 33)	© Ezra Stoller/Esto	© Ezra Stoller/Esto
George Nakashima's addition to Ben and Bernarda Shahn's house. (CMP Vol. I, p. 37)	© Ezra Stoller/Esto	© Ezra Stoller/Esto
George Nakashima and the first Altar of Peace completed. 1986. (CMP Vol. I, p. 40)	Nakashima Foundation for Peace	Neal Boenzi. Courtesy of Nakashima Foundation for Peace.
George Nakashima's sketch for the Altar of Peace. (CMP Vol. I, p. 40)	Nakashima Foundation for Peace	George Nakashima. Courtesy of Nakashima Foundation for Peace
Aerial view of George Nakashima Woodworker complex. (CMP Vol. I, p. 43)	© Ezra Stoller/Esto	© Ezra Stoller/Esto
Cross section at right angle through plate and edge beam by George Nakashima. (CMP Vol. I, p. 68)	Nakashima Foundation for Peace	George Nakashima Collection, James A. Michener Arts Museum Archives. Gift of Mira and Kevin Nakashima.

Sketch depicting two types of fascia by George Nakashima. (CMP Vol. I, p. 69)	Nakashima Foundation for Peace	George Nakashima Collection, James A. Michener Arts Museum Archives. Gift of Mira and Kevin Nakashima.
Detailing for installation of the mural mosaic. (CMP Vol. I, p. 74)	Nakashima Foundation for Peace	Gabriel Loire and George Nakashima. George Nakashima Collection, James A. Michener Art Museum Archives. Gift of Mira and Kevin Nakashima.
Historical view of the west elevation from the north. (CMP Vol. I, p. 76)	George Nakashima Woodworker	Unknown author. Courtesy of George Nakashima Woodworker.
Historical view of the south elevation. (CMP Vol. I, p. 79)	© Ezra Stoller/Esto	© Ezra Stoller/Esto
Historical view of fireplace and niche. (CMP Vol. I, 81 & Vol. II, 58)	George Nakashima Woodworker	Unknown author. Courtesy of George Nakashima Woodworker.
Historical view of west elevation and Ben Shahn's mural. (CMP Vol. I, p. 83)	© Ezra Stoller/Esto	© Ezra Stoller/Esto
Craftsmen moving the Altar of Peace for Russia.	Nakashima Foundation for Peace.	Unknown author. Courtesy of Nakashima Foundation for Peace.
Historical view of south elevation (CMP Vol. I, p. 83)	Nakashima Foundation for Peace.	Unknown author. Courtesy of Nakashima Foundation for Peace.
George Nakashima standing in front of the Arts Building. (CMP Vol. II, p. 13)	George Nakashima Woodworker	Charles F. Sibre. Courtesy of George Nakashima Woodworker.
Nakashima family portrait (July 1967). Kevin Nakashima stands on "Keyhole" next to his parents Marion and George. (CMP Vol. II, P.50)	Nakashima Foundation for Peace	William A. Smith. Courtesy of Nakashima Foundation for Peace.
View of the cave. Ca. 1980. (CMP Vol II, P.51)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
"R" bench with wood plank lean-to display, 2001. (CMP Vol II, P.51)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
Interior of the Arts Building/Minguren Museum showing inaugural Ben Shahn's exhibition	© Ezra Stoller/Esto	© Ezra Stoller/Esto
George Nakashima's Arts Building opening exhibit.	© Ezra Stoller/Esto	© Ezra Stoller/Esto

Ben Shahn's opening exhibit, with Hans and Renata hermes (CMP Vol II, P.55)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
Meeting on Catholic Art (CMP Vol II, P.55)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
Urasenke Tea ceremony. Disashi Yamada left; Milly Johnstone far right foreground (CMP Vol II, P.55)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
Indian music concert with Tublu on flute, Julian lines on tamboura. (CMP Vol II, P.55)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
Family reunion meal. (CMP Vol II, P.55)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace
May Festival ca. 1968 "Koi-nobori" traditional Boys' Festival decorations, with banner and family crest from first Odakyu show in Japan (CMP Vol II, P.55)	Nakashima Foundation for Peace	Unknown author. Courtesy of Nakashima Foundation for Peace

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Eduardo Catalano's Hyperbolic Paraboloid, 1955. (CMP Vol. I, p. 34)	Unknown	Architectural Forum, November 1955
From left to right: Ben Shahn. "Maximus of Tyre," "Poet," "I Think Continually…" (shown in situ, May 1967), and "Gandhi." (CMP Vol. II, p. 52)	Unknown	Ben Shahn. Published with permission of the family of Ben Shahn.