Azrieli School of Architecture and Urbanism

MEXICO DSA

Conservation + Sustainability

2019

MEXICO CITY

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PUEBLA

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MORELOS

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Acknowledgements

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Thanks to Ing. John Cooke to join us in Mexico and for exchanging their knowledge on how to intervene unreinforced masonry structures.

This crucial opportunity to travel to and discover Mexico City and some of the UNESCO World Heritage Sites the XVIth convents, from Puebla and Morelos and UNAM Campus, with some of the conservation students (undergraduate and graduate) could not have been possible without the support of the Azrieli School of Architecture and Urbanism, and the International Research Seed Grant that Dr. Mariana Esponda got in May 2019 to study "Concrete Conservation: Developing Methodologies for Modern Heritage in Seismic Zones".

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For Pavilion:

Part of the research for this project was supported by the New Paradigm New Tools internship at Carleton Immersive Media Studio (CIMS) for Architectural Heritage in Canada (NPNT) research program supported by the Social Sciences and Humanities Research Council of Canada (SSHRC). Special thanks go to Professor Stephen Fai (principal Investigator of the New Paradigm/New Tools internship program and Director at CIMS), Lara Chow (Associate Director at CIMS), Mariana Esponda for leading the project, Sepideh Rajabzadeh (CIMS Research Assistant Intern for this project), Carleton Immersive Media Studio (CIMS), Carleton University. Arq. Alberto Hernandez and EPY CIG Company for the laser scanning to the Cosmic Rays Pavilion. Thanks to Adrian Soble, Khadija Waheed and Luis Panchi for helping gather the data for the project. Laila Cordero Espinosa for sharing her undergraduate thesis, as well as hosting the team in Mexico City.

En memoria de mi Tío Ricardo Esponda, por su impulso para restaurar la "Ruta de los Conventos"

Preface

The deterioration of heritage sites from natural disasters such as earthquakes is a loss to humanity's culture. However, most existing studies on earthquakes focus on the effects on building materials from a technical standpoint. Research on how to intervene and manage risk in modern buildings with heritage value is sorely lacking, specially if they are in a UNESCO World Heritage context. There is a need for more studies that balance the technical requirements with the understanding of the significance of built heritage. The intention of this Directed Research Study (DSA) in Mexico was to learn the risks posed to heritage buildings in seismic zones.

To understand the values, heritage significance and behaviours of these structures, the Conservation and Sustainability students from the Azrieli School of Architecture and Urbanism, Carleton University were exposed to two different activities during the technical workshop. First, to document two structures in the UNESCO World Heritage Site of the Central Campus of Ciudad Universitaria at UNAM in Mexico City and second, to provide hands-on restoration experience visiting the area of "Ruta de los Conventos" in Morelos and Puebla. These Monasteries from the XVI century, designated by UNESCO in 1994, were highly damaged and students observed the process of interventions and the decision-making process by the stakeholders.

The following report by the students is based on the recording and in-depth analysis (history, construction, and condition assessment) of the Chemistry Building B and the Cosmic Rays Pavilion, two modern structures designated from their attributes on the UNESCO World Heritage Campus at UNAM. As a result of this project, the students were able to gain skills in documenting structures from the recent past structures (XX century) affected by earthquakes and learned in situ a variety of historical construction techniques, building materials, evaluation of heritage attributes, challenges in the protection of World Heritage Site, as well the practice of and principles that could guide the conservation of heritage buildings in risk.

Report Objective

The main goal for the students was to gain skills in documenting a UNESCO World Heritage Site after a devastating effect of an earthquake.

1. Provided international experience to the Carleton students and explored interventions specific to the context of Mexico City, including: the ongoing challenge posed by the environmental phenomenon of earthquakes, its unique geological conditions, intervening within a vibrant, urban location and historical construction techniques.

2. Studied the strengths and limitations of the use of digital workflows in two modern structures damaged by a natural event.

3. Accurately record the interior and exterior of two concrete structures. In both buildings, students learned traditional and contemporary techniques - hand measurement and photogrammetry (DSLR cameras). In the case of Cosmic Rays Pavilion, the team developed the photogrammetry data into a point cloud model.

Then, the point cloud model was used to make an accurate HBIM in Autodesk Revit software to study the aging and the current state of the concrete shell more closely.

4. Identified character defining elements and materials of construction, conducted the condition assessment of the two buildings in its current state and identified priorities to repair.

5. Recognized areas of risk for the assets being studied, as a preventative form of disaster mitigation and management.

6. Best practices of intervention-consolidation-reconstruction in Mexico heritage buildings affected by earthquakes.

7. Understand appropriate intervention methods with compatible materials and the evolution of decision-making process in the last twenty years.

8. Understand the difference in structural behaviour between unreinforced Masonry (Ruta de los Conventos - 16th Century) and modern concrete in (UNAM Campus) buildings.

Not pictured: Luis Panchi Galvan, Danica Mitric, Erika Sieweke

Introduction

During the first two weeks of May 2019, 11 undergraduates from the Conservation and Sustainability program and 6 graduate (G) students from the Graduate Diploma of Architectural Conservation (GDAC) went to Mexico to study how the historical buildings were affected by the recent earthquake in September 2017. During the first week, they documented two modern structures at UNAM: Felix Candela's Cosmic Rays Pavilion built in 1951 with 5/8" thin concrete shell and the Annex of the Faculty of Chemistry. The students identified main materials, construction techniques, key damages, and causes of deterioration.

- Mariana Esponda

Team Members

Dr. Mariana Esponda

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Erika Sieweke
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Chris Stec
Khadija Waheed

Undertanding Earthquake Impacts to Historic Sites in Mexico City and Surrounding Areas.

Many historic cities have witnessed an increase in frequency and intensity of natural disasters, especially damage from consecutive earthquakes in the last twenty years (Italy - Umbria - 1997, Turkey, Greece and Mexico 1999, Arequipa Peru 2003, Southern Sumatra Indonesia 2007, China 2008, Italy - L'Aquila - 2009, Chile and Haiti 2010, Japan and New Zealand 2011, Russia 2013, Chile 2014, Nepal and Chile 2015, Myanmar and Italy 2016, Mexico 2017, Peru and Ecuador 2019, Haiti, and Alaska 2021). These events prove that the evaluation of the built heritage is a critical issue in the preparedness for and mitigation and management of earthquake disasters.

A magnitude 8.2 on September 8, 2017, just offshore from the state of Chiapas was followed by a magnitude 7.1 on September 19, this time much closer to Mexico City, and caused heavy destruction in 11 states. There were more than 2300 heritage buildings damaged, most of which were in the states of Puebla, Morelos and the Greater Mexico City.

The DSA in Mexico wanted to contribute and to provide general knowledge on how important the preservation of both typologies is - unreinforced masonry from the colonial period as well as the modern heritage structures from the UNAM Campus that were affected by earthquakes. Specifically, the modern heritage encompasses constructions between 1930 and the mid-1970s, whose architectural features are technological advances, and representation of new expressions to unique functional demands. As Canada Historic Places stated, "The Heritage of Modern Era is often undervalued by the general public, and is underrepresented in the heritage sector, with only 3% of our National Historic Sites of Canada".

Much of the damage which occurred during the recent earthquake was related to the existing conditions, contemporary changes made to the structures by using not compatible materials, and lack of maintenance.

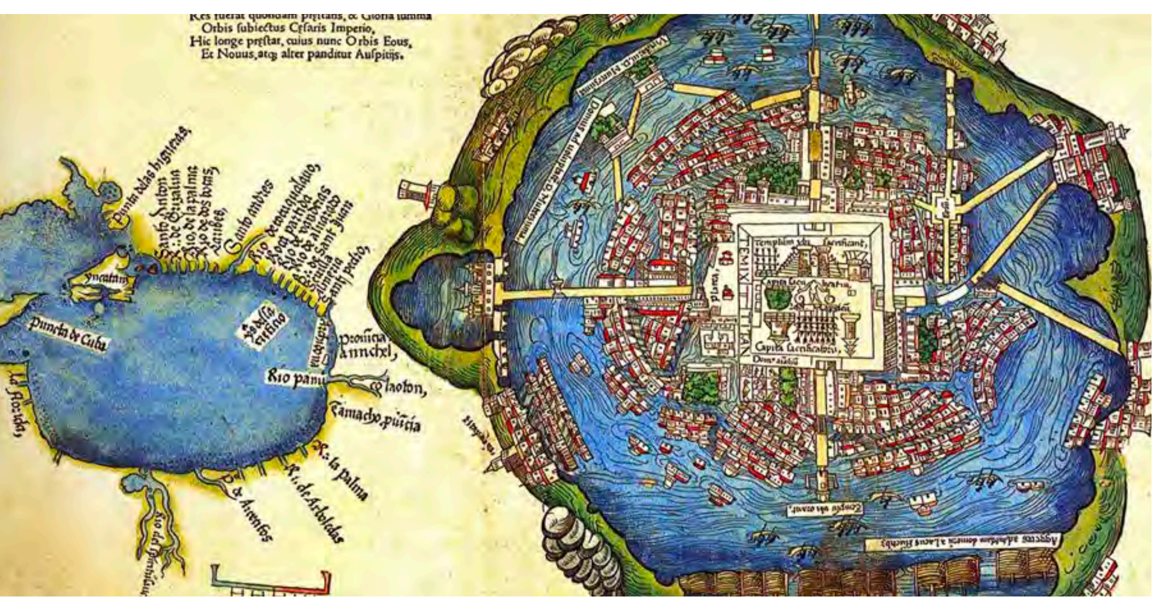
Robert Heatley 2017
Huaquechula

Mexico City

A History

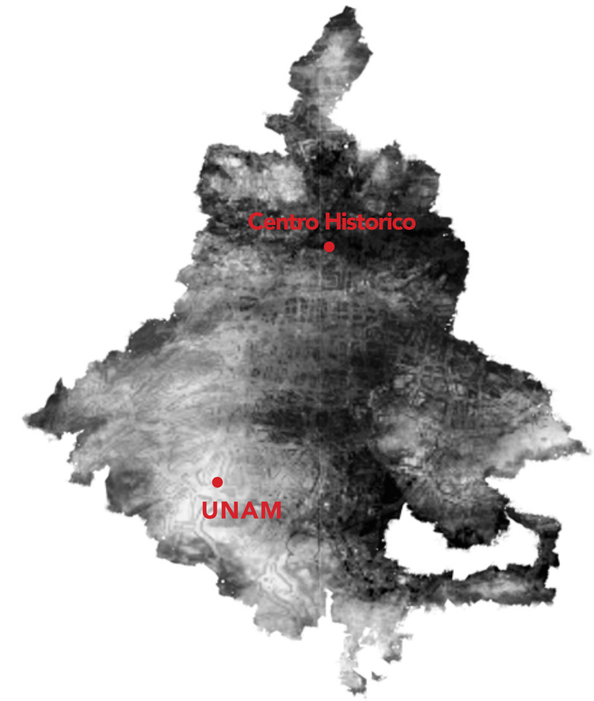
Mexico City is the capital and largest city of Mexico and the most populous metropolitan area in the American continent (21 million). Mexico City is located in the Valley of Anáhuac that was inhabited by several indigenous groups from 100 to 900 A.D. The Aztec capital city of Tenochtitlán was founded in 1325 over a lake, the Lago de Texcoco. Aztecs built an artificial island by dumping soil into the lagoon, as floating pieces of land - chinampas. The Aztecs dominated all of Mesoamerica during that era and culturally they hold great value.

In 1521, the Spanish Hernán Cortés and his troops conquered Tenochtitlán with the assistance of other indigenous groups. The Spanish built México City over the ruins of the once great city. During the Colonial Period (1521-1821), there was a complex ethnic division including: Mestizos, Criollos, Benbos, Saltopatras, Natives, and Coyotes. The population intermingled and the Criollos class, mixed-blood citizens who eventually became a political force.



A 1524 European woodcut map of Tenochtitlán, island capital of the Aztec Empire.

Mexico Valley c.1519
by Mary Hanna



Mexico City topographic map
by Jessica Babe

The Catholic Church influenced the city and the people, and religious orders like Franciscans, Dominicans, Augustinians, and Jesuits established convents throughout Mexico. Mexico City was one of the most important cities in America and served as the capital of the Vice Royalty of New Spain until the Independance War (1810 - 1821). Mexico City was invaded by the American army during the Mexico-US war in 1847 and later invaded by the French when Emperor Ferdinand Maximilian of Hapsburg ordered to build Avenue of the Empress (today's Paseo de la Reforma promenade).

In 1876, Porfirio Díaz assumed power and marked the city with many European styled buildings such as the Palacio de Bellas Artes and the Palacio Postal. During the Mexican Revolution, he was overthrown and the city's architecture tranformed. Growth of the city beyond the historic centre caused modernist construction to flourish. Today, it remains one of the most important cultural and financial centers in the world.

The Earthquake of 2017

The Earthquake of September 2017: Damages, Diagnosis and Rehabilitation Criteria for Heritage Buildings

Lecture by Dr. Roberto Meli

As one of the world's most earthquake-prone countries, Mexico has been a victim of many seismic events of moderate to high intensity. Intersecting tectonic plates create subduction zones that generate high-intensity earthquakes, which can be very destructive, especially in places built on soft soil like Mexico City. In the 20th century alone, 183 earthquakes with a magnitude greater than 6.5 have occured in the area, with most of them having epicentres located on the Pacific Coast. More recently, the September 2017 earthquake struck Puebla with a magnitude of 7.1 and caused heavy damages from Puebla to Morelos and the Greater Mexico City area.

In historic buildings, the typical seismic response of these massive, rigid and fragile structures include a short period of vibration (0.1 - 0.5 sec), shock absorption and inertia forces. The Puebla earthquake of 1999 showed that the cracking of stone was the most common damage, with the main failures being located in the bell towers, roofs, domes, main facades and even turning top of the facades. In the case of multi-storey civil buildings built with stone masonry walls and wooden beams floor systems, damages included walls tilting out of plane, their diagonal cracking, as well as the partial collapse of the floor systems (which were not attached to the facade). When both horizontal and vertical movements of the terrain occur, a building's nave responds with lateral motion and vertical shaking, causing broken openings. However, vertical shaking is only very important in areas that are in or near the epicentre. Three methods of safety assessment diagnosis exist. 1. Historical analysis 2. Qualitative analysis 3. Quantitative analysis

Structural rehabilitation principles and guidelines were developed within the international organization ISCARAH-ICOMOS. The requirements for rehabilitation measures include minimal intervention, effectiveness (demonstrated in the long term), compatibility and reversibility. That's why the use of modern materials, such as concrete should be carefully applied in conservation projects due to modifications in the structural behaviour.

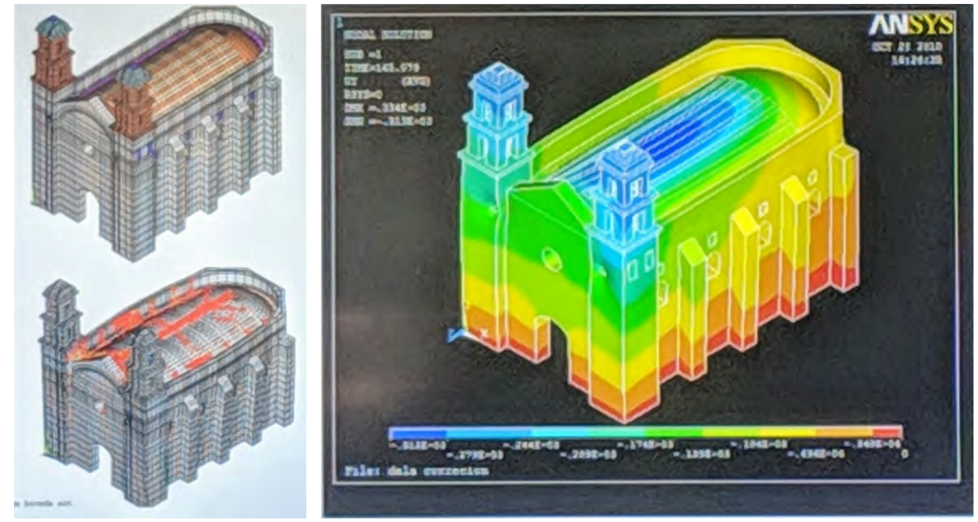
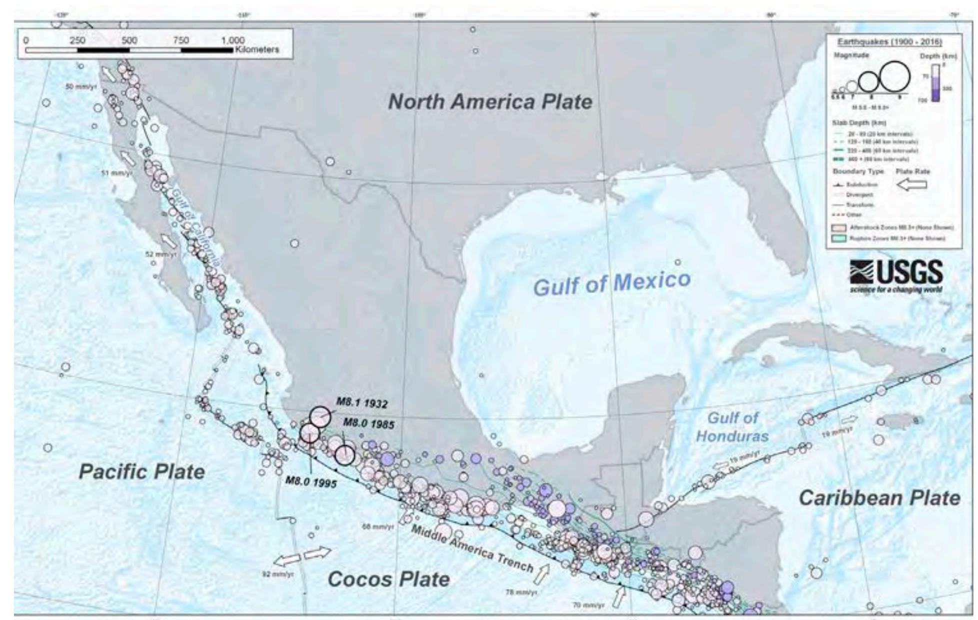


Image provided by Dr. Roberto Meli
An example of a quantitative analysis of a church using mathematical models in a simulation software to determine the effects of internal forces on the historical building.

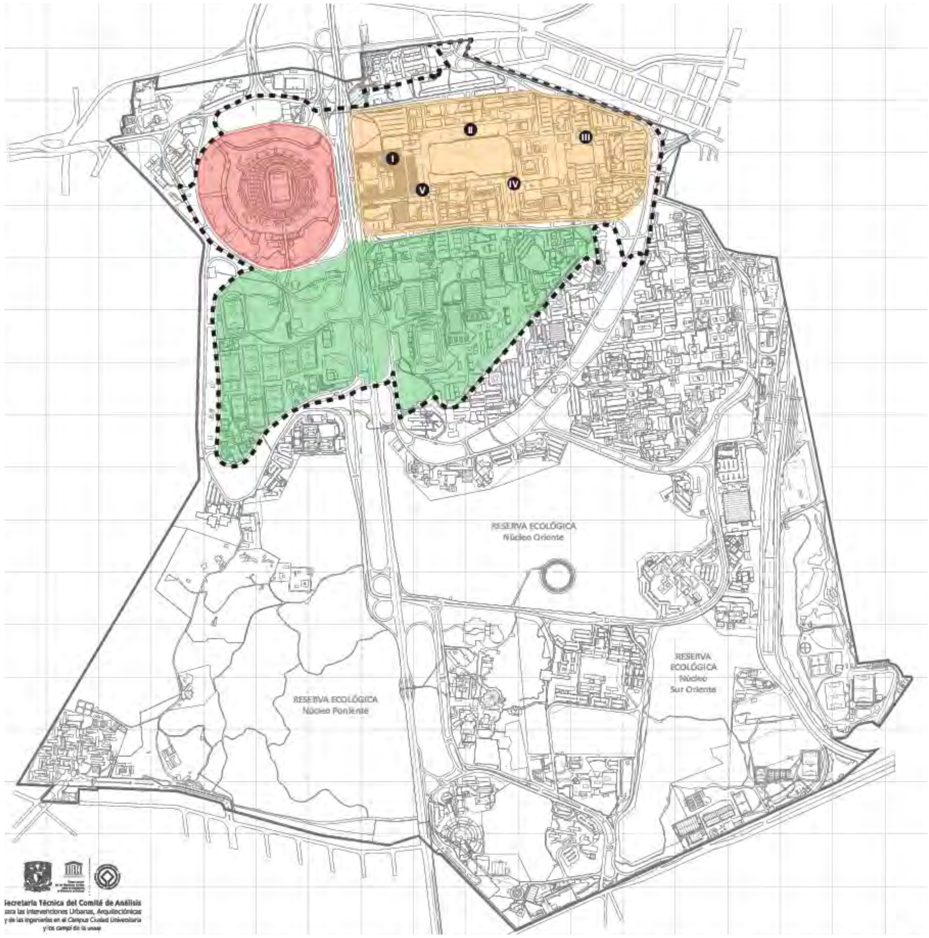


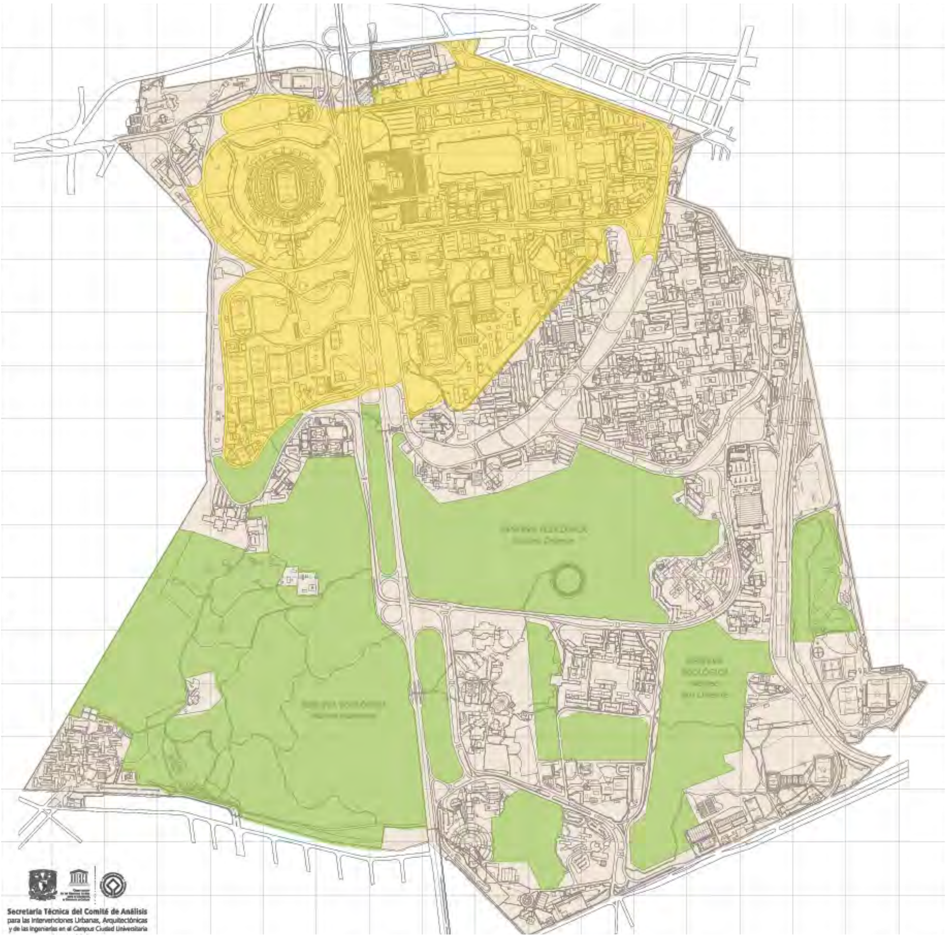
Map by the US Geological Survey depicting the boundary between three tectonic plates: the Cocos plate, the North American plate, and the Pacific plate.

UNAM

Universidad Nacional Autónoma de México
National Autonomous University of Mexico

From left to right: Mary Hanna, Sepideh Rajabzadeh, Rachel Bricknell, Adrian Soble (G), Chris Stec, Jessica Babe, Luis Panchi Galvan, Khadija Waheed, Erika Sieweke, Meighen Katz (G), Kate Coulthart (G), Jeannine Senecal (G), Clarisse Miranda, Melina Grandmont, Zabdi Falcon (G), Christie Ellis Wong (G), Danica Mitric and Professor Mariana Esponda.





W.H.S

Stadium

Faculties, Headquarters, Museum

Sports Facilities

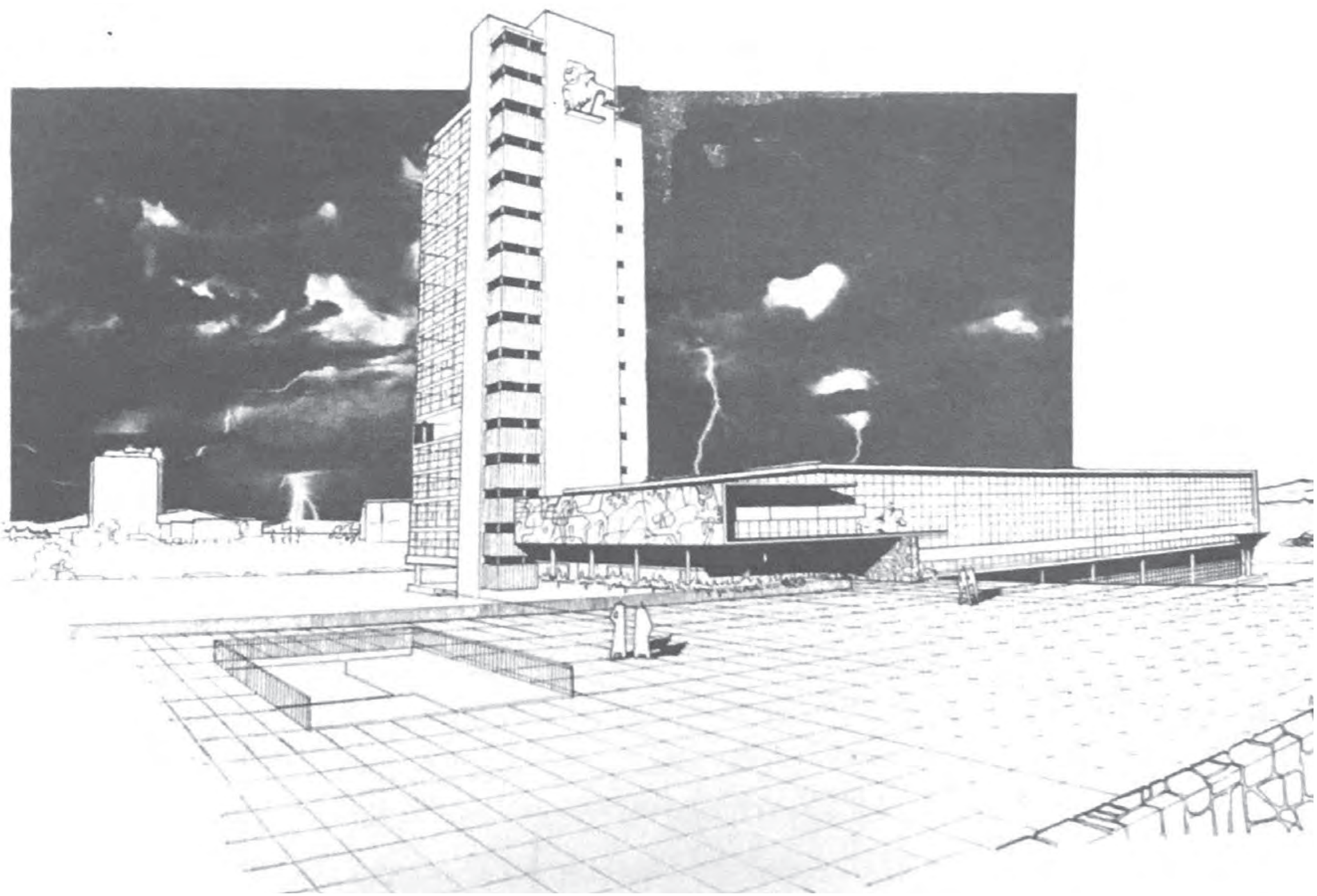
UNESCO Designated Areas
Secretaria Técnica del Comité de Análisis
Management plan for the central campus
UNAM, Annex 2 p.181, p.187

UNAM Main Areas

Control Growth

W.H.S 176 Ha

Ecological Reserve 237 Ha



Perspective drawing of the *Rectoría* building design proposed by Mario Pani and Enrique del Moral.

UNAM Campus

Background Information

Constructed: 1949 – 1954

The Central University City Campus was inscribed in 2007 as a UNESCO World Heritage Site. The area represents the works of over 60 architects, engineers, and artists who helped construct the university campus. It is a unique example of mid-century modernist architecture that incorporates urbanism, landscape design and references to local traditions.

The city campus itself was built on an ancient lava field and designed by architects Mario Pani and Enrique del Moral and comprises of over 40 faculties and institutes along with a number of facilities for recreational activities, arts, and museums. The campus was, aside from Brasília, the only urban planning project designed completely out of the modernist movement.

UNAM

Espacio Escultórico

Constructed: 1977

Artists: Manuel Felguerez, Federico Silva, Sebastian Hersúa, Helen Escobedo and Mathias Goeritz

The Espacio Escultórico is located in the cultural center of UNAM within Mexico City. The sculptural space was created in 1977 by 6 artists. It is the only structure that sits within the ecological reserve of the Ciudad Universitaria.

The intention of the piece was to contrast the surrounding nature with geometric forms where ecology and art are presented. The design of the space also has connections to the cosmos, which references Mexico's pre-Hispanic culture.

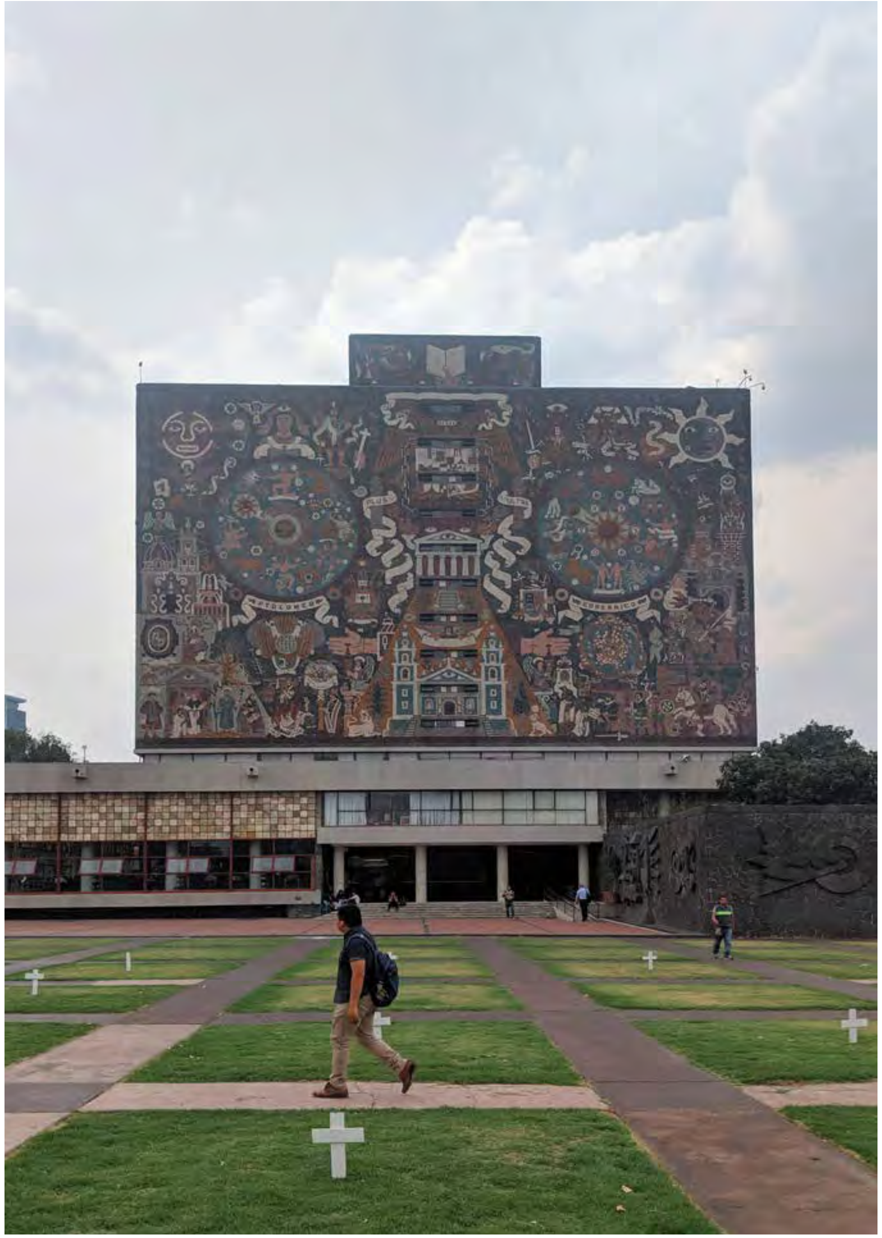
The circular base measures 120 meters in exterior diameter and is circled by 64 modular pieces which are 4 meters in height. The center of the space is composed of tezontle, a dark grey volcanic rock left by the eruption of the Xitle volcano in the 1st century AD.

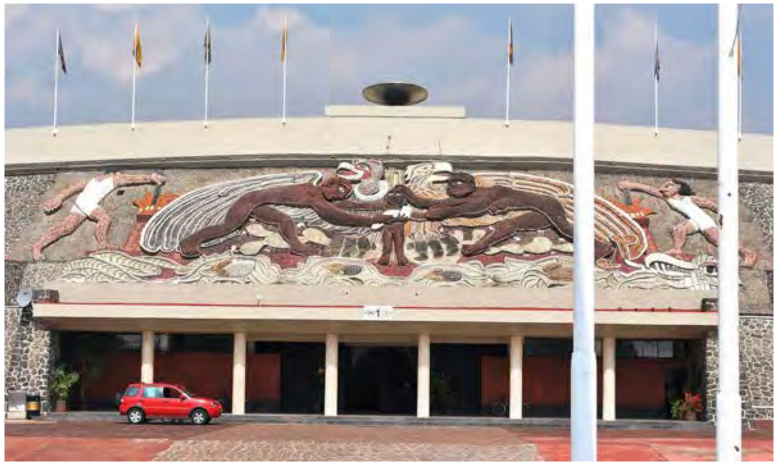
Biblioteca O'Gorman

Constructed: 1950 – 1956
Architect: Juan O'Gorman (with Maria Saavedra and Juan Martinez de Velasco)

The four façades of the building are covered with the 'Historical Representation of Culture' mural, created by the Mexican artist Juan O'Gorman. The mural was made out of thousands of naturally-coloured stone tiles, something that had never been done at such a large scale. It is still today considered as one of the largest mosaic murals in the world. This mural, along with the other mosaic murals on the campus, became one of the most important character-defining elements of the UNAM campus.

The Central Library is considered an architectural treasure in the campus as well in Mexico City. The building and the mural are visual representations of Mexican culture, and tell the stories of the distant past, as well as the history of Mexico City and the univeristy in the 20th century.





Estadio Olímpico Universitario | UNAM Olympic Stadium

Constructed: 1952
Architect: Augusto Pérez Palacios, Raúl Salinas Moro, Jorge Bravo Jiménez
Artist : Diego Rivera

The University's Olympic Stadium was constructed for the 1968 Summer Olympics in a system of stepped terraces, made with indigenous volcanic stone. A high relief mural by Diego Rivera decorates the main entrance. The natural coloured stones composition portrays a condor and an eagle on a cactus, with their wings stretched over a family. In the scene, the mother and the father are offering the dove of peace to their son. At the extremities, a male and a female athlete light the torch of the Olympic flame. Finally, a feathered serpent, symbolic of the pre-Hispanic god Quetzalcóatl, is represented at the bottom.

la Facultad de Arquitectura / UNAM Faculty of Architecture

Introduction meeting at the Faculty of Architecture with Dr. Cortés Rocha

Founded in 1781, la Facultad de Arquitectura in UNAM was the first School of Architecture in the continent. The faculty has since then enlarged and offers a broader spectrum of programs, including Industrial Design, Urban Design and Landscape Design. These new programs hold about 20% of students, while the other 80% enroll in the Architecture program. In total, 8 000 undergraduate students along with 1 000 professors are part of the faculty, and they publish 20 books every year. With the Canberra international accord agreement between North American countries as well as Australia, China, Korea and the Commonwealth, the architecture degree is taught in similar ways in universities across these countries. At UNAM, the programs consists of an agglomeration of 16 ateliers, each one with approximately 500 students and working on different projects, methodologies and topics. The students get to choose which atelier they want to take part in, which creates a dynamic faculty with a comprehensive view on many aspects of architecture. Finally, the program consists of five knowledge areas: technology, history and theory, environment and urbanism, social service and coop, as well as studio and research methods.

La Facultad de Medicina Mural Project / Faculty of Medicine Mural Project /

Hands - on experience in the restoration of one of the most important murals by architecture students.

Constructed: 1954
Restoration from 2014 - 2020
Artist: Fransisco Eppens

The glazed ceramic mosaic mural "Life, Death, Miscegenation and the Four Elements" was completed by Mexican artist Francisco Eppens Helguera on the exterior West facade of the School of Medicine at the UNAM in late January 1954. This enormous mural, which represents the 'beneficial miscegenation' of the Indigenous and the Spanish people, is what the artist considered his best work. The mounting of the mural on the exterior wall was a challenge due to the curvature of the large rectangular facade measuring 20 meters high by 18 meters long. The mural therefore had to be made in sections of precast reinforced concrete slabs and assembled onto the wall to follow the curvature. In 2013, the Institute of Engineering of the UNAM conducted a detailed analysis of the condition of the mural and the wall behind it as a preventive maintenance due to the recurrence of earthquakes in the area. After analyzing the capacity of the original building materials, combined with the fast pace of construction and the related techniques in the Ciudad Universitaria, it was determined that the current structure presented important deterioration and needed an intervention.

This restoration project required the dismantlement of the entire mosaic wall and the numbering and tracking of each individual piece and its original location.

The level of damage on the wall was caused by the weight of the concrete pieces that support the mural, the aging of materials and various climate factors. The restoration criteria for the wall consists of reintegrating the structural elements of support by adding materials that are similar to the original ones and that comply with the seismic structural security guidelines. This compliance is crucial to make possible the conservation of the mural as an artistic element integrated with the architecture. The restoration of the wall called for the use of clay bricks (vitro cotta), which were fabricated in the same factory as the one that produced the original materials in the 1950s. Multiple colour and texture tests were completed to achieve a similar appearance in the reconstruction of the convex-shaped wall. As part of a larger context, this intervention along with other conservation works in the central campus have a common objective to guarantee the security of structures that are vulnerable to seismic events, as well as to preserve the "Outstanding Universal Value" of this World Heritage Site.

"La vida, la muerte, el mestizaje y los cuatro elementos" / "Life, Death, Miscegenation and the Four Elements"

From left to right: Workshop and storage room for the mural pieces /Original mural on the Faculty of Medicine prior to the intervention /Tour of the construction area and exposed facade of the Faculty of Medicine .

Félix Candela

1910 - 1997

Félix Candela, Spanish architect and engineer, has become well known worldwide for his innovative works including thin concrete shells in the 20th century. Born in Madrid (Spain) in 1910. He graduated in 1935 from La Escuela Superior de Arquitectura. Candela won a scholarship to study in Germany and further his knowledge on concrete shells. However, his academic plans were truncated as he joined the republicans right after the outbreak of the Spanish Civil War in 1936. He got imprisoned in a concentration camp in Perpignan, France until the end of the war in 1939. After the Spanish Civil War, 25000 exiles fled to Mexico. Candela was one of the 25 Spanish architects of the exile.

Candela's innovation in the field of concrete shells is attributed to the profuse use of the double curved or hypars geometry to design and built hundreds of double curved thin-shell concrete structures also known as 'hypar' shells. He was integrating technology with artistic and financial aspects of such designs. His time in Mexico, from 1939 until 1971, is described as his Golden Age. These years represent a significant and crucial part of his professional life where he designed his most dazzling structures such as the Vicente Paul Chapel, Cosmic Rays Pavilion, Medalla Milagrosa Chapel, Restaurant Los Manantiales, and the Palacio de los Deportes all in Mexico City.

Works

Los Manantiales, Xochimilco , Mexico, 1958
Restoration in progress

In the lake of Xochimilco, stands one of Felix Candela´s masterpieces: Los Manantiales restaurant. The formwork for the concrete is made of a series of straight boards. The reinforced concrete shell 2 inches thick that forms an "eight-petal flower", derived from a peculiar geometry generated by the intersection of four hypars that rotate on an axis, creating a groin vault of eight segments. The shell opens a clearing of more than 30 meters and covers an area greater than 900 square meters without intermediate supports. This original structure, the best example of "free edge shells", extended Candela's worldwide fame through the image of the weightless concrete flower. The form, as well as the techniques used to achieve it, were highly inventive.
Conservation and Sustainability students observed the damages that the earthquake and the differential settlements next to the lake had caused to the foundation fracture in one section of the perimeter. This displacement created deformations in the geometry of the superstructure.

Felix Candela

Sketch by
Christie Ellis Wong

Felix Candela: The Shell Builder and His Legacy

Lecture by: Dr Arq. Juan Ignacio del Cueto Ruiz-Funes,
Universidad Nacional Autónoma de México (UNAM)

His time in México, from 1939 until 1971 was influenced by the Mexican Modern Architecture of Juan Segura Gutiérrez, José Villagrán García and Juan O'Gorman, Candela became passionate with buildings of thin concrete shells. He integrated architecture and engineering by mixing these new modern ideas with the ones he had brought back from Spain, as well as the State of the Art and technologies in Europe.

Some of Candela's first buildings in México include the Hotel Papagayo (Acapulco, 1941), the Casa en Tepoztlán (1944) and the Hotel y Ciné en Guamúchil (Sinaloa, 1946). Shortly after completing these buildings, he founded his own construction company named Cubiertas Ala, which can be translated to 'wing covers'. The first shell he built was the cylindrical vault of Boliches mar, completed in 1950.

Candela worked as a structural constructor alongside Arq. Jorge González Reyna, to create variances of "Hyperbolic Paraboloid (hypar)", based on economic resources and structural requirements. Their works aimed to create a structurally resistant shape that would demand minimal material while covering the largest surface possible. In fact, Candela

disregarded flat roofs. He believed that they did not represent a logical solution, since a 15 cm concrete thickness is required for a flat roof whereas only 4 to 5 cm is needed for a parabolic one. The parabola is therefore the best solution, since it allows to cover a greater area given the same amount of material.

In 1951, Candela designed the hypar shell of the Pabellón de Rayos Cósmicos in UNAM with Arq. Jorge González Reyna. The pavilion would serve as a laboratory specializing in the measurement of neutrons, where the rays of the sun would be studied. The framework of the hypar shell consisted of straight lines that were curved into a saddle shape to create a double curvature. It was erected by Cubiertas Ala in only 8 hours, and the concrete was poured over it with a thickness of 15 mm in the center, decreasing to 6 mm on the edges.

'The Umbrella' is a structural unit that transfers all the loads of four segments of the parabola through the column and into the ground. A framework of steel rebars is covered with 6 cm thick concrete, which in theory could be less but also serves to protect the rebars from oxidation. The design was very cheap to build (only 7 USD per meter square), making it

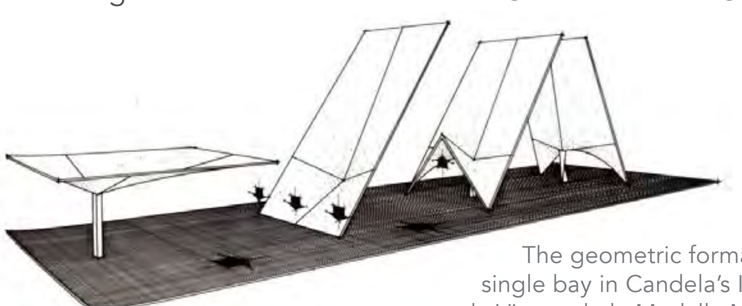
Iglesia de la Virgen de la Medalla Milagrosa designed by Felix Candela, Mexico City, 1954

an economical solution to mass-produce and use repeatedly. Candela designed his first church with the umbrella, using two central colonnades of tilted and off-centered columns which created a triangular section. The shell of La Medalla Milagrosa took 13 months to build (from March 1953 to April 1954) and only cost 660 Mexican pesos.

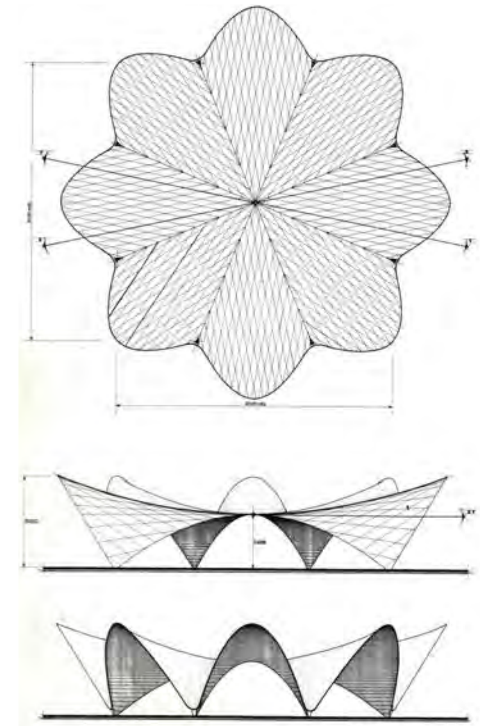
From the idea of the groin vaults, Candela came up with the design of the Restaurante Los Manantiales, which consists of the intersection of 4 hypar vaults that create a flower in plan. The 8 hypar shells overhang on all windows to create a perfect lighting all around the restaurant throughout the day. Architect Joaquin Alvarez Ordoñez worked with Candela on this project and designed the interior. The building was completed in 1958, but has since then unfortunately suffered great damage from the September 2017 earthquake.

The last building that Candela built was the Palacio de los Deportes in Mexico City, meaning Sports Palace, and was completed in 1968 for the Summer Olympics. The distinctive roof was clad in copper plates and supported by an elliptical frame of steel, aluminum and reinforced concrete. The building was viewed by an international audience, which allowed Candela to be noticed worldwide for his architectural and structural ideas. He became an influence for architects in many countries and his legacy remains very important today. His company, Cubiertas Ala, built over 200 buildings in Mexico City alone, as well as 800 more in other cities.

Candela became an influence for the next generation of architects. He began his teaching career at UNAM (1953-71) before moving to Chicago, where he taught at the University of Illinois (1971-78) and spent his last years before he died in 1997. Today, archives of his work are kept at Columbia University, Princeton University and UNAM.



The geometric formation of a single bay in Candela's Iglesia de la Virgen de la Medalla Milagrosa.

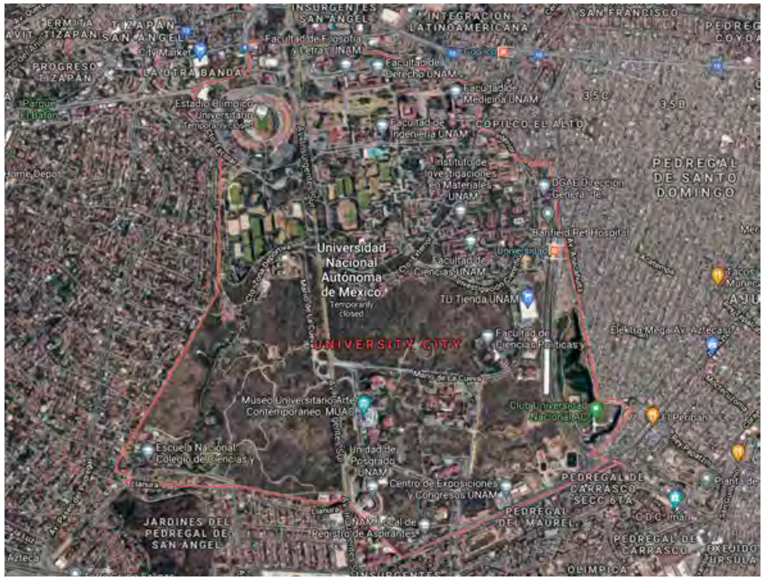


The geometry of Candela's Restaurante Los Manantiales formed by the intersection of four hypar vaults.

Palacio de los Deportes designed by Felix Candela in 1968, Mexico City

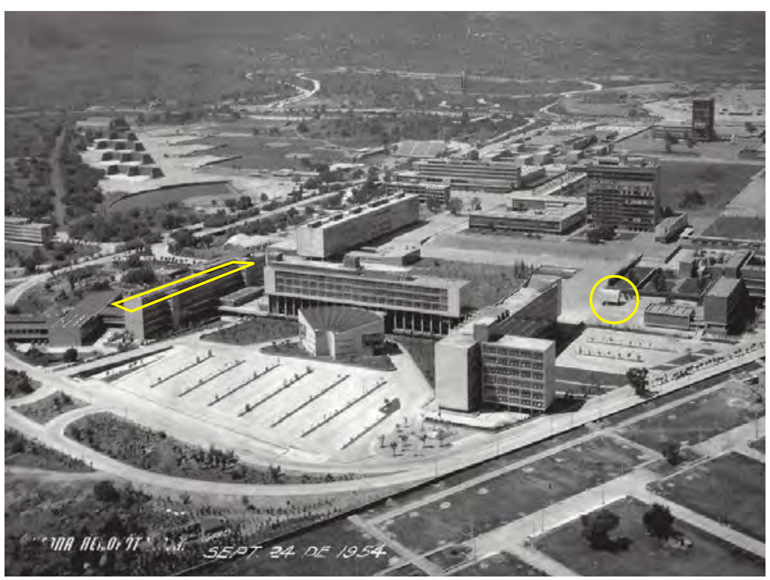
Damages to Los Manantiales following the 2017 earthquake.

Site Location



UNAM University City, Mexico City

Chemsitry Building B (UNAM)



UNAM (Chemistry Building B + Cosmic Rays Pavilion)
**highlighted in yellow*
Photo from the compañía mexicana de aerofoto, 1954, fundacion ICA.

Cosmic Rays Pavilion (UNAM)

Part 1: Cosmic Rays Pavilion

Constructed: 1951

The Pavilion is located on the UNESCO World Heritage campus of the National Autonomous University of Mexico (UNAM). A team of 4 students : Sepideh Rajabzadeh, Adrian Soble, Khadija Waheed and Luis Panchi Galvan spent 6 days in May 2019 in Mexico City recording this modern heritage hyperbolic paraboloid building and used photogrammetry to capture the building. One of the students Sepideh Rajabzadeh was able to participate thanks to the support of Stephen Fai + The NPNT internship grant with CIMS lab. She was able to continue its data development and new discoveries along with professor Mariana Esponda until project completion in Canada in July 2019. Using digital equipment such as DSLR cameras, a drone, and computer software the team captured and processed the exact condition and geometry of the building on site.

The Cosmic Rays Pavilion with a 5/8" thick reinforced concrete shell is the thinnest major structure ever built. Its strength comes from its hypar geometry, a form that offers extra stiffening to the structure. Three stiffening arches were added to the structure as Candela was not convinced at this time that the concrete would be strong enough at such a thinness, though he later discovered that the shape is strong enough without the arches. The concrete shell structure is elevated on three arched concrete columns which rest on a concrete platform elevating the pavilion by 15 cm from the ground plane. The pavilion was built as a physics laboratory to allow the cosmic ray to enter the interior space for measurements and nuclear disintegration, but now it is a storage space for board games and sports equipment.

Project Objectives

This documentation was undertaken to better understand the building's structure, its evolution, to assess its performace after the earthquake of 2017 as well as supporting the ongoing research on the as-built, current condition documentation of the Cosmic Rays Pavilion. The project conducted in Mexico City between May 5th - May 13th 2019 was to collect data and between May 13 - July 11th 2019 to produce a Heritage Building Information Model (HBIM). This research was lead by Sepideh Rajabzadeh and supported by Carleton Immersive Media Studio (CIMS)

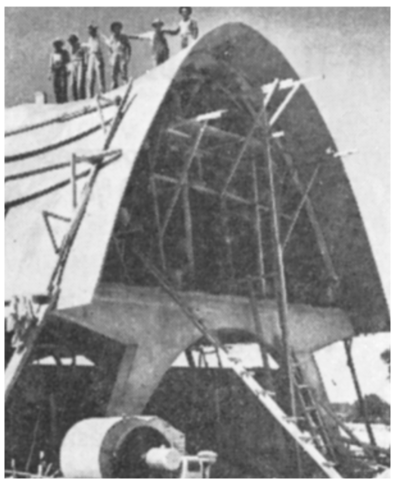


Photo from Felix Candela Original Images, Felix Candela Papers c 1455. Department of special collections princeton university library.

Work Week

Sun 5	Arrival
Mon 6	Tour of UNAM
Tues 7	- Tour of pavilion - Interior material catalogue - Placing targets
Wed 8	- Exterior photogrammetry - Context photos - Drone documentation - Exterior material catalogue - Exterior condition assessment - Interior documentation
Thurs 9	- Photogrammetric models and data quality testing - Elevation photo quality testing - Statement of significance research - Interior photogrammetry
Fri 10	- Exterior elevation photos - Exterior photogrammetry - File organization - Handover document development
Sat 11	- Handover document development - Handover

New Paradigm New Tools Internship (NPNT): Project Deliverables

- Site Measurements
- Statement of Significance
- Condition Assessment
- Point Cloud model based on photogrammetric data
- HBIM in Revit based Point Cloud Model
- As-found 2D Architectural drawings based on HBIM

Supplementary Data

- Site Photo Collection
- Context Photos
- Elevation photos
- Photogrammetric Documentation Photos
- Material Catalogue

Team Members

Sepideh Rajabzadeh (Team Lead supported by CIMS)

Luis Panchi Galvan

Adrian Soble

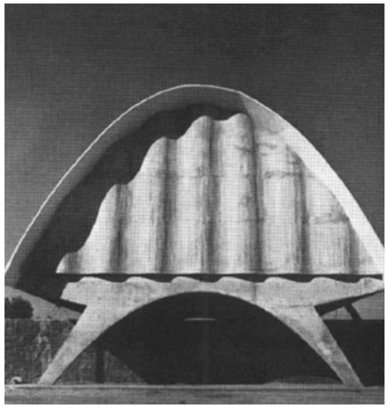
Khadija Waheed

Lessons Learned

Understanding how the building was constructed and evolved throughout time though an HBIM model

Gap exists between the red roof membrane and the hypar concrete shell which varies throughout the entirety of the pavilion and it is at its greatest in the middle of the roof.

Results show that the traditional and contemporary techniques produced the same results. However, using new digital techniques led to more in-depth discoveries of the state of the building. Over the years, there has been moisture damage on the concrete shell due to the improper removal of the waterproofing roof membrane and this long-term damage is changing the curvature, and probably the capacity of the pavilion.



Cosmic Rays Pavilion,
Mexico City, 1951

Statement of Significance

Located on the UNESCO World Heritage Site, Universidad Nacional Autónoma de México, the Cosmic Rays Pavilion (CRP) is an example of concrete shell architecture. Designed by Felix Candela in 1951, this double curvature thin concrete shell was Candela's first prototype model of a hyper parabolic structure.

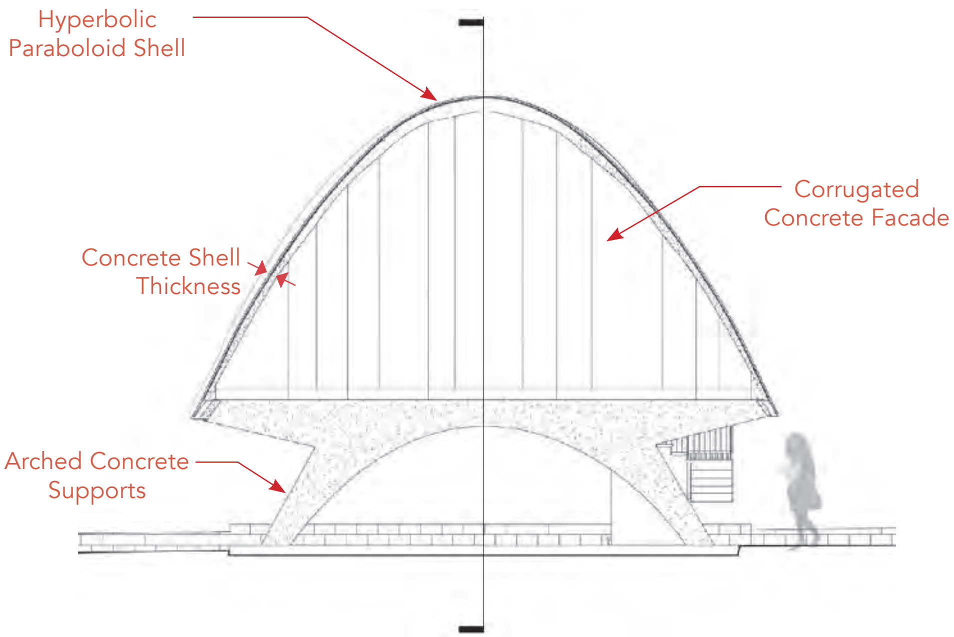
Heritage Value

The CRP is recognized for its historical associations and architectural values. Félix Candela was known to be one of the most innovative architects specializing in reinforced concrete thin shells. With the Cosmic Rays Pavilion, he sparked international attention in the 50s and paved way for his practice to be further explored. In his career, with the help of reinforced concrete, he was able to contribute towards modern architecture. Examples of his work include domed, cylindrical and hyperbolic structures. He mostly uses these types of structures to cover large spaces through his design.

Architectural Value

Although these shells were thin and light, through mathematical calculation, Candela was able to increase strength while being economical with construction material. As a result, he was able to create simple and beautiful concrete shell forms. With these shells Candela was able to achieve thicknesses as little as 15mm and it was evident that he was exploring the maximum capabilities of reinforced concrete structures.

Character Defining Elements



North Elevation of the HBIM in Revit
Drawn by Sepideh Rajabzadeh

Hyperbolic Paraboloid Shell

Location: Roof Structure

The double curvature roof line features two hyperbolic paraboloid forms joined to create the roof. This double curve enables the shell to have a minimal thickness without compromising strength and is typical of Candela's work.

Concrete Shell Thickness

Location: Roof Structure

The concrete shell of the roof is approximately 15mm in thickness, but ranges from 10mm at the top of the structure and 30mm at the bottom. Such a thin structure for this time was unprecedented.

Arched Concrete Supports

Location: Ground Level

The double parabolic structure is raised off of the ground and supported by 3 pairs of arched concrete supports.

Corrugated Concrete Facade

Location: North + South Facade

White concrete walls enclose the ends of the shell structure on the north and south facades. The ondulating surface creates a unique vertical pattern.

Original Staircase (removed)

Location: Ground Level

The original staircase designed by Candela was attached to the side of an arched concrete support. The staircase was later removed and the current staircase wraps around a separate srtucture added to the building.

Material Identification

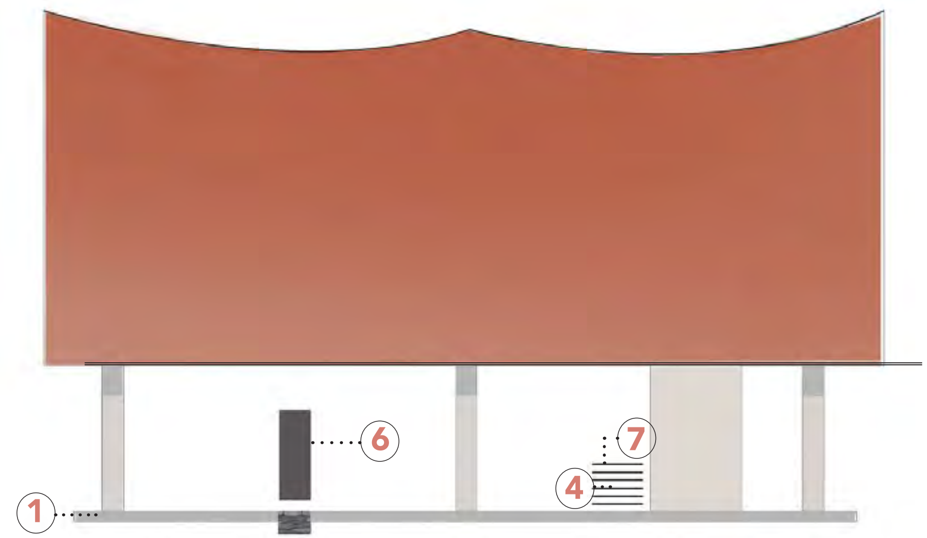
Original Materials

Exterior

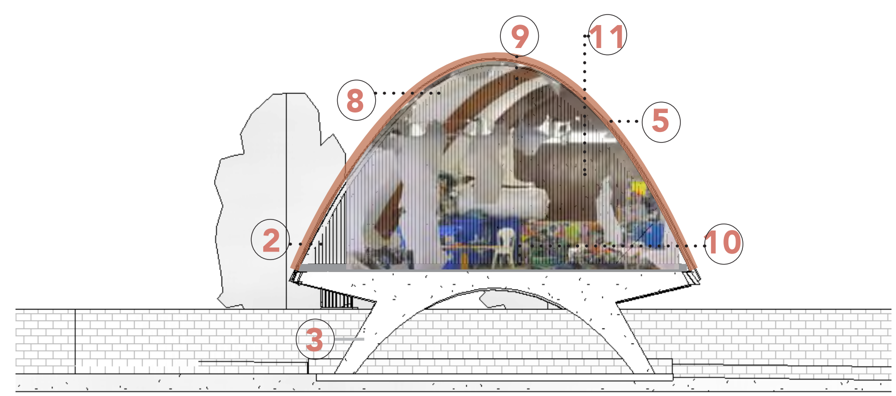
1 Concrete - Edge Pedestal
2 Concrete - Corrugated Wall
3 Concrete - Arched Supports
4 Concrete - Stairs
5 Concrete hypar shell + Waterproof Red Roof Membrane
6 Volcanic Black Stone Wall
7 Metal Gate + Railing

Interior

8 Concrete Wall
9 Brown Painted OSB Wood
10 Linoleum Floor Tiles (original floor was *vitricotta*)
11 3mm Cedar Wood Paneling



East Elevaton 1:100

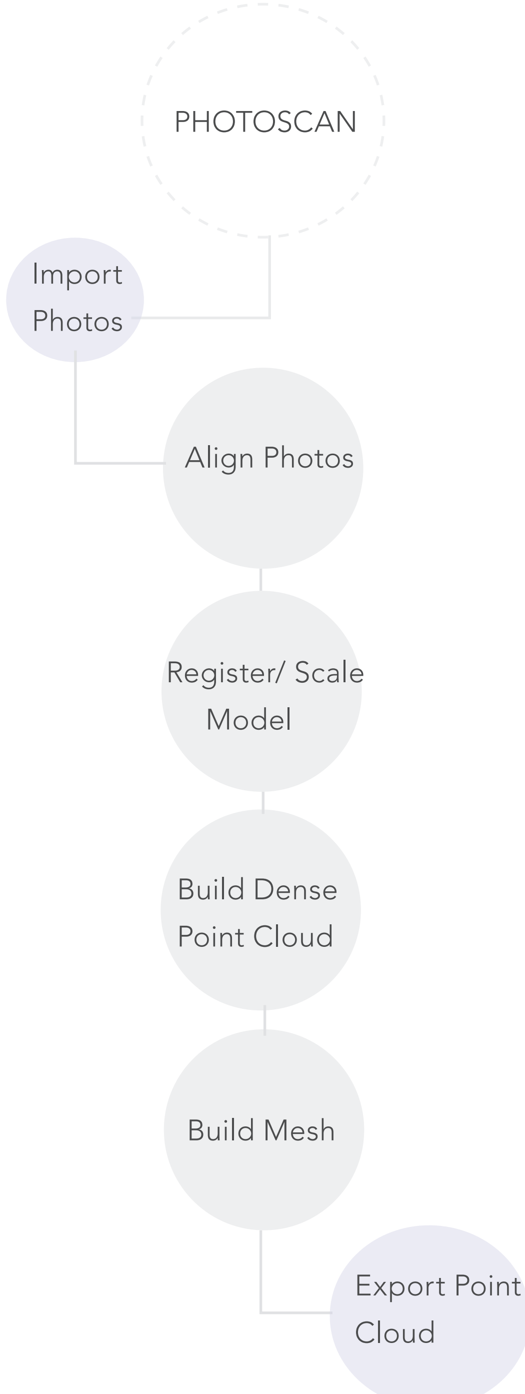


South Section 1 :100
Drawn by Sepideh Rajabzadeh
+Mary Hanna

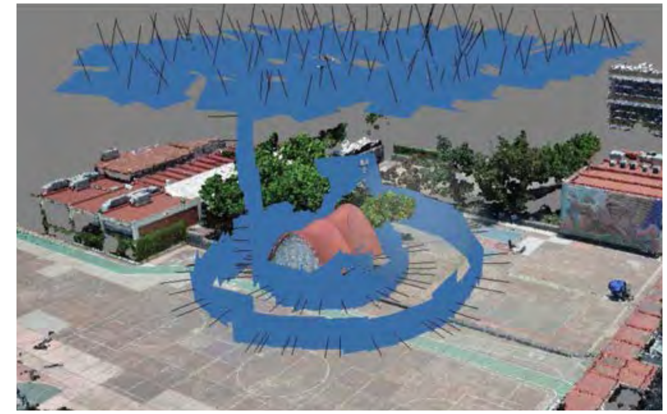
Methodology

Data Collection

Following a detailed material catalogue, condition assessment, and placement of targets markers on the pavilion, the team conducted a digital documentation of the pavilion. Documentation began with the capture of exterior photgrammetric images using DSLR cameras. Interior photogrammetric elevation photos were then taken and combined in Agisoft Photoscan to create the point cloud data to then be processed into a point cloud model. Exterior photogrammetry was also created using photos from the DSLR cameras, as well as through the use of a drone that allowed the team to collect data from the form of the roof, the site, and all exterior angles. The two point clouds were then brought into Revit and combined manually. All the quality testing was done in Revit before starting the HBIM.



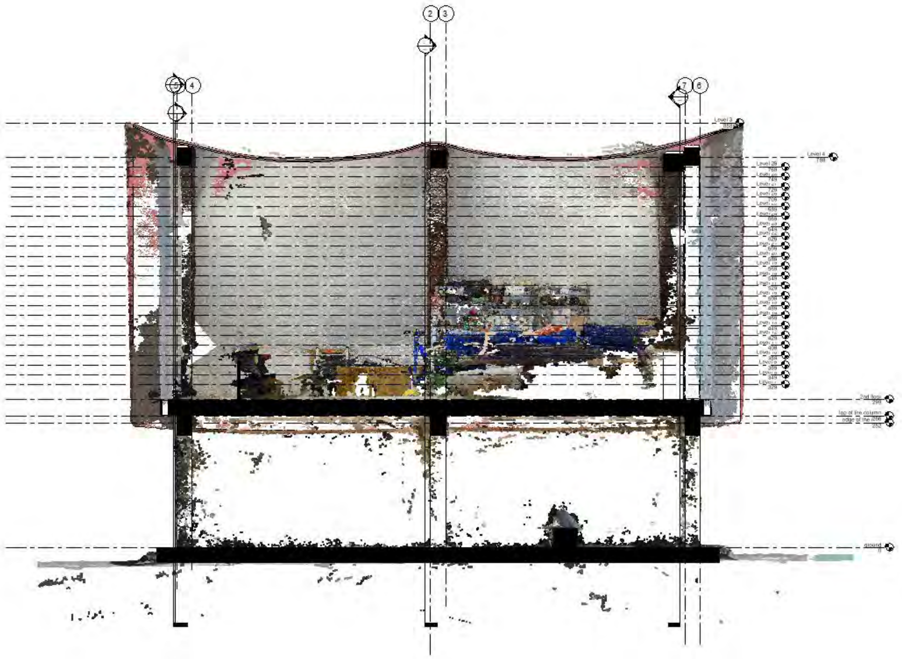
Photogrammetry workflow in Agisoft Photoscan by Sepideh Rajabzadeh (CIMS)



Point cloud model in Agisoft Photoscan Software. Blue squares depict the location of exterior photos taken with DSLR cameras and drones by Sepideh Rajabzadeh (CIMS)

Dense cloud model in Agisoft Photoscan Software by Sepideh Rajabzadeh (CIMS)

Mesh and textured model in Agisoft Photoscan Software by Sepideh Rajabzadeh (CIMS)

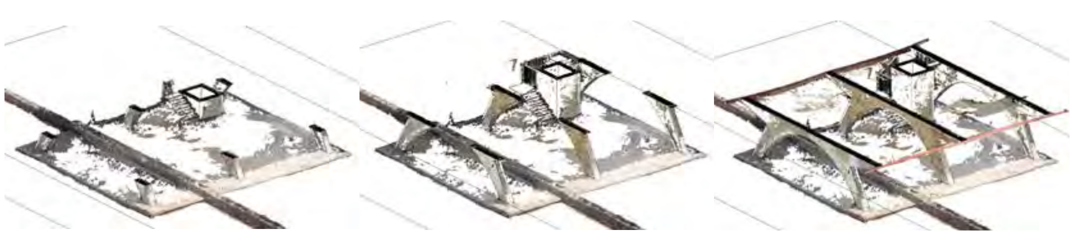


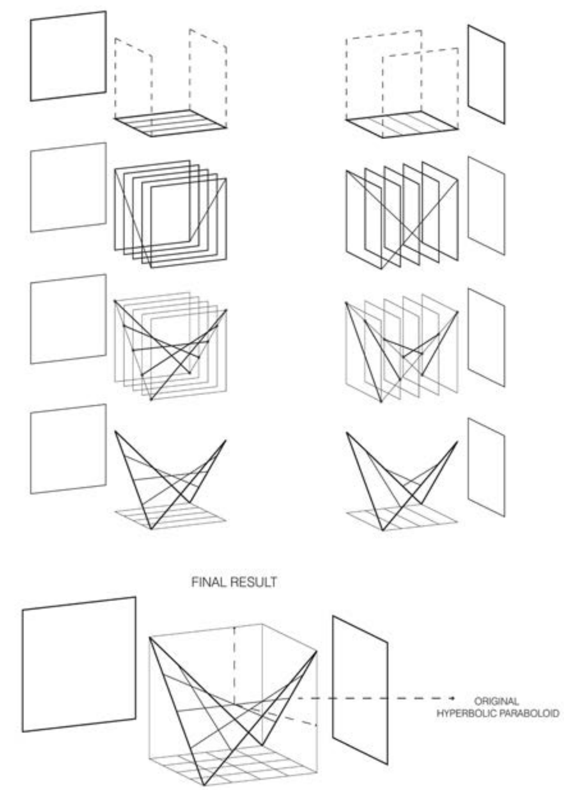
North-south section of the pavilion from HBIM and Point Cloud model overlay in Revit by Sepideh Rajabzadeh

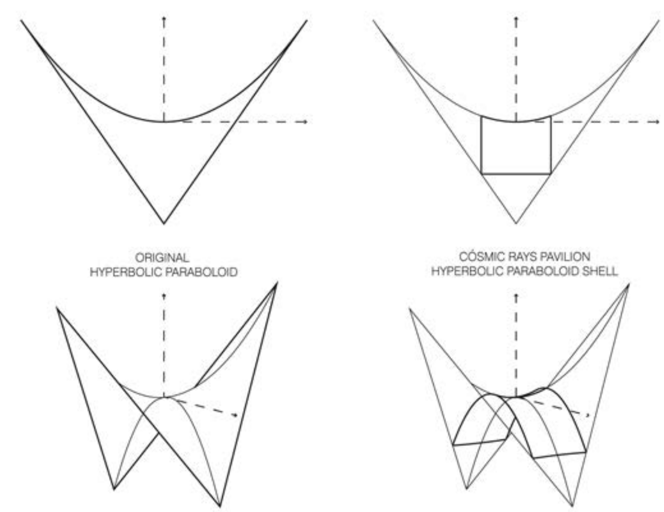
Methodology

Hypar Revit Model Workflow

The pavilion was modeled in Revit using the point cloud model developed from the photogrammetric data attained on site with Professor Esponda's supervision. This detailed point cloud allowed for an extremely high level of accuracy in modeling HBIM. By creating sections through point cloud at regular intervals, building elements could be modeled and adjusted to the point cloud within millimetres of accuracy. This method of modeling was particularly useful for the unique hypar roof structure and ultimately led to further discoveries.



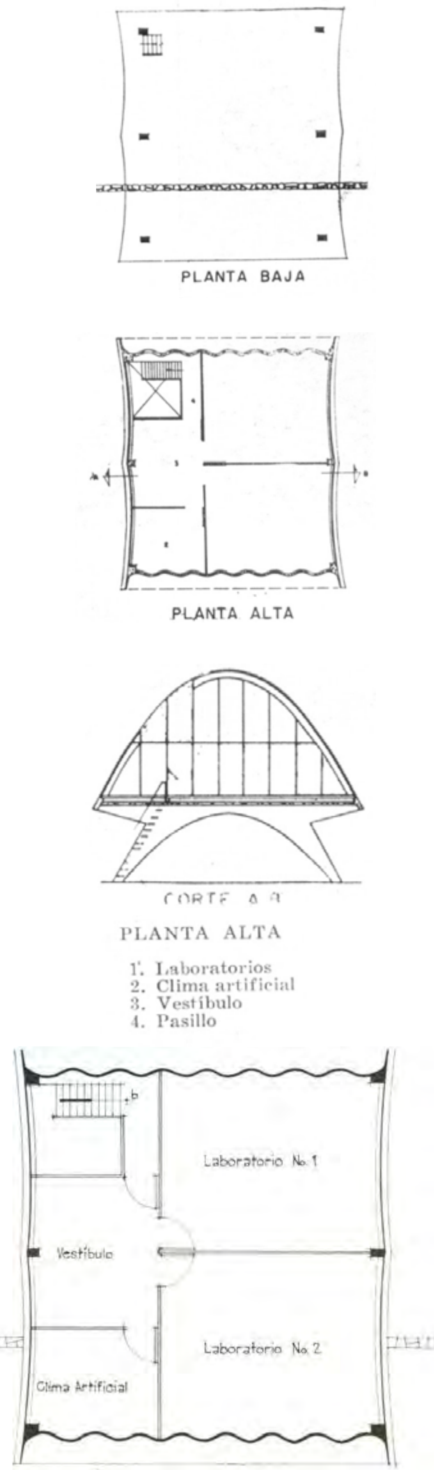




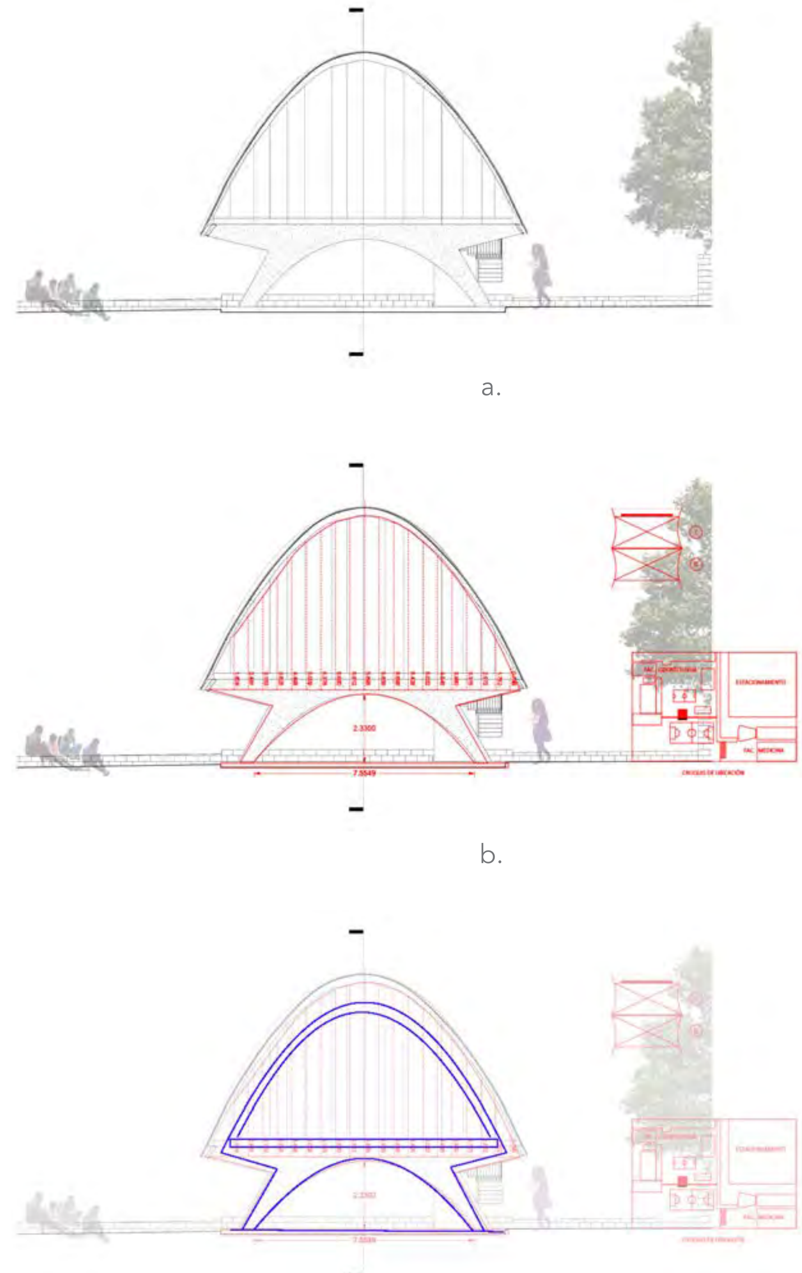
Analysis of the original hypar geometry from which the final shell geometry of the pavilion was created by Laila Cordero.

Comparison of Traditional and Digital Techniques

This study of the Cosmic Rays Pavilion combined the use of information obtained through traditional documentation techniques provided by Laila Cordero and data captured through contemporary techniques. By the four Canadian students mentioned previously. (refer to page 17) Archival drawings provided the team with a greater understanding of the as-built conditions of this unique structure, while the accuracy of the Revit model (HBIM) allowed for a much deeper understanding of the current physical conditions of the building. The use of digital technologies in the documentation of the pavilion created a potential for new discoveries however, the comparison of traditional and current digital techniques is a key step in the study of this historic building and to decide the best maintenance approaches for this pavilion.



Original archival drawings of the Cosmic Rays Pavilion.



a.

b.

c.

Comparison of the HBIM by Sepideh Rajabzadeh (a.) to drawings (red) drawings produced by Laila Cordero (red) using traditional documentation technique (b.) with archival drawings by Felix Candela in blue (c.)

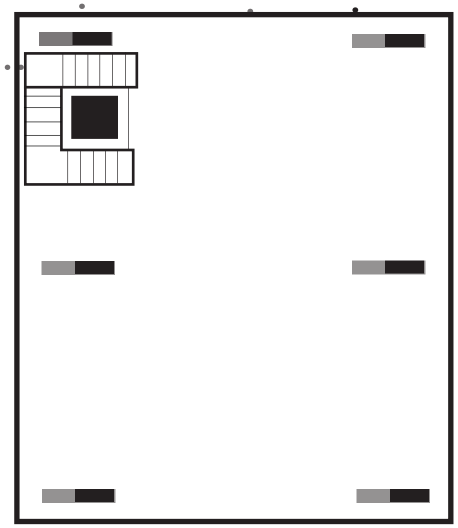
Exterior Condition Assessment
documented by Khadija Waheed

Moisture and Staining of Plaster

Vandalism on plaster

Plaster Spalling

Moisture and Staining of Plaster



Ground level key plan 1:100
Drawn by Mary Hanna

Flaking Plaster

Plaster Spalling

Plaster

Plaster conditions, although sparse, are severe in regards to the functionality of the building. Chipped/ spalled areas ruins the aesthetic of the building and impede on its heritage value. In addition, the plaster is used as a membrane to protect the structural components of the Pavilion. The deteriorating plaster occurs on the exterior of the structure and is due to its exposure to natural elements such as moisture.

Legend

- 1 High Degree of Deterioration
- 2 Moderate Degree of Deterioration
- 3 Low Degree of Deterioration

Exterior Condition Assessment

documented by Khadija Waheed

Concrete

Concrete conditions are severe in regards to the functionality of the building. Graffiti ruins the aesthetic of the building and impede on its heritage value. In addition, there are reinforcement corrosion cracks and if not treated as soon as possible, they may result in structural failure as well as spalling which is the result of excess water which causes the concrete to flake and break off. Causes of these conditions are mainly due to human interactions in addition to moisture penetration.

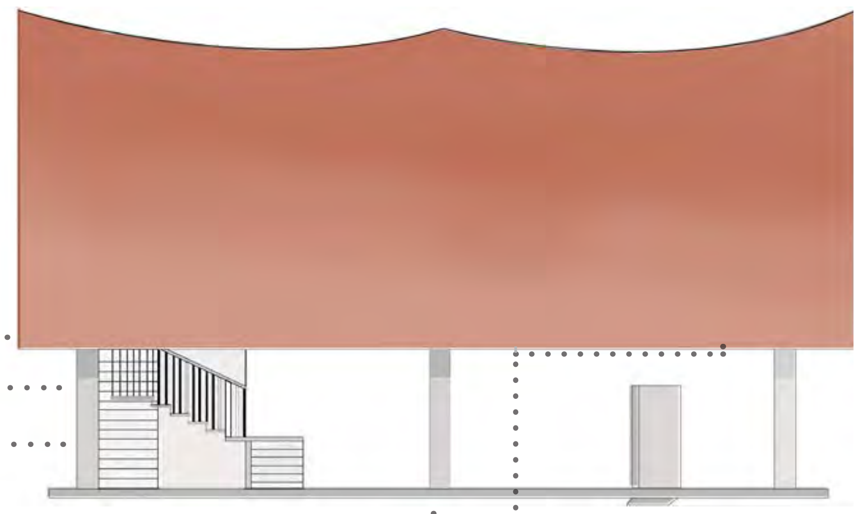
Profile Detachment

Metal Oxidation. Surface level exposure of member to air and moisture.

Concrete Spalling: exposed rebar

Metal

The metal elements present within the Pavilion are the railings of the stairs that are safety purposes and the vent. The corrosion that is present on the metals are the result of exposure to air and moisture. Where corrosion is present, it is recommended that proper treatment of these members is undertaken to protect the oxidation from further weakening metal elements.



West Elevation
Drawn by Mary Hanna

Metal Oxidation
Surface level exposure of a member to air and moisture

Reinforcement corrosion crack

Legend

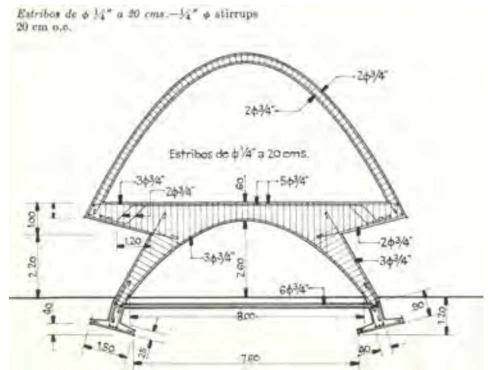
1 High Degree of Deterioration

2 Moderate Degree of Deterioration

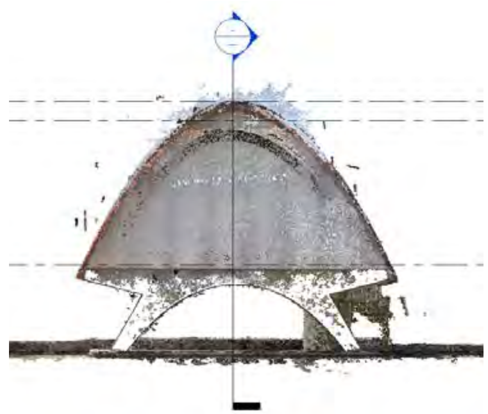
3 Low Degree of Deterioration

Conclusion

This innovative hypar concrete structure was the seventh concrete shell built by Candela at that time and was also the first hypar thin-shell concrete built in Latin-America. Furthermore, the construction methods that Candela developed for this hypar shell were pioneering of its time, not only for Mexico but around the world. The HBIM can be studied further for seismic analysis on the concrete shell, damage scenarios, and risk management purposes in the future. Finally, it was crucial to continually reference the archival images and to understand the traditional technique that was used in order to better understand the building, and to make sure the analysis provided by the contemporary tools were accurate.



Archival drawing of east-west section.



North elevation of HBIM in Revit by Sepideh Rajazadeh

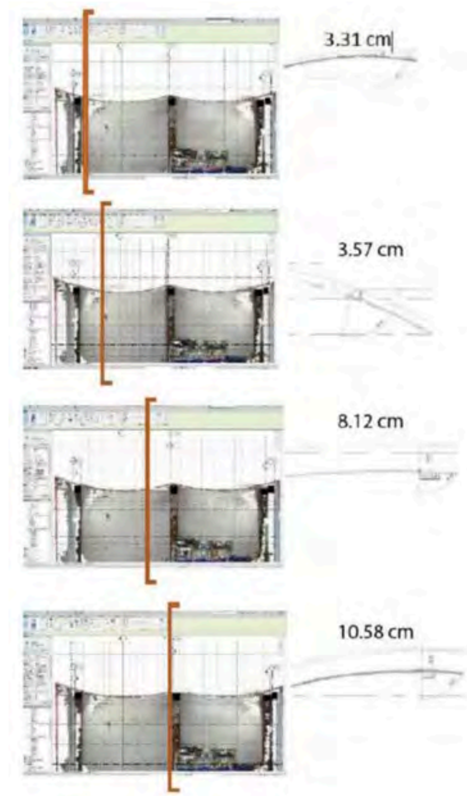
New Discoveries

After analyzing the digital 3D model, professor Esponda and Sepideh Rajabzadeh discovered a gap between the red roof membrane and the concrete shell. This discovery was made possible through the use of contemporary documentation to visualize the current physical state of this building at a high degree of accuracy.

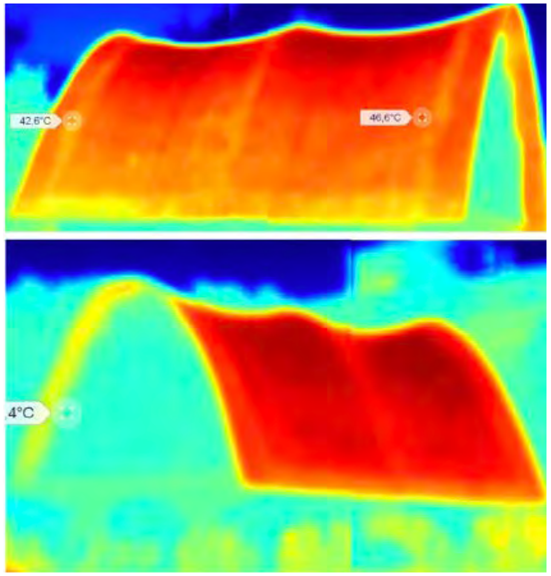
By analyzing the historical images of the pavilion in combination with the current digital model, the team has also discovered a slight deviation in the curvature of the structure over time. The results found could suggest two hypotheses, either the profile of the curvature has been modified due to earthquakes, or the change is due to improper maintenance and application of multiple membrane layers.

These discoveries could not have been possible solely through the use of traditional documentation techniques. Subsequent studies of the model revealed that the size of this gap varies throughout the entirety of the pavilion and is at its greatest in centre of the pavilion.

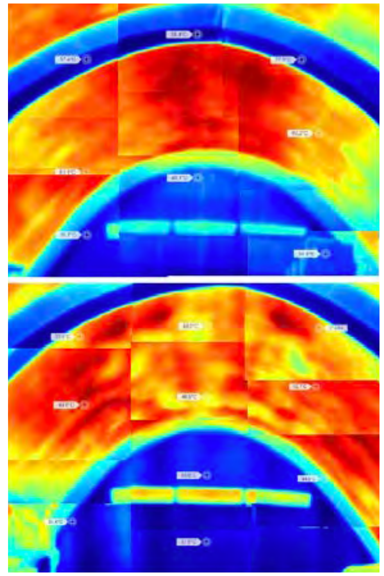
Gap between concrete shell and roof membrane.



Section studies of the pavilion from HBIM in Revit by Sepideh Rajabzadeh

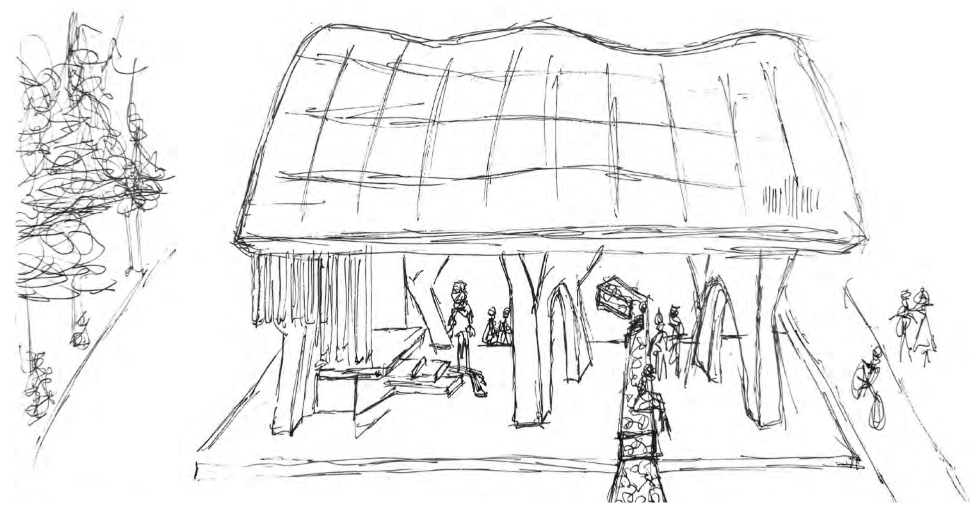


Even temperature distribution across the exterior surface of the pavilion.



Uneven temperature distribution across the interior surface.

Once the Revit model was created, further studies were completed to understand how the building was constructed and how it evolved throughout time. As previously mentioned, one of the more interesting discoveries that we came across was to find that there is a gap between the red roof membrane and the concrete shell. Furthermore, a series of thermographic images of the pavilion were provided by our colleague from Universidad Nacional Autónoma de México (UNAM), Laila Cordero. These images show an uneven temperature distribution accross the interior face of the concrete shell suggesting the presence of pockets of water on the concrete shell itself. This evidence therefore supports the theory that the separation of the roof membrane was likely caused by inadequate maintenance of the membrane layers.



drawn by Khadija Waheed

Part 2: Facultad De Química Edificio "B"
The Chemistry Building

Constructed: 1954
Architects: Fernando Barbara Zetina, Carlos Solorzano and Felix Tena

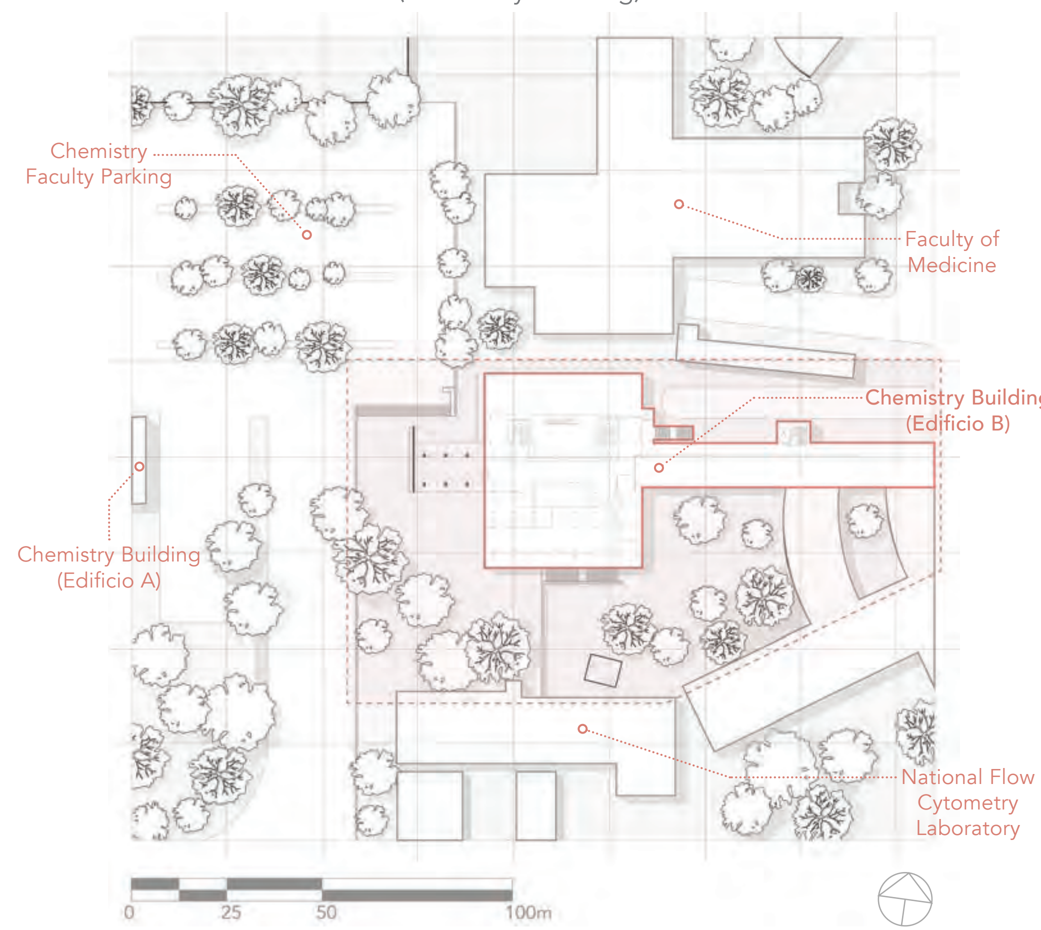
The Faculty of Chemistry at UNAM is composed of a complex of buildings within the UNESCO-designated area of the Ciudad Universitaria. In May 2019, Carleton students conducted documentation of the main Chemistry Building, Edificio B, originally the Escuela de Veterinaria, which is composed of laboratories, classrooms, a library, and common study areas for students arranged around courtyard in the centre of the faculty complex. The arrangement of these buildings optimizes several passive sustainability systems including cross-ventilation and daylighting, while features such operable windows, *brise-soleils*, large open doors at the lobby level, and study space under a covered terrace all contribute to the building's connection to the exterior.

Furthermore, the Chemistry Building exemplifies several characteristics of a modernist architectural style that unifies all buildings on the university campus. The modernist language and international style of the building gives way to a clean aesthetic where rectangular forms are emphasized and where materials meet in simple, well-executed joints. Exposed volcanic stone, metal frames and concrete cladding present traditional materials of the region in contemporary ways, while the use of large expanses of glass bring the exterior context into the building and take advantage of the campus' natural landscaping.

UNAM Campus Map

Facultad De Química
(Faculty of Chemistry Buildings)

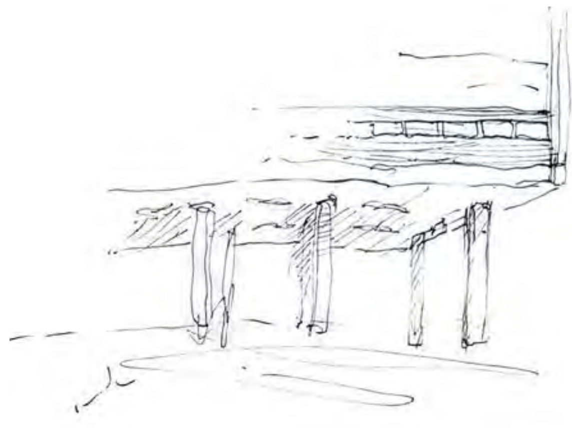
Facultad De Química (Chemistry Building)



Primary Scope of Work

General Documentation

Drawn by Jessica Babe



Cantilevered entryway to the Chemistry Building at the northwest corner / Christie Ellis Wong

Architectural Data Collection for Heritage Documentation

Overview

The primary focus of the work at the UNAM Chemistry Building B focused on architectural data collection and heritage documentation. This documentation is to be used in support of further work by Dr. Esponda and Carleton research assistants.

On-site documentation, carried out from May 7th to May 13th 2019, was limited to photography, site sketches and observations, and hand measurements. Documentation was focused on character defining elements, material distribution, representative material conditions, and baseline seismic data.

This project is a collaboration of both graduate and undergraduate students from Carleton University's Faculty of Engineering and Design. The team members were: Kate Coulthart, Christie Ellis Wong, Jeannine Senécal, Zabdi Falcón, Meighen Katz, Rachel Bricknell, Mary Hanna, Jessica Babe, Chris Stec, Danica Mitric, Erika Sieweke, Mélina Grandmont, and Clarisse Miranda.

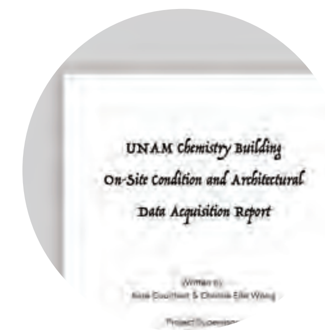
Project Deliverables

5000+ Photo Inventory of:

- Material Distributions
- Material Conditions
- Character Defining Elements

Measurement Data to be used in the production of orthographic drawings by way of fieldnote drawings (PDF)

Material Conditions Sheets and Accompanying Summary Reports (doc)



Final Report

Project Limitations

The project was constricted due to a series of limitations. The limitations were as follows:

- Technology limitations
- Availability of existing building documentation
- Onsite time limitations & building access
- Team member experience

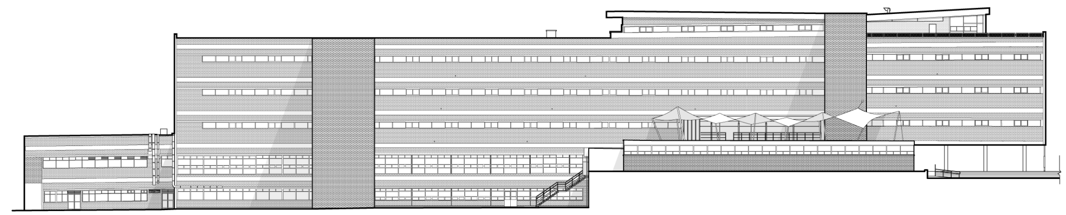
Facultad De Química (Chemistry Building)

Work Week Schedule

Sun	Mon	Tues	Wed	Thurs	Fri	Sat
5 Arrival	6 Tour of UNAM	7 Tour of Chem Bidg.	8 On-Site Working	9 On-Site Working	10 On-Site Working	11 Off-Site Working
12 Off-Site Working	13 On-Site / Off-Site Working	14 Site Visits (Puebla)	15 Site Visits (Puebla)	16 Site Visits (Morelos)	17 Site Visits (Morelos)	18 Departure

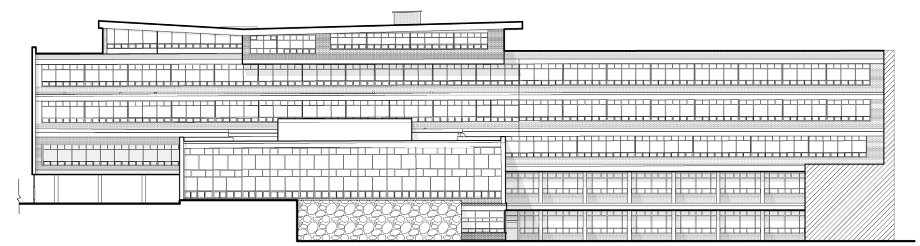
Work Week Scope

- Material Distribution Field Notes & Photos
- Sampled Material Condition Field Notes & Photos
- Photo Documentation of Character-Defining Elements
- Seismic Photogrammetry Data Collection
- Interior Measurements of Alterations
- Site Sketches



Chemistry Building Edificio "B" North Elevation

Drawn by Jessica Babe



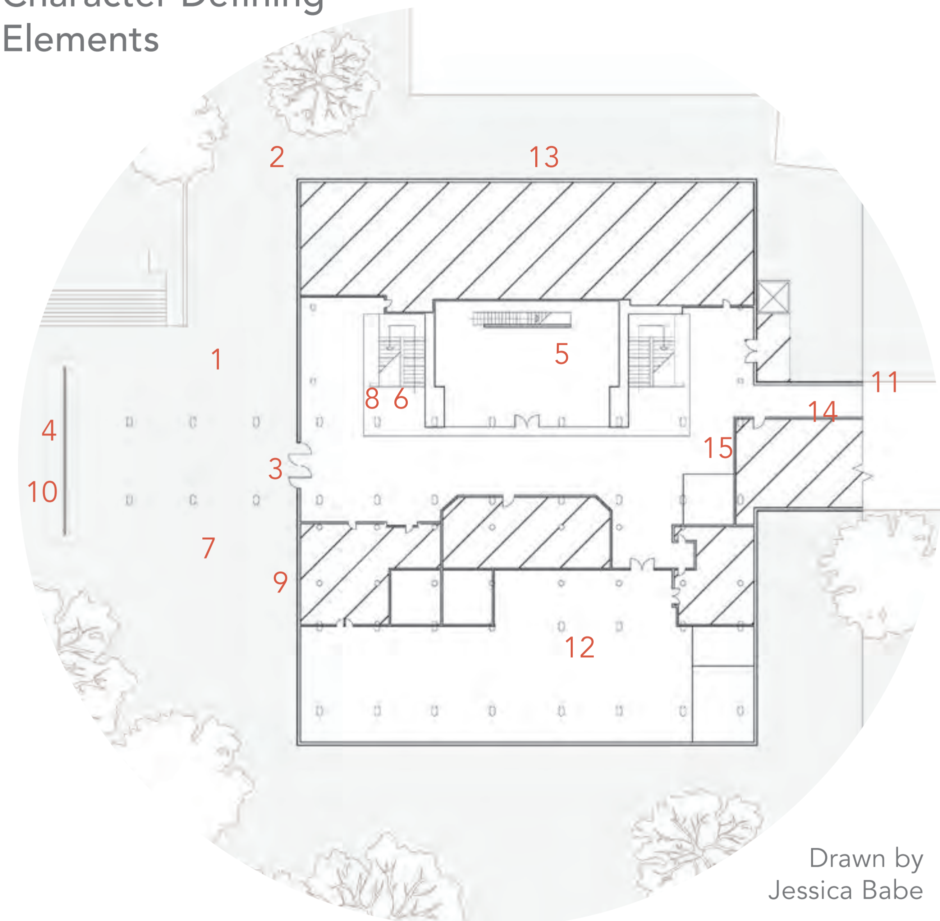
Chemistry Building Edificio "B" South Elevation

Drawn by Jessica Babe

South Elevation orthographic image

Measured exterior elevations of the Chemistry Building were produced from a combination of photogrammetric data and rectified photography. All drawings produced over the course of this project provide current and accurate information for ongoing monitoring of this UNESCO World Heritage Site.

Character-Defining Elements

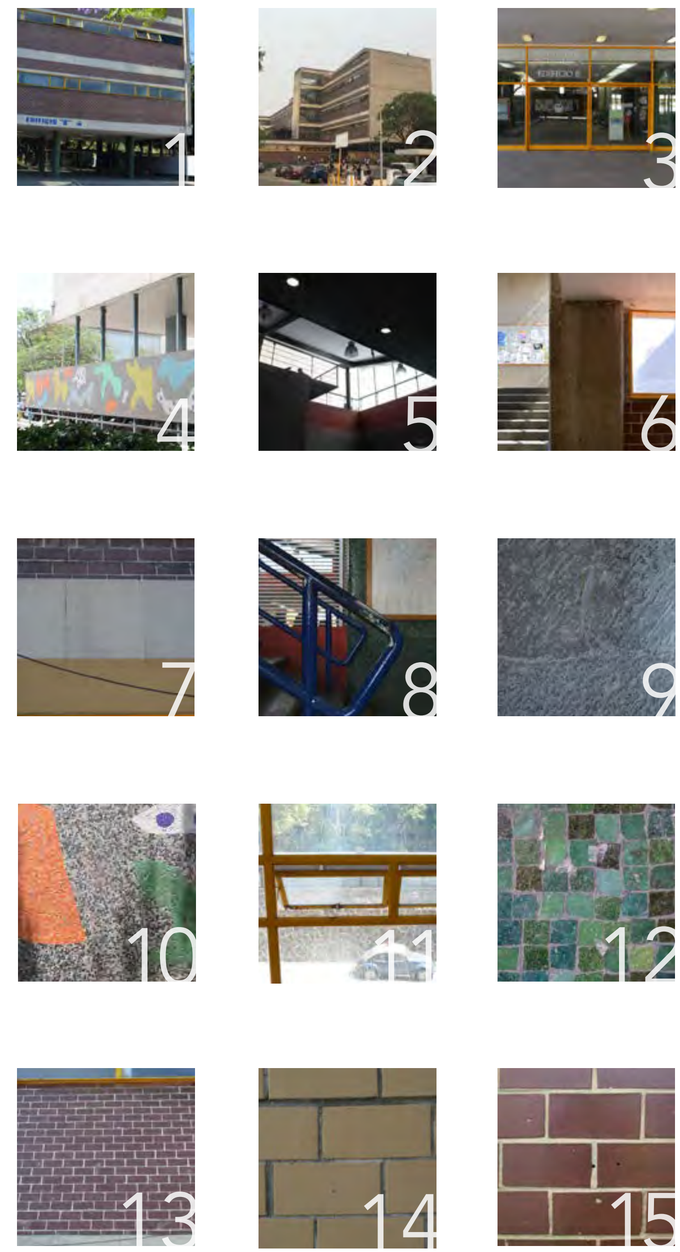


Drawn by
Jessica Babe

Mexican Nationality and Modernism

The UNAM campus was built on the notions of modernism and progression following the Mexican Revolution. The idea was to build a layered campus with multiple commissioned architects that would instill ideas of Mexican Nationality and Modernism throughout the city.

Mesoamerican motifs and volcanic rocks flood the Campus City and shed light on the historic values on which the University was built. The Chemistry Building is a great example of new material exploration and modernist architectural ingenuity that takes into consideration the cultural values that exist throughout the site.



1 Cantilevered Entryway
2 Horizontal Massing
3 Main Entry Doors
4 Art Installation (Mosaic)
5 Ground Level Courtyards
6 Exposed Concrete
7 Concrete Paneling
8 Handrails
9 Basalt Stone
10 Mosaic Tiles
11 Metalic Mullions + Frames
12 Wall Tiles (Columns)
13 Exterior *Vitricotta* Tiles
14 Interior *Vitricotta* Tiles (Cream)
15 Interior *Vitricotta* Tiles (Red)

Left to right: North facade of the cantilevered entryway / Horizontal massing and articulation viewed from the south courtyard / Main entry doors / Art Installation

Cantilevered Entryway

Location: Northwest Corner

The cantilevered entryway is an immediate focal point upon arrival at the chemistry building. Large expanses of glazing emphasizes this defined point of entry that seamlessly draws the exterior landscape into the interior space. Furthermore, the elevation of the building onto 'pilotis' or columns is a clear expression of modernist values which speaks to the campus' architectural language as a whole.

Horizontal Massing

Location: Northwest Corner

The horizontal massing of the building is another expression of the modernist style. The elongated forms of the chemistry building are further enhanced by a repetition of rectilinear elements across all of the facades.

Main Entry Doors

Location: West Facade

The main entry doors present a welcoming entrance to the building. The large revolving doors are painted a shade of yellow seen throughout the entirety of the building and remain open throughout the day, allowing for an uninterrupted flow of students and visitors.

Art Installation (Mosaic)

Location: West Facade

An art installation in the form of a tiled mosaic is found immediately in front of the main entrance. Mosaic pieces such as this one are a typical form of artistic expression throughout the UNAM campus and often tell stories about the history of the university city. The nearly 15m long mosaic is composed of playfully-coloured handcrafted tiles forming organic shapes.

Ground Level Courtyards

Location: Ground Level

Two courtyards were originally constructed on the ground level of the chemistry building. Archival drawings of the building show that both were once fully open to the exterior, however, they have since been partially or completely enclosed. The northernmost courtyard is a student study space that is still open to an exterior space covered by a large canvas awning. The southern courtyard has now been integrated into the faculty library.

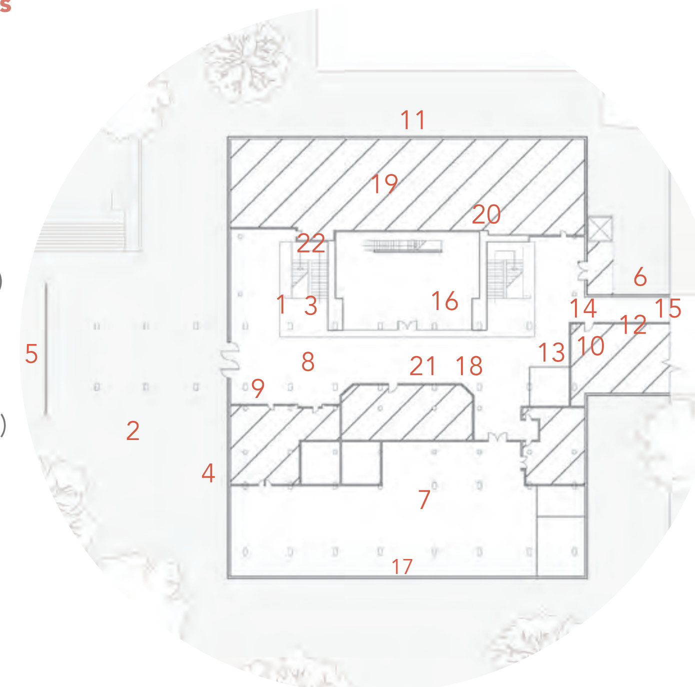
Material Identification

Original Materials

1 Exposed Concrete
2 Concrete Paneling
3 Metal Handrails
4 Basalt Stone
5 Mosaic Tiles (Mural)
6 Metallic Mullions + Frames
7 Wall Tiles (Columns)
8 Adoquin Stone
9 Wood Paneling
10 Wood Doors
11 Exterior *Vitricotta*
12 Interior *Vitricotta* (Cream)
13 Interior *Vitricotta* (Red)
14 Suspended Ceiling
15 Floor Ceramic Tiles

Added Materials

16 Metal *Brise Soleil*
17 Metal Screen
18 Wall Tile
19 Canvas
20 Metal Shades
21 Glass Block
22 Aluminum Mullions + Frames



Exposed Concrete

Location: Interior Piers and Stairwells

Exposed concrete is a material largely used throughout this building's interior which draws attention to the structural elements of the building. The exposed concrete piers and stairwells create large monolithic forms to contrast the numerous tile finishes of the interior and exterior. The material reflects the modernist architectural style of the UNAM campus as a whole.

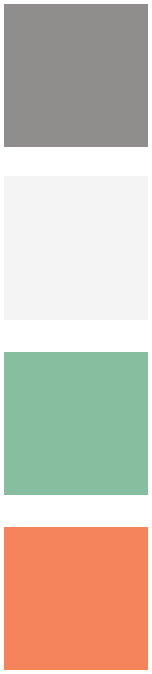
Concrete Paneling

Location: Exterior Facades

Concrete paneling can be found along all of the exterior facades and is key to the articulation, rhythm and repetition of the building's exterior. This is due in part to their lighter colour as well as their size in contrast to the small tiles and large rectangular window frames.

Facultad De Química (Chemistry Building)

Coloured tiles of the mosaic outside the main entrance of the



Metal Handrails

Location: Stairwells

The metal handrails are painted a dark shade of blue and are found along the main exterior and interior staircases of the building. They showcase an industrial style of metal craftsmanship that contribute to the building's modernist aesthetic.

Basalt Stone

Location: West Facade

Large pieces of the dark grey Basalt stone cover parts of the west façade towards the south side of the building, as well as the stairs leading down to the open courtyard (Jardin de la Ardillas / Garden of the Squirrels), and parts of the interior stairwells. This type of igneous stone is a common building material throughout the UNAM Campus as it is an indigenous material that characterizes many works of architecture in this part of the country. Basalt stone is extremely durable and as a result many sources of this material date back to the notable eruption of the Xitle volcano in pre-Hispanic times.

Mosaic Tiles

Location: Main Entrance (West Facade)

A large horizontal mural can be found in front of the main entrance to the Chemistry Building, above a narrow pond of water, meant to reflect the mural and function as a cooling mechanism. The mural itself is composed of pieces of hand-crafted tile of various

organic shapes, sizes, and shades of colours. It is a vibrant part of the entrance to Edifice B and as a result, the mural is a focal point of this area of the UNAM campus.

Metallic Mullions + Frames

Location: Door Frames and Exterior Windows

Painted yellow mullions and frames can be seen across all of the chemistry buildings and distinguish this faculty's buildings from others on the UNAM campus. These metal mullions are painted in a shade of yellow that create contrast and highlight the rectilinearity of this modernist building. Several window frames are painted in a lighter shade of yellow indicating areas that have undergone repairs and maintenance.

Wall Tiles (Columns)

Location: Interior + Exterior Columns

Various shades of green wall tiles cover columns throughout the building, both on the interior and exterior. These original tiled columns exist on every floor and can be identified by their composition of original hand-crafted tiles. However, due to damages over time, or in certain cases human interventions, many of the original wall tiles have been replaced with mass-produced green tiles. This has had an impact on the quality and authenticity of the original columns.

Adoquin Stone

Location: Ground Floor

The floor of the ground level of the Chemistry Building is finished with Adoquin stone tiles, distinguished by its grey colour with subtle pink tones. Adoquin is a type of stone quarried in Mexico and formed from a mix of volcanic ash and local aggregates. This material is then compressed for millions of years and thus becomes lightweight and durable for construction use. It is a grade of Cantera which is a volcanic quartz-based stone containing various colour aggregates. Similar to the Basalt stone used in this building, Adoquin stone is an indigenous material to Mexico.

Wood Paneling

Location: Library + Ground Floor Interior

Dark wooden paneling is found throughout the library as well as in certain areas of the main floor interior. These veneer panels are glazed in a dark brown stain and have a distinct vertical articulation that characterizes these interior spaces.

Wood Doors

Location: Interior (All Floors)

Wood doors make up the majority of doors throughout the interior of the building. Although not as prominent a feature of the interior as the coloured tiles and painted frames, the large number of these wooden doors and their repetition on all floors are an important display of the building's original materials.

Exterior *Vitricotta* Tiles

Location: Exterior Facades

The red-coloured exterior *Vitricotta* tiles compose the majority of the exterior facade finish. The *Vitricotta* tiles in combination with the concrete paneling and yellow window frames all contribute to a modular articulation of the facade. This quality is typical of many faculty buildings in the surrounding area of the campus.

Interior *Vitricotta* Tiles

Location: Interior (All Floors)

The use of Vitri cotta tiles throughout the interior continues the repetition and rectilinear articulation of the exterior facades within the building. These interior tiles are found in both a red and a cream-coloured finish.

Suspended Ceiling

Location: Interior (All Floors)

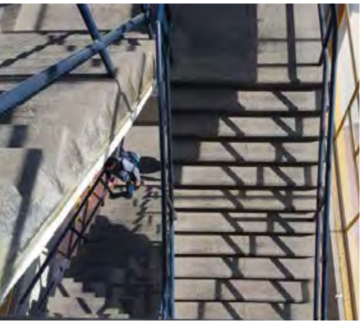
Each of the suspended plaster ceilings found in the main corridors of the building are of a material finish that is original to the building. The original material largely remains intact throughout most of the building.

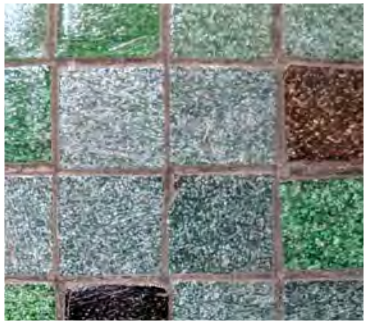
Floor Ceramic Tiles

Location: Interior (All Floors)

Ceramic tiles cover the floors of the upper levels of the building. The colour of these tiles range from light forest green to variations of beige in coherence with colours used in other finish materials such as column tiles and wall paint.

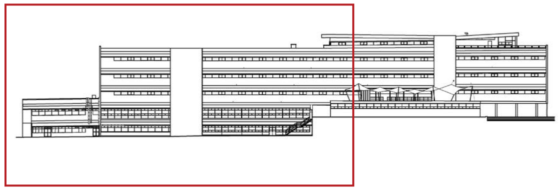
From left to right: Painted blue handrails in the interior stairwells / Basalt stone walls of the stairs leading to the outdoor courtyard / Painted yellow mullions and frames on the ground floor / Hand-crafted wall tiles on interior column / Interior Adoquin stone floors of ground floor entryway / Cream-coloured Vitricotta tiles located in upper

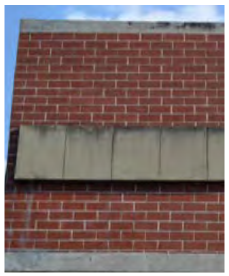


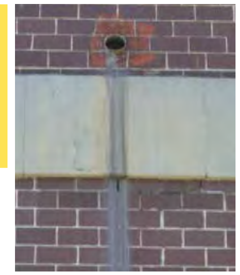
Exterior Condition Assessment

North Elevation

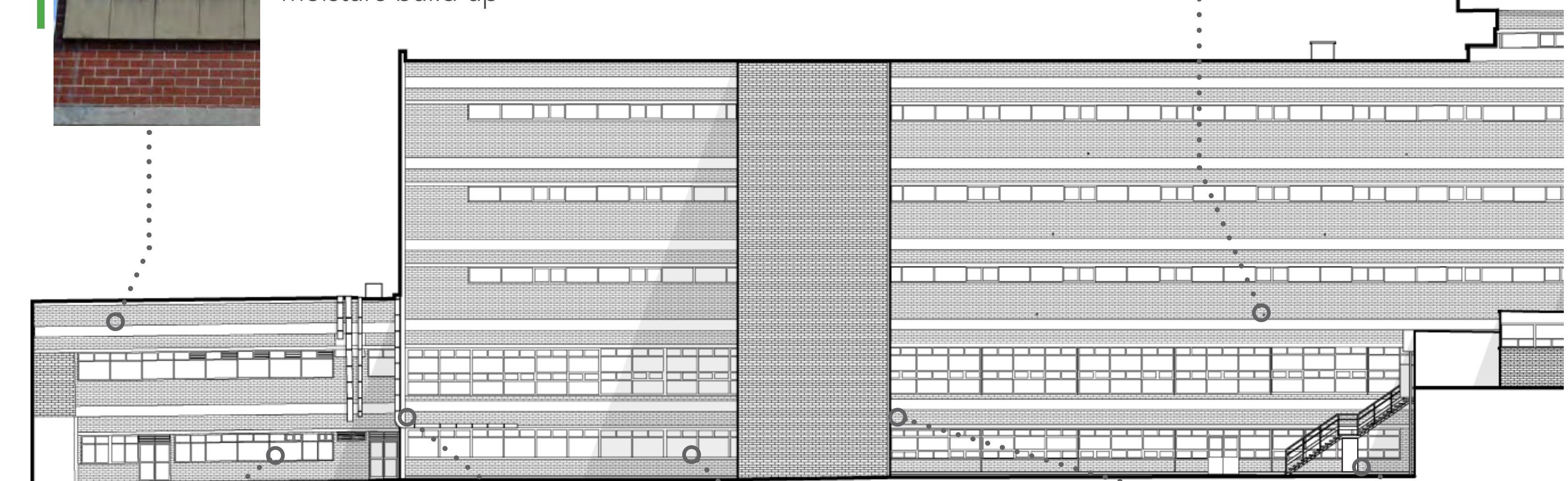




Low
Surface staining and discolouration due to moisture build-up

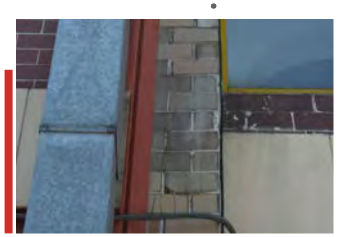


Moderate
Surface staining and mortar loss due to improper drainage detail.



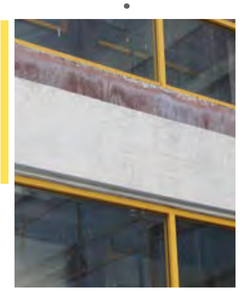
1:400 Drawn by Jessica Babe

Severe
Cracking and material loss of concrete sill and exposure of rebar due to corrosion of metal.



Severe
Cracking in wall tiles and replacement of damaged tile with new material.

Severe
Oxidation of metal window frame due to moisture presence.



Moderate
Cosmetic surface cracking.

Severe
Biological growth due to moisture presence.

Concrete

Concrete is a prevalent material used throughout this building for both structural and aesthetic qualities. It manifests in the building as slabs, columns, and exterior panels among other elements.

The concrete throughout the building is experiencing numerous pathologies; some may have structural implications while others are superficial. Material conditions include: cracking, corrosion, material loss, and exposed rebar, moisture-related finish issues. These are often due to human intervention, and seismic effects.

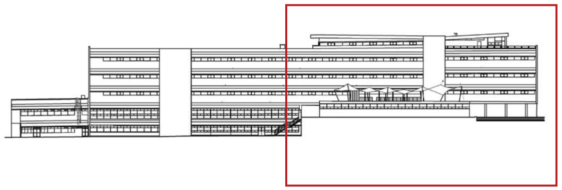
Vitricotta

The main deterioration conditions of vitricotta are cracked and chipped glazing, poor repairs, applied substances, material loss of the units/ mortar and secondary finish deteriorations. Whilst many of the damage conditions are not yet impacting the building heritage and character, there are a number of severe conditions which detract from the architectural aesthetic in general and which, if left unaddressed, will lead to further conditional decay.

Facultad De Química (Chemistry Building)

Exterior Condition Assessment

North Elevation



Metal Mullions + Frames

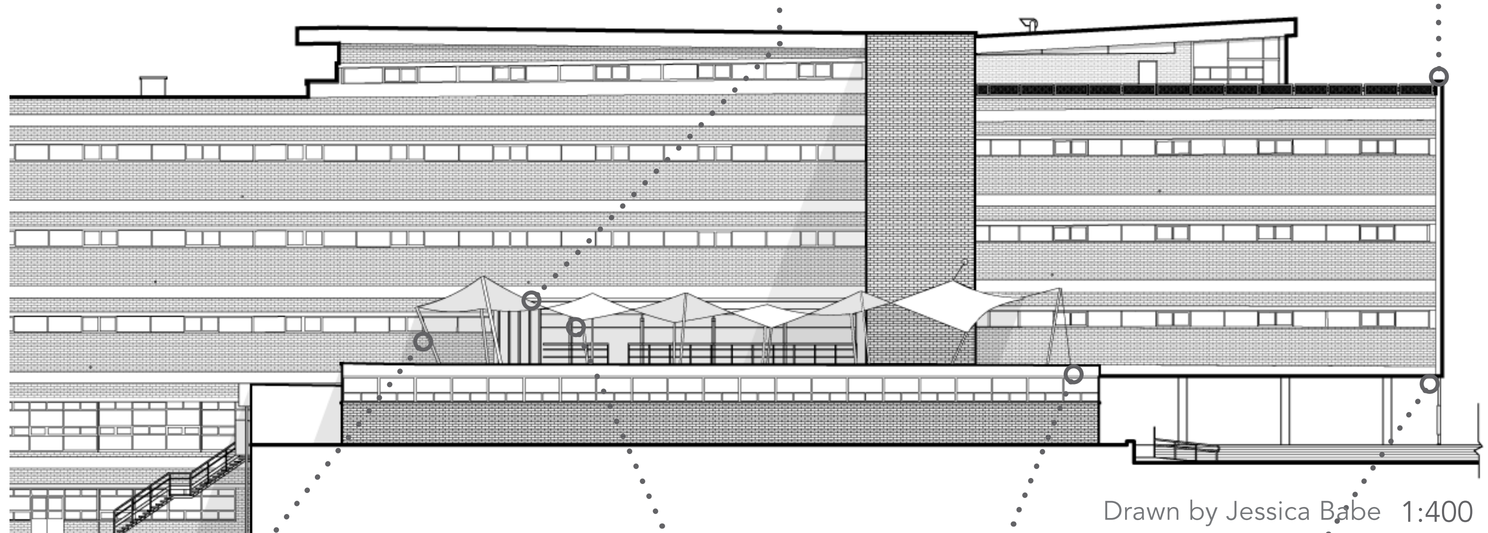
Metal mullions and frames are a very predominant aesthetic feature visible from both the interior and exterior spaces of the building. However, many of the original mullions show evidence of extensive deterioration that has occurred over time which can largely be attributed to moisture presence. This deterioration ranges from mild rust staining to areas with severe signs of corrosion of the metal mullions as well as other metal connections and fasteners. Many severe areas of oxidation are located on the north facade and throughout the basement level. Some mullions have also been replaced in recent years and are identified by a lighter shade of yellow.

Other Metal Elements

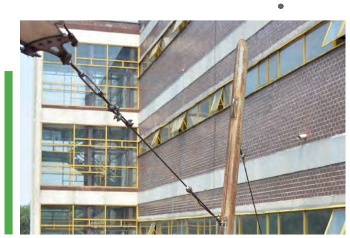
Other metal elements present within the building hold a substantial amount of the aesthetic character and heritage values associated with the design of the Chemistry Building. Many examples of poor maintenance and paint applications can be observed on all floors and along the exterior facades of the building. Where corrosion is present, it is recommended that proper treatment of these members is undertaken to protect the oxidation from further weakening metal elements - especially structural components.

Moderate
Patch repair of canvas cover following previous physical damage.

Moderate
Hair cracking and delamination of cement parging due to sun exposure.



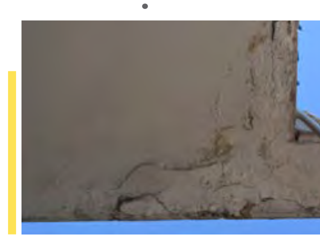
Drawn by Jessica Babe 1:400



Low
Surface level oxidation of metal supports due to exposure to air and moisture.

Severe
Oxidization due to exposure to air and moisture without proper maintenance.

Severe
Deformation and material loss of parapet due to extensive biological growth.



Moderate
Peeling paint and discolouration due to moisture infiltration.

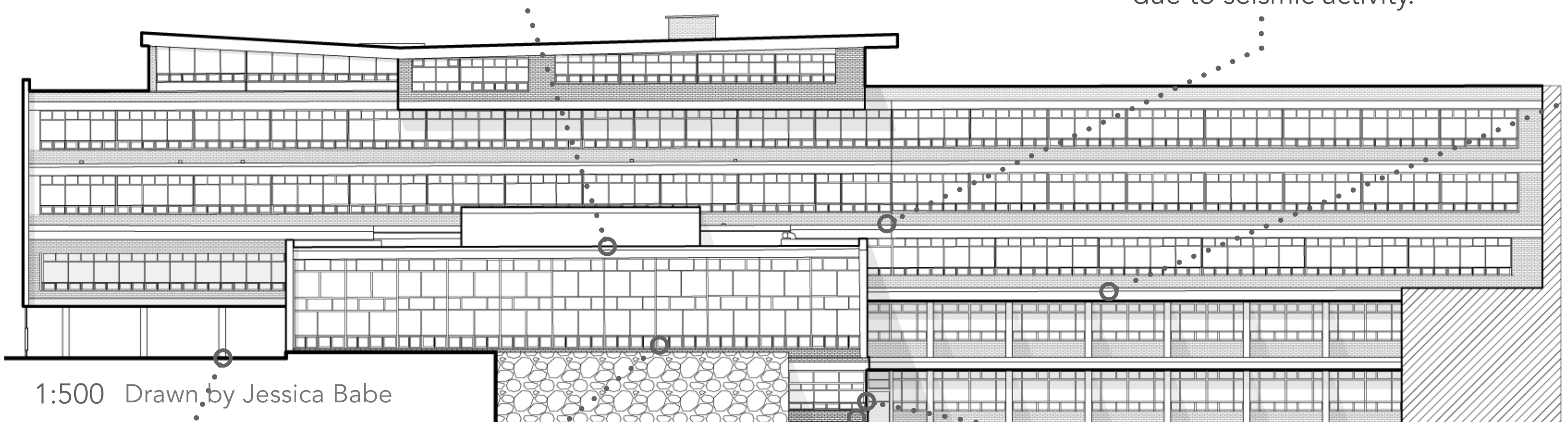
Exterior Condition Assessment

South Elevation

Severe
Discolouration, cracking and material loss of concrete panels due to moisture infiltration.

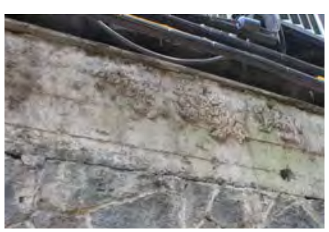
Severe
Separation of concrete floor slabs and material loss of concrete panels due to seismic activity.

Moderate
Discolouration due to salt deposits on the concrete surface.

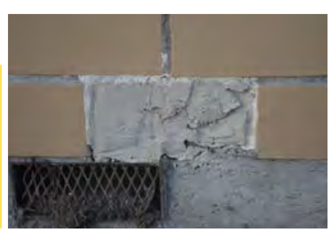


1:500 Drawn by Jessica Babe

Severe
Material loss of original wall tiles potentially due to seismic activity.



Severe
Salt crust due to wetting and drying cycles of moisture produced by HVAC equipment.



Moderate
Material loss of original *Vitricotta* tile repaired with concrete infill.

Severe
Deep cracking along concrete sill potentially due to seismic activity.

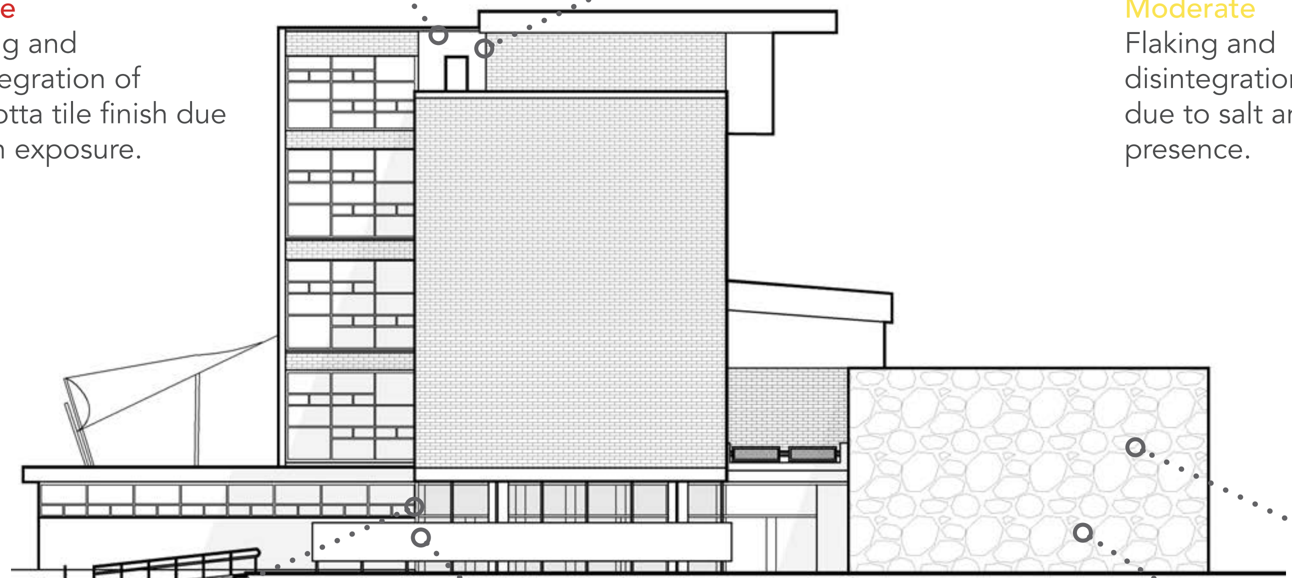
Wall Tiles (columns)

Material loss is the most prevalent form of deterioration of new and character-defining original wall tiles. The application of opaque substances, the intrusion of metal rods into tile-covered columns and walls, as well as minimal cracking and grout failure have been observed throughout the entirety of the building. Deterioration is more prevalent within the newer tiles applied in sheets than in the original hand installed tiles. None of the above deteriorations are structural issues, but given the fact that the green wall tiles are character-defining elements of the building, their deterioration and lack of repair means a diminishment of architectural character.

Exterior Condition Assessment

West Elevation

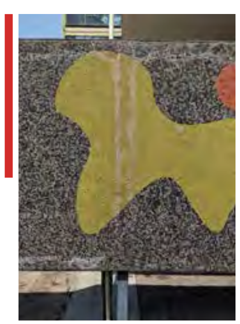
Severe
Flaking and disintegration of Vitricotta tile finish due to sun exposure.



1:300 Drawn by Jessica Babe

Moderate
Flaking and disintegration of bricks due to salt and moisture presence.

Severe
Mortar loss and fracturing of Vitricotta tiles due to moisture build-up under window sill.



Severe
Discolouration of mosaic tiles due to moisture presence.

Severe
Painting of discoloured areas of Basalt stone along the base of the stone wall.

Moderate
Efflorescence and grout discoloration due to moisture presence.

Basalt Stone

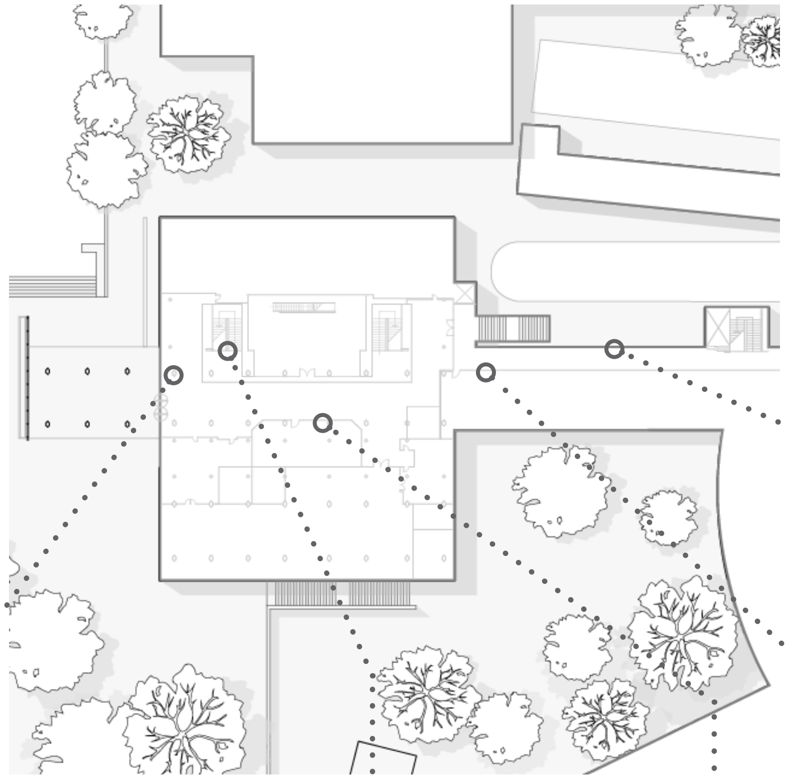
Basalt stone is a material that is indigenous to Mexico and is an expression of an architectural aesthetic that is unique to the university campus. This material has largely been shown to be quite durable, with most of the damage coming from human interventions. Other minor forms of deterioration are also visible in some areas such as surface cracking or efflorescence. Through regular inspection and maintenance this deterioration can be monitored.

Mosaic Tiles

The tiles of the mosaic art installation are largely in good condition with the exception of areas that have undergone some discolouration. This deterioration pattern is likely due to water that has fallen onto the mosaic from the cantilevered west façade above. As there is no other evidence of severe material loss, regular maintenance and cleaning of the façade may address this issue.

Interior Condition Assessment

Ground Floor



Drawn by Jessica Babe

Severe
Material loss of wall tiles around base of coloumns caused by seismic activity or settlement.

Severe
Material loss of Basalt stone steps due to physical impact.

Low
Hair cracking of mortar joints between glass blocks. The blocks themselves are in fair condition.

A condition assessment of the interior of the building was conducted and has identified several reoccurring forms of material deterioration. Natural deterioration patterns such as material loss, cracking, discolouration and oxidation are typical for all interior levels. Deterioration due to anthropogenic causes such as patch repairs and improper construction details are also common. Both the natural deterioration and human interventions have had an impact on the architectural character of some of these interior spaces and may need to be addressed in the near future.

Due to restricted interior access, the interior scope of the conditions documentation is limited to public areas and main interior corridors.

Severe
Material loss and discolouration of metal window frame due to metal oxidation from moisture build-up.

Severe
Material loss of Adoquin stone floor at material junction on a typical upper level.

Moderate
Replacement of vitricotta tiles. Appears to be continuous on all upper floors and aligns with separation of exterior concrete slabs on south elevation.

Severe
Patch repair of missing vitricotta tiles around door frame on typical upper floor using concrete infill. Damage or loss of original tiles likely due to seismic activity.

Site Visits

Part 3: Site Visits + Hands On Restoration Experience

Mexico City

Mexico City

1 Casa Azul (Frida Kahlo Museum)
2 Estudio Diego Rivera y Frida Kahlo
3 Xochimilco
4 Los Manantiales

Centro Historico

5 Museo de las Constituciones
6 Colegio de San Ildefonso
7 Palacio de Inquisición
8 Templo de San Agustín Palacio Nacional
9 Palacio Nacional
10 Palacio de Minería
11 Palacio de Correos
12 Palacio de Bellas Artes
13 Templo Mayor
14 Centro Cultural de España
15 Catedral Metropolitana de México
16 Torre Latinoamericana
17 Torre Reforma

Casa Azul / Museo Frida Kahlo

Constructed: 1904
Architect: Guillermo Kahlo

Frida Kahlo (1907 – 1954) was a Mexican artist who became popular in the 1970s for her self-portraits and other paintings that were inspired by nature and artifacts of Mexico. She questioned the identity, postcolonialism, gender, class and race in Mexico through her work, which was a mixture between realism and fantasy.

The original Casa Azúl, located in the Colonia del Carmen neighborhood of Coyoacán in Mexico City, was Kahlo's birthplace and was the home she grew up in. She spent most of her youth confined in the house due to a series of health problems. She later married Diego Rivera, a Mexican muralist, and lived in the house with her husband. In 1954, Kahlo passed away in a room on the upper floor. Her ashes are now displayed in a pre-Columbian urn in the museum.

The original structure of the house was designed in a French style but was later adapted by Kahlo and Rivera in 1941 to have a bigger garden and brighter colours such as the cobalt blue walls. The house was rehabilitated into a museum in 1958, after Frida passed away. Today, it showcases the lifestyle of the wealthy Mexican bohemian artist during the beginning of 20th century.

Estudio Diego Rivera y Frida Kahlo

Constructed: 1929 – 1932
Architect: Juan O'Gorman

Before the modernist movement took hold of Mexico, architect and painter Juan O'Gorman was commissioned to build two modern functionalist houses for artists Diego Rivera and Frida Kahlo. Inspired by Le Corbusier's work in Europe, O'Gorman included steel-framed ribbon windows, reinforced concrete slabs, spiral freestanding staircases, accessible flat rooftops, *pilotis* and open plans in his design. However, there are aspects of local Mexican culture and architecture that are also evident, mostly in the use of colour.

The complex is comprised of 3 houses-studios, a photographic laboratory and a garage. They embody the principle of "minimal expense for minimum effort".

Xochimilco

Xochimilco is a region at the southern edge of Mexico City known for its agricultural traditions, partially human-made landscape, and the historic heritage of the area. In this area, during Aztec times, chinampas – human-built islands, or 'floating gardens' – were constructed for agricultural purposes. Well-irrigated by the lake waters below, this system is highly productive, sustainable, and uses small areas of land extremely efficiently.

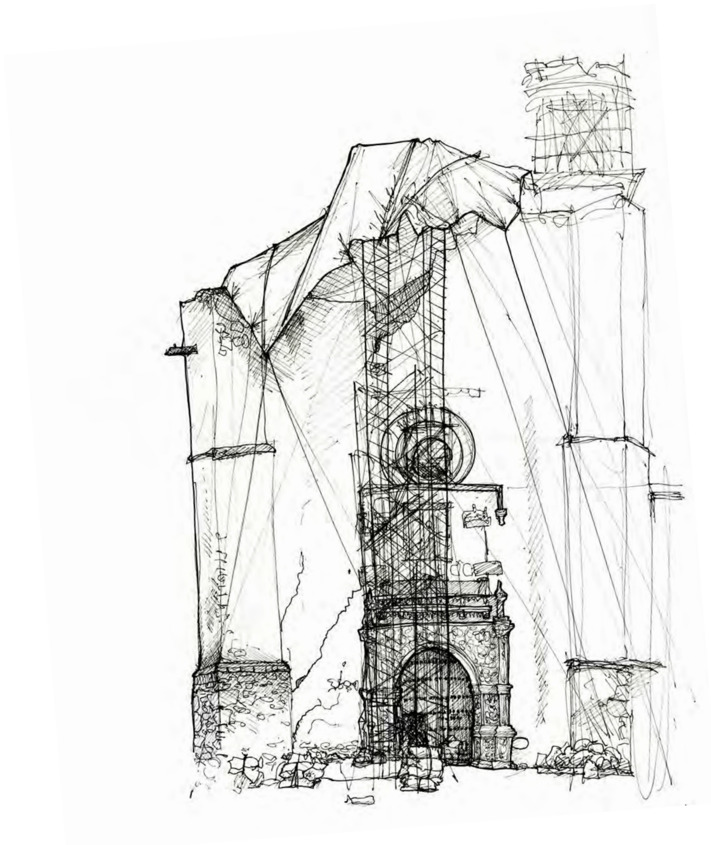
The productivity of Xochimilco supported the tremendous development of the Aztec capital, Tenochtitlán. Farming in this dry area of Mexico would have been unimaginable without the utilization of innovative techniques. Because of this relationship between the agricultural zone and the flourishment of the city – the UNESCO World Heritage Designation for the site, inscribed in 1987, is listed as 'Historic Centre of Mexico City and Xochimilco', and the region is considered an "ecological reserve." Xochimilco is also designated on a national level as a protected natural area.

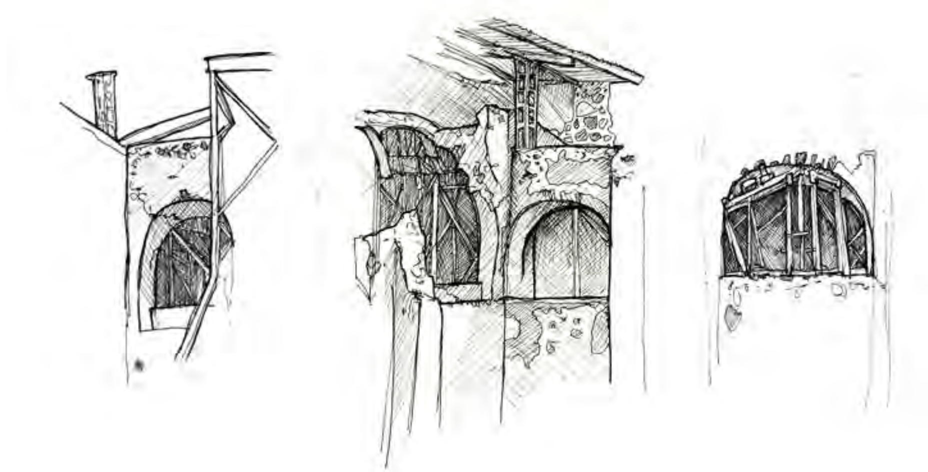
Los Manantiales

Constructed: 1958
Architect: Félix Candela

Los Manantiales restaurant (translated as The Springs) was built along the water in Xochimilco. The formwork for the concrete is made of a series of straight boards, each pivoted slightly to create the curvatures of the building. The construction was made of 2" thin shell reinforced concrete and its form comprised of intersecting hyperbolic paraboloids.

Candela's work can be characterized by the creation of challenging curved forms of concrete using highly inventive techniques. Candela worked heavily with hypars throughout his career, beginning with one of his first experiment with this formal type at the Cosmic Rays Pavilion in UNAM.





Sketches (Huaquechula + Teposcolula) drawn by Christie Ellis Wong

Centro Historico, Mexico City

Museo de las Constituciones

Constructed: 1576 – 1645
Architect: Diego Lopez de Arbaizo

The Museum of the Constitutions was designed as an adaptive reuse of the former temple of the San Pedro and San Pablo College, initially founded by Jesuits in the Viceroyalty of New Spain. After the Mexican War of Independence, its function shifted from theological to political as it held the first sessions of the Constitutional Congress in 1824. The building later became integrated with the National University (now UNAM) in the 1930s.

In 2011, the University worked on rehabilitating the space into a museum that would tell the country's story through its constitutions. In 2016, a new project was proposed that considered the restoration of architectural and artistic elements, adaptation of spaces, compatibility of walls and furniture, as well as multimedia tools to showcase additional contents. The new museum opened to the public in 2017, as a way to commemorate the centennial anniversary of the Constitution drafted during the Mexican Revolution.

Colegio de San Ildefonso

Constructed: 1712 – 1740

The *Colegio de San Ildefonso* was established in 1588 as the San Ildefonso College Jesuit Boarding School. From 1712-1740 the structure was rebuilt as we know it today and the expulsion of the Jesuits in 1767 lead to the building being used for a variety of programs including a college directed by the secular clergy, a temporary site for the School of Law, and quarters for American and French troops.

The building featured murals by artists José Clemente Orozco, Diego Rivera, and David Alfaro Siquerios. It was the home of the mexican muralist movement from 1922-30. Additions were made to the building over the years, but it sat empty between 1978 - 1992 when it then became the home of the Mexican Muralist Movement. In 1991, the building was fully restored and in 1992, it reopened as a museum and cultural centre to hold exhibitions, performances, festivals, and public lectures. Today the building struggles with structural problems from regular sinking processes, as do many historic buildings in Mexico City.

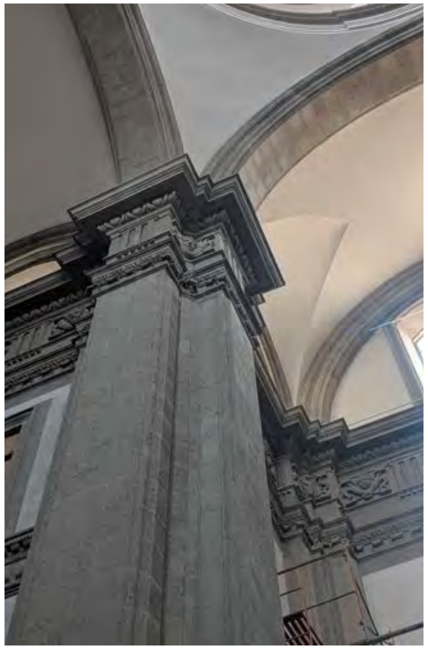
Palacio de Inquisición / Historic Prison Rehabilitation Project

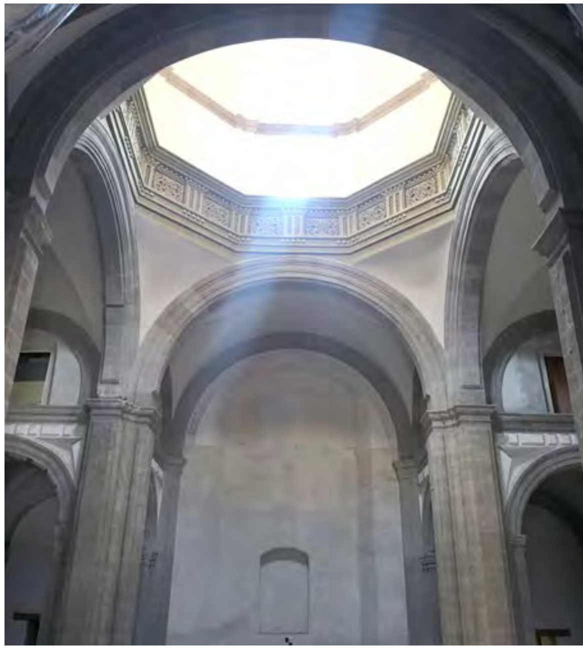
Constructed: 1732 – 1736
Architect: Pedro de Arrieta
Rehabilitation : 2016- 2020
by Dr. Xavier Cortes Rocha

The former Inquisition Palace was built in the historic center facing the Church of Santo Domingo. Along with multiple other buildings in the area, its New Spanish Baroque facade is covered with *tezontle*, a red porous volcanic stone, with windows and doors framed with chiluca, a gray-white stone.

During the Spanish Inquisition, the building functioned as a prison up until the Mexican War of Independence. However, the place's long association with the cruel practices that occurred in its walls made it difficult to convert it to another purpose. Nevertheless, it was eventually sold to the National University (now UNAM) and converted into the School of Medicine.

When UNAM relocated to *Ciudad Universitaria* in the 1950s, they maintained ownership of the building and began working on a restoration of the arches and a rehabilitation of the interior. Today, the structure serves as the Museum of Mexican Medicine.





Templo de San Agustín

Constructed: 1587
Adaptive Reuse Project Architect: Julio Valencia (2013-2021)
Project Engineers: Roberto Meli & Roberto Sánchez

The old Temple of San Agustín, located in the Historic Center of Mexico City, was the first Augustinian convent built in New Spain. In the 19th century, the building was divided and part of it was destroyed. The National Library was inaugurated in its walls in 1884 and the whole was added to the heritage of the University in 1929. The added weight accelerated the sinking of the structure and caused damages such as cracks in vaults, walls and quarry elements. The vaults of the main nave were reinforced, ornamental elements were repaired, and the front facade was restored, in addition to the removal of moisture and vegetation growth on walls over the course of conservation works in 2013 and 2015. Once the restoration is complete, the former convent will host exhibitions, concerts, plays and other activities.

Palacio Nacional

Constructed: 1526
Architects: Rodrigo de Pontocillos and Juan Rodríguez

UNESCO World Heritage Site, as part of the Historic Centre of Mexico City.

The National Palace is located in the main square of Mexico City, facing the Constitutional Plaza known as el Zócalo, and measures over 200 meters in length. Much of the current building's materials were taken from Moctezuma's "Casas Nuevas", a complex that served as the Aztec Royal Palace, when the Spanish conqueror Hernán Cortés ordered its destruction in 1523. A new palace was to be erected on the same site for the viceroyalty. The Cortés Palace had to be rebuilt after being almost completely destroyed in 1692. Friar Diego Valverde was appointed to reconstruct the palace, for which he departed from the previous fortress-like appearance to build a new Baroque Viceroy Palace. After the Mexican War of Independence, it was renamed National Palace and the first ministries were inaugurated. Between 1929 and 1951, the famous artist Diego Rivera painted murals across the palace depicting Mexico's history.

Palacio de Minería

Constructed: 1797 – 1813
Architect: Manuel Tolsá
Rehabilitation by Rafael Angel Esponda (1970-1976)

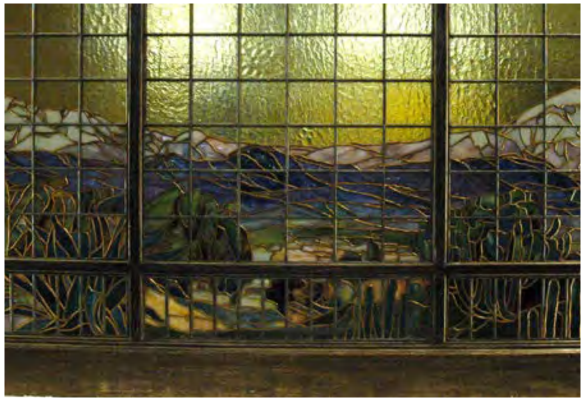
The "Palace of Mines" was initially built to house the Royal School of Mines and Mining of the Royal Court. Its front façade now faces the Plaza Manuel Tolsá and the equestrian statue of Carlos IV of Spain, which was also sculpted by the architect. Fausto Elhuyar, a scientifically-trained mineralogist, was the first director of the college. He planned the first areas of the school, which Tolsá designed in the Neoclassical style. The palace was later added to the heritage of the UNAM when they relocated to *Ciudad Universitaria*. The biggest challenges during the 60s-70s were the problems found in the foundation and therefore its structural instability. It was necessary to complete a total restoration and rehabilitation in many of its main areas. The Faculty of Engineering continues to use the building as an educational center where they have classrooms, auditoriums, computer laboratories, a library, etc. Additionally, the building was required to fulfill cultural functions. A recent rehabilitation project included allowing

Source: FundacionCentro Historico

Palacio de Correos

Constructed: 1907
Architect: Adamo Boari

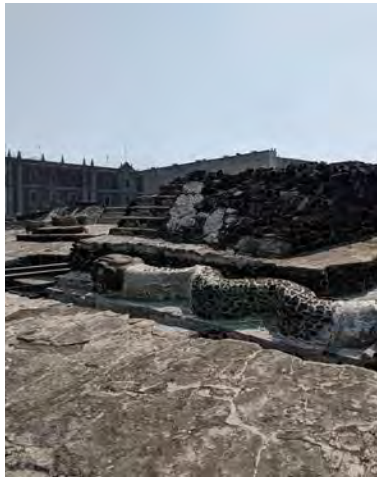
The *Palacio de Correos*, also known as "Correo Mayor" or Main Post Office, was constructed when the post office became a separate government entity. Due to the volume of mail, it was decided that the function should have its own building. Construction began in 1902 on the site of the old Hospital of Terceros Franciscanos and was completed in 1907. In the 1950s, the building was renovated for expansion as the economy was growing and two bridges were built to connect the Palacio with the Bank of Mexico building.



Palacio de Bellas Artes

Constructed: 1904 – 1934
Architects: Adamo Boari, Federico Mariscal

The Palace of Fine Arts is located in the Historic Center of Mexico City, next to the Alameda Central park. The Italian architect Adamo Boari initiated the design and construction, but soil complications and political problems due to the Mexican Revolution caused construction to stop by 1913. It was only in 1932 that the Mexican architect Federico Mariscal continued the work. The completed building is composed of contrasting architectural styles: the exterior, designed by Boari, is prominently Neoclassical and Art Nouveau, while the interior, designed by Mariscal, is Art Deco.



Templo Mayor

Constructed: 1325 – 1519
Intervention: Began 1991- Present

The Templo Mayor was the central temple of the Aztec capital of Tenochtitlán, founded in 1325. It was built to honour and service the sun deity Huitzilopochtli and the god of rain Tláloc. The temple had seven major additions during its life span, with each addition acting like a skin that enclosed the temple that was there before. In 1521, the Spanish conquered the city and destroyed it to build their capital for New Spain over top. Remains of the previous Aztec capital were found during archaeological excavations in the late 19th to 20th century, and an Urban Archaeology Program was created in 1991. Today, the temple is located beside the Metropolitan Cathedral, el *Zócalo* and city hall.

Centro Cultural de España

Intervention: 2002 - 2004
Conservation Architect:
Alfonso Govela

The Cultural Center of Spain in Mexico is located in the Historic Center of the capital. In 1985, the building was heavily damaged by the earthquake. It was in ruins until the Mexico City government ceded it to the Spanish government in 1997. The Spanish Agency for International Development Cooperation (AECID) decided to rehabilitate the building in order to establish in it a new headquarters for its network of cultural cooperation centers. Today, the former mansion houses a multidisciplinary cultural space that offers numerous activities, including: cinema; music; live arts; humanities and literature; children's activities; art, science and technology exhibitions.

Catedral Metropolitana de México

Constructed: 1571 – 1813

Architects: Claudio de Arciniega, Juan Gómez de Trasmonte, José Eduardo Herrera, Jose Damian Ortiz de Castro & Manuel Tolsá

The grandiose Metropolitan Cathedral of Mexico was built in the capital's Zócalo, the main square in the city which used to be the ceremonial center in the Aztec city of Tenochtitlán. Its construction was done over the three centuries of the colonial period and was influenced by multiple artistic movements in the fields of architecture, painting and sculpture, to only name a few. As a result, the cathedral is a beautiful mix of styles ranging from Gothic, Baroque and Neoclassical in its altarpieces, sculptures, columns, shelves, balustrades, vaults and domes. Today, the cathedral is the largest in all of Latin America and has become one of the most important temples of Christianity in the world.

Torre Latinoamericana

Constructed: 1949 – 1956
Architect: Augusto H. Álvarez

The *Torre Latinoamericana* is one of Mexico City's most significant landmarks. The height of the building in the context of the highly seismic area is root for its technological and architectural associated values. However, it should be noted that this is not the city's first skyscraper, nor its tallest. That being said, the building's profile and massing has become iconic for the city's skyline and significant view planes.

A large connection detail located in the groundlevel lobby is a key focal point and mechanism that provides much of the Torre Reforma's resistance to seismic forces.

Torre Reforma, Mexico City

Lecture by: Benjamín Romano & Ismael Vásquez

Constructed: 2008 – 2016
Architect: Benjamín Romano (L.BR&A)
Structural Engineer: Ismael Vázquez

Torre Reforma is a skyscraper in Mexico City on the Paseo de la Reforma, an avenue that was designed in the 1860s and inspired by the great boulevards of Europe. The building runs 57 stories high and has become the tallest skyscraper in the city, in addition to winning the 2018 International Highrise Award for being the world's most innovative high rise. The site includes a 1929 historic house, which is listed for its values by the National Institute of Fine Arts.

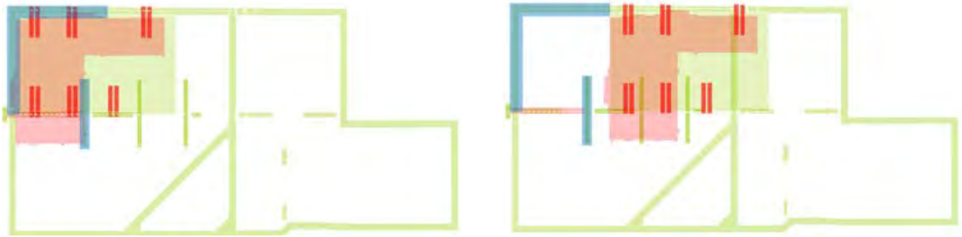
Historical House displacement

Since the interior of the heritage building had already suffered from its previous alteration into a nightclub, it was decided to integrate it harmoniously as the main entrance of the skyscraper. The first challenge of protecting this house was that digging had to be done underneath it to accommodate the nine underground parking levels. The team's response was to excavate the stone foundation of the house and demolish its existing basement. During this process, they inserted a waffle slab embedded in concrete and created a cantilevered mesh of steel rebars to lift the house and move it. The displacement was done with a large hydraulic machine over multiple hours and allowed for the new basements to be excavated. Six weeks later, the house was brought back to its initial position within three hours. This was considered to be a technological breakthrough in Mexico, as it was the first time this technique was executed on a heritage building with the challenges of the soil.

The existing heritage building on the property was relocated in order to better integrate it into the overall design of the Torre Reforma.

Sustainability Strategies

The new skyscraper received a LEED platinum certification for the many sustainable features of its design, including on-site water treatment for net zero water needs and well-incorporated passive system strategies. For instance, the two open terraces allow a cross ventilation between the interior and exterior throughout the day since they are not fully enclosed. However, one of the challenges of using this material was that the curing of concrete generates a lot of heat. Due to the amount that had to be poured in the hot climate of Mexico, the workers needed to create a microclimate to avoid premature drying and cracking of the concrete. As part of a thorough climate analysis which also included prevailing winds and annual temperatures, a solar study allowed to determine how to maximize natural light while



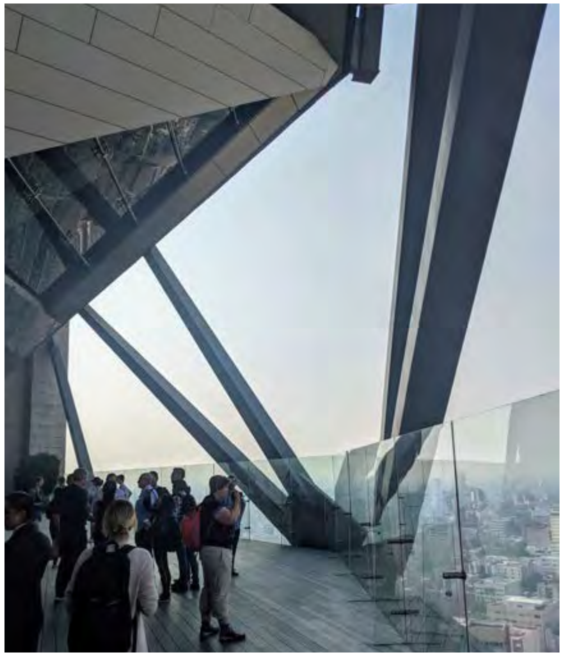
Initial heritage building location (left) and location after displacement (right).

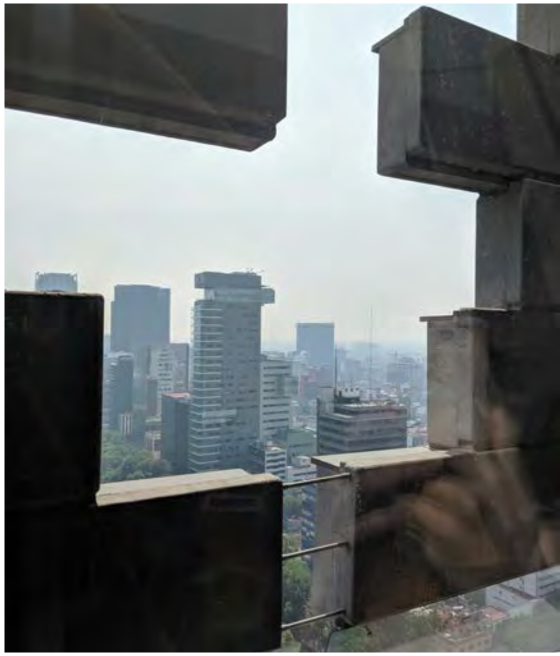
minimizing unwanted heat gain. As a response, vertical fins were installed above windows in order to control the depth of horizontal shadows at different times of the day and during various seasons.

Structure

The design of Torre Reforma was a close collaboration between architect Benjamín Romano and structural engineer Ismael Vázquez. Due to the intensity and frequency of earthquakes in Mexico City, the team had to consider many aspects that would make the building safe and resistant to these natural disasters. To avoid resonance with the movements of an earthquake, it is important for a building to have a different frequency of acceleration than that of the soil it sits on. In addition, much of the skyscraper's resilience to earthquakes comes from its two concrete shear walls. In fact, while the use of only one shear wall makes a building very stiff, integrating a second ones makes the structure more flexible and allows it to perform better during an earthquake. The design of the exterior walls also reduced the need for columns in the interior spaces, with only a few columns located at steel connections and allowing an open floor plan.

From left to right: Concrete stratification viewed from an upper level observation deck at the Torre Reforma / Windows of the tower are deliberately placed according to patterns of seismic movement.





Site Visits + Hands On Restoration Experience

Ruta de los Conventos / Listed a UNESCO Heritage Site in 1994

Regional Map

Morelos

21 Ex Convento de San Juan Bautista

22 Ex Convento de San Guillermo

Puebla

23 Templo Santa Maria de la Asunción

24 Capilla San José de Gracia

25 Ex Convento de Tecali

26 Catedral de Puebla

27 Templo de San Martin de Tours

28 **Teotihuacán**

Introduction to the Earthquakes' Impact on the World Heritage Site "Ruta de los Conventos"

During the 2017 Earthquake several buildings and their tangible and intangible values were detrimentally impacted.

These convents include San Guillermo, Totolapan, Morelos and Huaquechula Monastery. The first had suffered cracking and fracturing in its barrel vaults. Part of the bell tower collapsed and the pendentive dome had completely failed during the earthquake. The damage also included the failure of many of the buttresses in the courtyard.

These vaulted roofs of Totolapan were constructed using poor quality adobe mortar and small rounded river stone. They had been repaired throughout the years with cementitious grout which had magnified the failures. Coated in non waterproofed plaster, moisture had degraded the structure prior to the earthquake. The Huaquechula Monastery had its upper portion of the bell affected by the earthquake. This significant mass collapsed and fell through the first ribbed vault of the roof of the nave. The main entrance had weakened the wall underneath an ornate rose window due to its reinforcement in 2001 using concrete and steel. This therefore resulted in a shear fracture. After its assessment, it is clear that these two monasteries did not have sufficient maintenance previous to the 2017 Earthquake and therefore had undergone extensive damages with weak preventative measures. In specific Totolapan has extensive use of portland cements and Huaquechula has steel reinforcement in its bell tower and concrete slabs at the cloister. These inflexible materials provided stiffness to the walls and roofs resulting in differing return periods for the buttresses and failures. Preventative methods and treatements such as using shock absorbers during seismic events improves the durability of the structure. Students learned on this portion of the trip the importance of using appropriate materials in rehabilitation and how essential it is to the integrity of heritage fabrics

Due to the general lack of understanding among the Architectural/Engineering community as to how unreinforced Masonry (URM) structures function, how to preserve them and, where necessary, how to rehabilitate these structures, we visited and studied in the last days of the Mexico trip, several convents from the 16th century in Puebla and Morelos that were highly damaged during the 2017 earthquake. John Cooke, a Canadian conservation engineer, joined the Carleton team to deeper the understanding of the structural behaviour and identify building pathologies.

These buildings designated by UNESCO are representative of the architectural model adopted by the first missionaries who evangelized the indigenous populations. The churches were constructed circa 1535 and 1548. Specifically, the Totolapan Monastery, in Morelos, suffered significant damage.

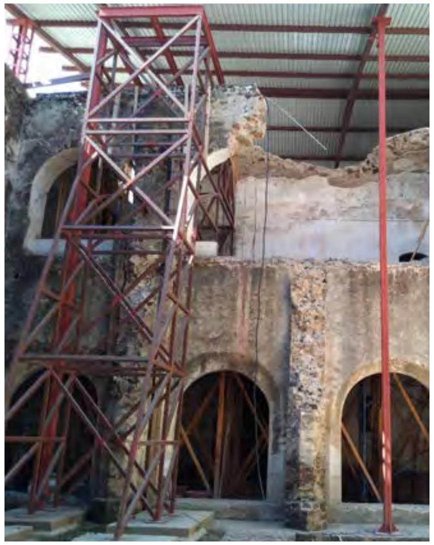
The students observed how the barrel vaults of the church experienced significant cracking and fracturing. Part of the bell tower collapsed. The pendentive dome completely failed during the earthquake, shearing where the vault is the thinnest. The damage to the cloister includes significant fracturing of the barrel vault roofs, cracking of the walls and failure of many of the buttresses in the courtyard. At the east and west side of the courtyard, the barrel vault roofs had collapsed. These recent events prove that it is critical to evaluate the current state of built heritage in order to be better prepared for future earthquake disasters.

Roberto Heatley
2017

Ex Convento de San Juan Bautista, Yecapixtla, Morelos

Constructed: 1535 - 1540

The former Augustinian convent in the municipality of Yecapixtla is part of the *Ruta de los Conventos* program, a pilgrimage route that goes through the main religious sites in the State of Morelos. The 14 convents of the pilgrimage route are designated as UNESCO World Heritage Sites, with this particular one being recognized for its mural paintings. Character-defining elements of the building also include its textured volcanic stone, its walls finishes in battlements and merlons, as well as the Gothic style rose window at the main entrance.



Ex Convento de San Guillermo, Totolapan, Morelos

Constructed: 1536 - 1545

The former Augustinian Convent was designated as a World Heritage Site in 1994. After it suffered great damage from the 2017 earthquake, the INAH got involved for the restoration of the building. Fernando Duarte, coordinator of Historical Monuments of the INAH Morelos Center, explains that an incompatible intervention made to the structure about 25 years ago using concrete beams made it behave differently with the oscillation generated by the earthquake. This intervention combined with the lack of maintenance, caused the collapse of the inner part of the vault.




Templo Santa María de la Asunción, Molcaxac, Puebla

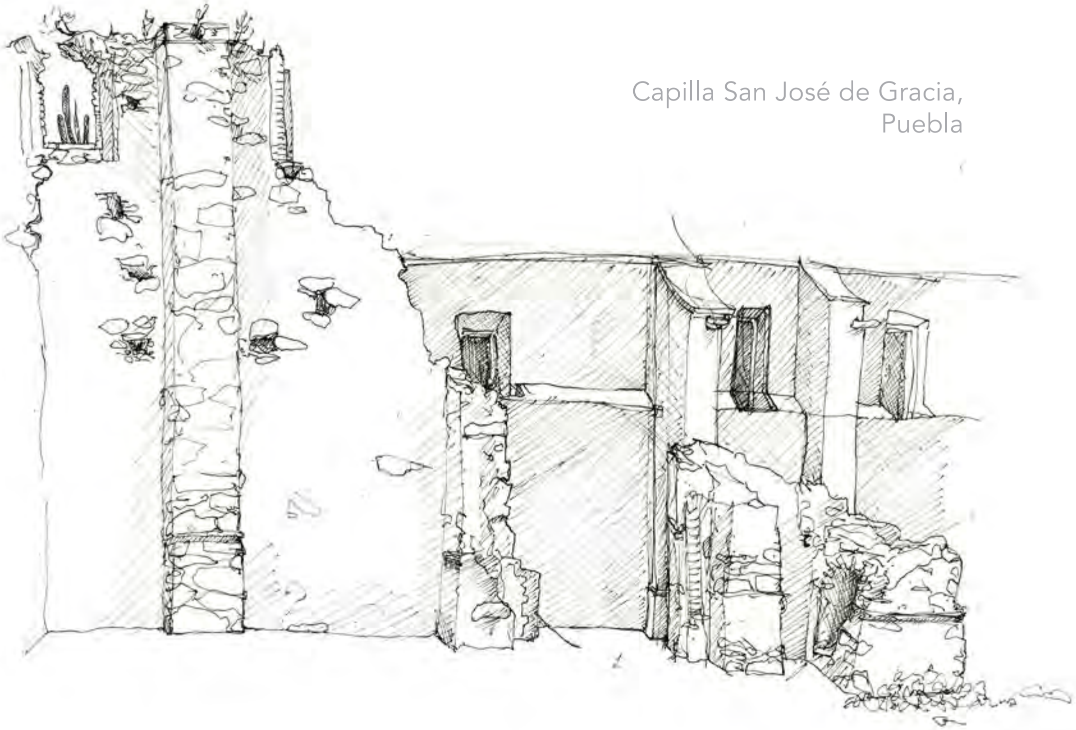
Constructed: 17th - 18th century A.D.

The Temple of Saint Mary of the Assumption, located in Molcaxac, Puebla, was painted in a striking blue colour and ornamented with details painted in white. In the state of Puebla, the choice of colour on religious buildings is more than a matter of aesthetics and usually carry a deeper meaning. In fact, blue and pink are typically symbolic of a Marian advocation, while yellow and white would be the colours dedicated to Jesus, and green combined with yellow would be for Saint Joseph.

Since its construction, the bell tower was rebuilt in 1938. Interventions were then made in the 1990s, when concrete was added to the tower slabs, and metal bracing was later added in

1999. After 2017, the tower was damaged by the rigidity of the concrete and, as a result, could not oscillate at the appropriate frequency during the earthquake. The addition of concrete was not suitable to maintain its structural integrity. Cracks occurred in the barrel vault and some of the arches.

The current state of the church presented both minor and high damages. Therefore, the restoration works will be limited to the recovery of ornamental elements and the maintenance of the vaults to avoid humidity accumulation in the walls. The bell tower will be consolidated by injection of mortar into cracks.



Capilla San José de Gracia,
Puebla

Templo Santa María
de la Asunción
Puebla

San Juan de Bautista
Morelos

Sketches by Chritie Ellis Wong

Site Visits • • •

Bottom left photo: Students learning about traditional lime mixtures and pigments

Capilla San José de Gracia, San José de Gracia, Puebla

Original Construction: 16th century A.D.
Addition: 18th century A.D.

The initial church was built in the 16th century, but was already in ruins by the 18th century when the current building was erected. Initially, the addition's buttresses were casted into the ruin, which had to be cut for this intervention. A gap was later added between the historic structure and the newer church to better distinguish the old from the new. The exterior paint colour was also changed from its initial light blue to its current olive green and yellow. This change of colour could perhaps symbolize a deeper meaning, namely the shift from a Marian advocation to the worship Saint Joseph. Architects Elisa Vera and Ivan Ríos Peralta from PROSUCO, whom specialize in the conservation of ruins, had been working on the site for 10 months due to its deterioration following the earthquake of 2017. Their restoration works included the structural separation of the building with the ruin, the recovery of the geometry in the arches along the body of the church, the consolidation of the structure of the walls and maintenance works in vaults to avoid humidity.

Ex Convento de Santiago de Tecali, Tecali de Herrera, Puebla

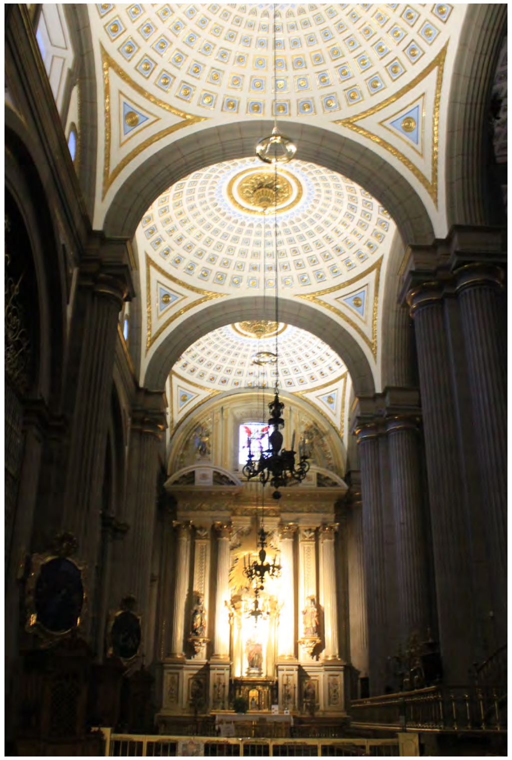
Constructed: 1540 - 1564
Architect: Claudio de Arciniega

The former convent was built by the Franciscans and designed in the Colonial Spanish Renaissance style in New Spain during the 16th century. Only a century later, the friars left the convent due to some disputes they had with the episcopal authority. Today, only ruins of the convent remain in front of the Plaza de Armas. Along the length of the nave, columns are joint by semi-circular arches, which used to support a wooden roof. While the roof is completely removed, remains of paintings representing angels are still visible at the entrance.

The name of the place is of Nahuatl origin, with the terms *tétl* (stone) and *calli* (house) that can be translated as *Casas de piedra* (houses of stone) when combined.

Christie Ellis Wong





Catedral de Puebla, Ciudad de Puebla

Constructed: 1575 - 1647
Architects: Francisco Becerra & Juan Gómez de Trasmonte

The Cathedral of Puebla, also known under the name of "the Cathedral of Our Lady of the Immaculate Conception", is the episcopal seat of the Archdiocese of Puebla. It is one of the most important buildings located in the heart of the historic center of the "City of Angels", which was declared a World Heritage Site in 1987. The Roman Catholic Church was built in a combination of Neoclassical, New Spanish Baroque and Herrerian architectural styles. At the main entrance, a large open-air atrium provides a stage for the front façade and its two massive bell towers, which are a little more than 70 meters high. At the time, this was the highest church in the Spanish colonies. Flying buttresses arranged laterally on the roof made it possible to build a structure this high. In the interior, the main highlight is the *Altar de los Reyes*, which was designed by Manuel Tolsá and added in 1797. More recently, the church was damaged in both earthquakes of 1999 and 2017.

Templo de San Martín de Tours, Huaquechula, Puebla

Constructed: 1569
Restoration Architect: Pablo Vidal Tapia

The restoration of the Franciscan temple in Huaquechula was conducted by experts from INAH (Instituto Nacional de Antropología e Historia) who began working on the restoration of its roof. In doing so, they found the original ashlar masonry of the 16th century, which had been hidden under 15 layers of whitewash for centuries. The ribbed vault detailing represents an important example of the convent architecture in Puebla at the time. The choir, the nave and the polygonal presbytery are all defined by their carved stone ribs design — with the presbytery having the most elaborate — are separated into four sections by arches. Floral motifs were often created in Franciscan buildings and can be observed in this temple. Today, architects and the community are still working on restoration of the religious building after it was affected by yet another earthquake in 2017.

Teotihuacán

Constructed: 1st - 7th century A.D.

Teotihuacán is a Mesoamerican pyramid complex located in the city of San Juan Teotihuacán, a valley northeast of Mexico City. The complex links *the Templo de Quetzalcóatl*, the *Pyrámide de la Luna* and the *Pyrámide del Sol* (Temple of the Feathered Serpent, Pyramid of the Moon and the Pyramid of the Sun). The archaeological site was designated as a UNESCO World Heritage Site in 1987.

The name of the site translates to "where the gods were created" which reflects the cultural and religious significance of the area. The Pre-Hispanic city was built between the 1st and 7th centuries A.D., when the area developed into a large urban city spanning about 36 square kilometers and housing about 25 000 people. The city became one of the largest in the Americas during this time. Teotihuacán is considered a model city that had a great influence on future city development and urban planning of later cultures.


Pirámide del Sol | Pyramid of the Sun

Conclusion

The results of this DSA have provided to the Carleton students new insights into monitoring risk assessment on modern heritage buildings and a better sense to the challenges that World Heritage Sites (W.H.S) present. These outcomes will support best practices to conserve modern heritage structures affected by earthquake for future generations. Furthermore, it will increase awareness on the need to develop methodologies on risk assessment and engage public and private stakeholders in the active protection of heritage assets. This collaboration between Carleton University and University Nacional Autonoma de Mexico as well as other stakeholders was mutually beneficial. The findings of this research will inform the decision-making process for future interventions made these heritage buildings.

The DSA allowed students to understand the value of historic sites and heritage documentation within Mexico City, Puebla, and Morelos. Documentation and assessment conducted in UNAM allowed for an understanding of the damages that occurred to the Cosmic Rays Pavilion (CPR) and Chemistry Building B due to the 2017 Earthquake

With the support of two research grants - New Tools New Paradigm through CIMS lab and the International Research Seed - the study trip was concluded by writing four articles and presented in international conferences (Structural Analysis of Historical Construction SAHC 2021, CIPA Heritage Documentation 2021 and Cambridge Historical Construction 2020). Two articles were on the digital workflow used and discoveries for the pavilion to assess the performance of this concrete shell by the students Sepideh Rajabzadeh (intern at CIMS summer 2019), Laila Cordero (Mexican collaborator) and Dr. Mariana Esponda. The other paper highlights the lack of research for the conservation of the 20th century concrete hypars in Mexico. The fourth and last article was written by Dr. Mariana Esponda and the conservation engineer John Cooke, also presented in SAHC 2021 comparing the interventions for two convents W.H.S. affected by the 2017 earthquake. They analyzed the importance of using compatible materials along with appropriate repair procedures and the need for ongoing maintenance.

The ultimate goal for the field trip was to generate interest to encourage architectural students as well as more professionals to address proper interventions for modern architecture. In addition, through the hands on experience during the site visits, the conservation students learned about the modernist architecture and the use of concrete that flourished during the 20th century in Mexico City, as well as the preservation of pre-hispanic temples, Renaissance and Barroque buildings.

The study of the Mexican built heritage at high risk of further seismic damage offered a great opportunity for the architectural conservation students to understand its historical significance, to document current damages, to assess the risks and to study the treatments of interventions.

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