CONSERVATION OF ARTISTIC AND HISTORIC MONUMENTS IN MEXICO

Xavier Cortés-Rocha*

Facultad de Arquitectura, Universidad Nacional Autónoma de México
Ciudad Universitaria, Circuito interior s/n, Coyoacán 14350, México, DF, México

e-mail: xcortes@unam.mx

**Keywords:** Historic monuments in Mexico, Constructive traditions, Structural problems, State-of-the-art restoration techniques.

**Abstract.** Mexico has a wealth of artistic heritage in a variety of historic buildings constructed before the twentieth century as well as many artistically significant monuments built during that century. These buildings have different structural problems related to several issues, among them, the seismic nature of the country, poor maintenance, and uneven settlements resulting from the characteristics of the soil’s features and excessive pumping of water. There has therefore, been an important national tradition in the upkeeping of these buildings. During this last half century, approaches and techniques have evolved, from the conventional methods to new initiatives and approaches. This work shows the state-of-the-art technology and procedures that are currently used to preserve these buildings and brings forth future prospects to extend the conservation scope of historical and artistic monuments in Mexico.

*Professor Emeritus at the Facultad de Arquitectura, Universidad Nacional Autónoma de México.*
1 BACKGROUND

A country with a rich cultural heritage.

Mexico is a country with a rich built heritage with hundreds of archeological sites where remains of ancient cities still have many standing buildings. There are also several thousands of historic monuments built between the sixteenth and nineteenth centuries, most of which are in use to date, as well as a significant amount of buildings built during the twentieth century that are considered artistic monuments. In fact, many of these archeological sites, historic downtown areas, natural reserves and cultural landscape as well as other intangible heritage elements, have been recognized by UNESCO as cultural heritage of outstanding universal value. (1-3)

Several constructive traditions.

An inherent part of this cultural heritage lies in its several constructive traditions, as the native masters took advantage of the experience of Pre-Hispanic culture even before structural calculus systems was used and construction codes came into force. (4-6).

Later on, these traditions, which had itself various roots (From Romans, Visigoths and Moors), blended with the body of knowledge the Hispanic had. These roots came as part of the groundings brought by the Spanish mason masters, who transmitted these to apprentices and skilled masons known as “officers” in the trade workshops. (7-9).
We have no knowledge about Pre-Hispanic documents that describe their constructive practices, but we do know about the books used during the Viceroyalty period, from the European treatises during the Renaissance and after it, as well as the treatises written by Fray Andrés de San Miguel and by the unknown author of *Architectura Mechanica*. Although the author of the aforementioned treaty only referred to Spanish masters, history has proved that there was also influence of other European architects such as Alberti, Serlio and Vignola, among many others. The *Ten Books on Architecture* written at the beginning of the Roman Empire by the Roman builder Marcus Vitruvius Pollio were re-discovered during the early Renaissance and had thereafter impact on the following centuries. (10-12).

In the seventeenth century, Friar Andrés de San Miguel, who developed his work as a master of architecture in New Spain, left a manuscript with numerous writings regarding architecture and carpentry. Although it remained unpublished for a long time, his work is considered to be a link between architects of the sixteenth and eighteenth centuries. Friar Andrés de San Miguel, in contrast to European masters, wrote about the Moorish roofs and ceilings and acknowledged Vitruvius and Alberti when he referred to foundations and the thickness and heights of walls. (13-15).
Friar Lorenzo de San Nicolás and Vicente Tosca worked on several other important writings regarding building practices in Spain. It is worth mentioning that Father Tosca’s *Compendio Mathematico* included one book dedicated to architecture and stonecutting. (16-17).

In the eighteenth century, a Master of Architecture wrote in Mexico City “Architectura Mechanica, in accordance to the practice in this City of Mexico”. This document is a very interesting compendium of materials and construction procedures, which describes the profession’s rules and the examination process for becoming a master of architecture. This manuscript, which was found in Western United States, was published with an introduction and some notes by Mardith K. Schuetz at the University of Arizona Press. Figures 16 and 17.

We also know about the Fabric Books and the contracts concluded between the Novo-Hispanic architects with their masters. These documents have accurate descriptions of the materials and constructive procedures.

Furthermore, the San Carlos Academy and the military engineers brought new approaches and scientific understanding; therefore, various construction treatises in Mexico date back to the nineteenth century. (18-19).
Conservation of Historic and Artistic Monuments in Mexico.

Figures 18-19. San Carlos Academy in Mexico City and door at San Diego Fort in Acapulco.

In addition, abundant French and Spanish treatises reached Mexico; these included construction techniques, such as the steel or mixed construction known as the charpente métallique. (20-21).

Figures 20-21. Charpente métallique

Regulatory framework,

Conservation of Mexico’s built heritage has proved to be of such importance, that the nation reserved and undertook its safekeeping by establishing a regulatory framework that governs the protection and interventions to preserve monuments. These terms are set through in the “Ley de monumentos y zonas arqueológicos, artísticos e históricos” (federal act protecting archeological, historic and artistic monuments). (22-25).

Figures 22-25. Ley de monumentos y zonas arqueológicas, artísticos e históricos: Calakmul, Campeche; Historic downtown Morelia, Michoacán and, Ciudad Universitaria National Autonomous University of Mexico.
Experience has proved that a new way of protecting Mexico’s historic and artistic heritage is the result of consensus among local organisms and their communities. We have therefore envisaged creating a new regulatory framework that delineates responsibilities and attributions shared among federal, state and municipal authorities. In fact, we have developed several protection programs for historic centers that involve cultural, planning, social development, housing, tourism and even environmental institutions, with participation of local, state, municipal and federal authorities. We should only build common ground and establish clear and precise rules in the near future. (26-28).

*Figures 26-28. Several examples of revitalization work done by communities in collaboration with authorities.*

Additionally, Mexico contributes as an international stakeholder and is State party of the Convention for the Protection of the World Cultural and Natural Heritage of the UNESCO, collaborating thus to “ensure the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage”. Figure 29.

*Figure 29.*

**Stakeholders in the restoration process.**

We must however insist on the fact that Mexico has been concerned about its cultural heritage a long time before the setting up of this *Convention* in 1972 and has accordingly created effective systems of protection on an ongoing basis from the early nineteenth century onwards.

National organizations that have been in charge of protecting tangible and intangible cultural heritage in Mexico are *CONACULTA* (National Council for Culture and the Arts), *INAH* (National Institute of Anthropology and History) and *INBA* (National Institute of Fine Arts). These entities promote and guard arts and culture, anthropology and history as well as fine arts. However, religious organizations and owners of historic constructions as well as trusts that seek to protect monuments and sites, have proved to be vigorous partners that have provided very valuable actions to help federal and local governments in this task. (30).
Patronage has been increasing as a solid cultural practice in Mexico. The most extended and traditional example is that of the communities of neighborhoods and brotherhoods in charge of the festivities for the patron saints of churches. Not only do they collect funds to organize the festivity but rather go beyond that and take care of maintenance and even restoration works for their sacred places. Although their efforts do not always have the most appropriate results, professional advice and ad hoc programs should support their example of social commitment in order to achieve adequate restoration works. (31-32).

There are as well trusts and patronages that carry out, with professional advice, commendable activities to maintain the cultural heritage they own and even national monuments they sponsor. The grand organs of the Mexico City Cathedral, The Kings’ Reredos in the same monument and the Museum of Popular Arts are good examples of the aforementioned. (33-34).

Figures 31-32. Cultural heritage in small communities in Mexico.

Figures 33-34. King’s reredos in the Metropolitan Cathedral of Mexico and Popular Art Museum in Mexico City.
2 CURRENT DETERIORATION CAUSES OF HISTORIC CONSTRUCTIONS.

Problems due to external situations or deficient construction.

Various circumstances may cause deterioration of historic buildings in Mexico. Some are due to problems regarding the construction of the building itself, such as design deficiencies or the lack of systematic and timely maintenance. (35-36).

Figures 35-36. La Concepción church, Mexico City Downtown and Yanhuitlán aqueduct in Oaxaca

External situations such as floods, soil subsidence -particularly uneven settlements- soil landslide and, very importantly, the different magnitude earthquakes that occur within almost the whole territory, may as well cause deterioration. (37-38).

Figures 37-38. Santa María Amajac, Hidalgo and La Santísima church.

Among the first group of situations we mentioned, we may find failures in walls which have not homogeneous sections and are built with two outer layers of good quality stonework with an intermediate filling material of masonry, smaller stones and less quality mortar. (39-40).

Another type of failures are due to insufficient sections, particularly in buttresses that counteract the horizontal thrust of large barrel vaults. However, this situation might as well have to do with the sinking of the base because of soil yielding or increase in the forces due to changes in the vault geometry. (Flattening of the arch by reduction of its depth). (41-43).

**Insufficient maintenance**

The most frequent structural problem in all kind of constructions is, nevertheless, the one due to lack of maintenance, extension of cracks originated from several causes related to water leaks in stonework buildings. The ruin of floors and roofs in buildings with a wooden beam base system are even more frequent. In these latter, rotten wood is due to a sequence of: lack of maintenance in flat roofs, fissures, soil filling moisture, wet beams subject to rotting processes as well as to insect attacks, and thus causing collapse of parts of the buildings with only the vertical elements remaining standing. (44-46).

**Uneven settlements.**

Weak soil, saturated with water, such as that of Mexico City, was the cause of failure in construction of many of the most important religious buildings of the sixteenth century. Examples are the second cathedral of Mexico City, the large convent temples of San Francisco, San Agustín and Santo Domingo; all of which had to be re-constructed from foundations two centuries afterwards, with procedures that were planned and executed using a combination of Pre-Hispanic technologies. (47-50).
Huge buildings lent towards the area where the soil was weaker; for example, the Cathedral of Mexico City, where we may appreciate the correction on the west wall and the columns becoming higher towards the south. Conditions of buildings such as the temples of Santa Teresa la Antigua, Jesús Nazareno or La Santísima may as well cause concern to the unaccustomed eye. (51-55).


Figures 54-55. Jesús Nazareno and La Santísima churches.
An illustrious example of a building damaged by the uneven settlements caused by different types of soil beneath it is the Basílica de Guadalupe, whose foundations have some areas laid on bedrock and other areas laid on clay. On the other hand, the Cathedral of Mexico and the Santo Domingo church are examples of damage caused by the presence of previous constructions, in addition to excessive water pumping from the soil causing an uneven compression. In these cases, uneven settlements caused torsion and breaking of the buildings in addition to the very common cracking in vaults and walls. (56-57).

In several cities within the central part of the country, such as Celaya and Aguascalientes, water pumping from the soil and its compression process, have caused failures that affect the constructions, destroying many of the lightest ones and damaging most of the historic buildings. (58-59).

Soil landslide.

A less frequent reason for serious structural problems is the landslide of a geological layer over another one beneath a building. A successful case carried out by Meli, Sánchez and Santoyo, has been the Santo Domingo church in Zacatecas. In contrast to this latter, there is a critical example where, despite the work done to stop this situation in the imposing convent complex of Meztitlán, the rear part of the building partially collapsed. (60-61).
Figures 60-61. Complex of Santo Domingo, Zacatecas and Los Santos Reyes Convent, Meztitlán, Hidalgo.

**Natural disasters.**

Deterioration due to floods may as well be the consequence of natural disasters such as the one suffered by the buildings in Mexico City during the historic flood that occurred from 1629 through 1631. This flood kept most of the city under water during many months faced with the impossibility of draining. Walls in the ground floors weakened and most of the constructions collapsed. (62).

Figure 62. Mexico City, 1628, Juan Gómez de Trasmonte

In the northern border of Mexico, waters of the Falcón dam closed over a part of the Guerrero Viejo church, constructed in the eighteenth century at the ancient Revilla at the Río Bravo’s bank. This situation lasted several years and the building suffered partial collapse and damages that were difficult to repair. Further, some months ago in Acapulco, the waters closed over an important area of the city with constructions, causing thus deterioration and partial loss of many of them. (63).

Figure 63. Guerrero Viejo, Río Bravo, Mexico.
Last but not least, an unavoidable condition which causes severe damage to historic buildings on a recurring basis are earthquakes. (64-66).

Figures 64-66. Some examples of damage caused by natural disasters such as earthquakes.

3 PRESERVATION OF BUILT HERITAGE DURING HALF A CENTURY.

Traditional methods.

In general terms, normal scale damages and deformations have been dealt with traditional methods, striving to reconstruct the building’s integrity by means of what may be considered major maintenance works. (67).

Figure 67. Santa Apolonia chapel, Mexico City.

These may include:

- Increasing the foundations section. (68).
• Consolidation of walls and columns by means of filling cracks with pressure injected mortar. (69-70).

Figures 69-70.

• In case of very large cracks, masonry is woven again. (71-73).

Figures 71-73.

• Buttresses are widened as well as consolidated where necessary. (74-76).
In buildings with floor systems and flat roofs made up by wooden beams, substitution or reinforcement procedures are carried out.

Floors and roofs are completely substituted by changing the beams in the most damaged rooms.

Primary beams are added to shorten the span of the structure. (77-78).

Changing traditional procedures to more technologically advanced ones occurred in Mexico from around 1960. (79).

The aforementioned coincided with a significant population growth along with a disproportionate water pumping to supply the new demand. This situation had a profound effect on the clay soil’s compression, increasing the cases of tilts and twists caused by uneven settlements on heavy masonry buildings.
Consequently, structural repairs and interventions to strengthen foundations became priority issues and new techniques were developed, for example, control piles.

**Control piles.**

Credit for the creation of control piles must be given to Manuel González Flores. This invention had a profound impact, particularly in Mexico City where it has been used in foundations of large buildings. Control piles are concrete piles that rest on the firm layer, with an adjustable device on the top to control the emersion. Control piles were widely but selectively used in the most significant religious buildings, for example in the Cathedral of Mexico and the Basílica de Guadalupe among others. Different outcomes have come about. (80-81).

**Incorporation of concrete reinforcements**

Bernardo and José Luis Calderón were two architects with a solid grounding on structural analysis and calculus, who devoted the last decades of their professional practice to intervene historic structures of many of the larger and most outstanding civic and religious buildings, which had serious tilt and twist problems due to uneven settlements.

After diligent numerical analysis, reinforced concrete elements were incorporated to foundations in order to create platforms. Columns and embedded beams in masonry walls and vaults were constructed as a means of stiffening for the purpose of restoring the joint structural work. (82-83).
Among the buildings that have been restored with this technique, are the palace known as Casa de los Azulejos, as well as the churches of:

- San Francisco. (84-87).
- La Concepción
- Santo Domingo. (88-89).

All of them in Mexico City and two more examples in Amecameca and Orizaba, in the central part of the country.
Two major intervention works: The Cathedral of Mexico and the Basílica de Guadalupe.

During past decades, the restoration of two religious monuments of utmost importance in the country stand out for the complexity and seriousness of the damages that jeopardized their permanence mainly due to the risk their stability had. These buildings are the Cathedral of Mexico and the Basílica de Guadalupe; the former one located downtown of the city, and the latter one towards its northern part. (90-91).

Basílica de Guadalupe: a social symbol and an urban milestone.

In 1695, the foundation stone of the Old Basílica de Guadalupe was laid and in 1709, it was solemnly inaugurated. The monument is 44 meters high; masonry walls are cladded with “tezontle” (volcanic soft rock) squares, ashlar quoined corners and framed windows. (92-93).

In 1887, the sanctuary suffered a radical transformation. Two bays in its northern side were added and the Basilica lost its original double symmetry. (94-95).
From 1929 through 1938, and after having identified several cracks in the vaults, reinforcement and expansion works took place. In fact, it was in 1930, when the columns for the extension carried out in 1887 were removed, and a steel structure was incorporated to bear the weight of the vaults. One year later, other significant and drastic interventions took place in the interior as well as in the exterior of the monument. In 1963, after carrying out studies, works in the foundations initiated in order to control damages caused by soil landslide and uneven settlements. (96-97).

According to studies carried out by Enrique Santoyo at TGC firm, the soil in the slopes of Tepeyac hill, where the Old Basilica was constructed, is associated with stratigraphic variations and significant settlements within short distances. The aforementioned has caused the building to tilt forward. (98).

In 1965, Manuel González Flores set up the control piles he invented, and protected the columns with a thick concrete cover. However, five years later, it was necessary to carry out palliative works in order to confront the severe damages this building had. (99-100).
From 1973 through 1976, several reinforcement actions were carried out in order to guarantee the safety of the monument and protect its users. (101-102).

A new Basilica had to be built during the seventies while the old Basilica remained closed from 1976 through 2000. Structural works initiated towards the end of the twentieth century. These included its foundations and the maintenance works for the control piles that had been installed. A construction joint was built in order to separate the old and the new wall that had been constructed to recuperate the original size of the building. (103-104).

In 2002, a Master Plan was developed. Since then, and up to 2013 an integral restoration of the monument took place. (105-106).
The concrete protections of the columns were removed in 2004. (107-109).

Conservation works during that time, included the Holy Sacrament chapel as well as the nave, the constructive joint, systems, towers, atriums, roofs, stained glass windows, bell towers, domes and doors, as well as some areas in the old presbytery, several interior spaces and façades. After that, reparations focused on the floor, the organs and the vaults. (110).
The rehabilitation process of the Old Basílica de Guadalupe is an example of a systematic and responsible activity within the protection of cultural heritage in Mexico. (111).

Figure 111.

Cathedral of Mexico City.

The Cathedral of Mexico is one of the most important buildings of the cultural and historic heritage of our country, and a cornerstone in the legacy of the American Continent. (112).

Figure 112.

Since the beginning of its construction, the building had to face structural problems due to the soil where it was built. Major structural interventions have taken place along the last century.

Works that initiated in 1989 were part of an emergency plan to correct the geometry and to reinforce the structure of the monument. This work has been recognized as an important contribution to the attention of large structures of historical value, and will be showed in this same forum by those who carried out these works.¹

Consolidating the security margins of this monument was a goal reached during early twentieth first century by means of upgrading the soil and structural reinforcement of its foundations. (113-115).

¹ These works were kept under constant review of a Technical Steering Committee made up by: Fernando López Carmona; Roberto Meli Piralla; Enrique Santoyo Villa; Hilario Prieto Calderón; Fernando Pineda Gómez; Jorge Díaz Padilla; José Boyer Orozco; Efraín Ovando Shelley; Roberto Sánchez Ramírez; Agustín Hernández Hernández and Jaime Moreno Cid, chaired by the Director General of Sites and Monuments.
The Conservation Plan was the instrument that lead the actions carried out to protect this complex since 2001, as it was created to look after and carry on the works that had been done years back, as well as to analyze and carry out specific actions that needed detailed projects and sufficient time periods to be thoroughly and carefully undertaken. Interventions done since 2001 took care of a wide range of needs in the buildings and included from major issues, such as the relation between structure and soil, to detailed moulding replacement in reredos. (116-118).

Maintenance and conservation of roofs and vaults in this group of buildings has been an ongoing action. Works of consolidation and restructure of the façades were carried out; atriums and pavements were levelled and renovated; hydraulic, electrical and sewage systems were set up, and gates and elements such as pillars and atrium crosses were as well repaired. The archeological windows built in the south atrium stand out among these works, as they have enabled visitors to observe the archeological remains of the annex buildings of the ancient Cathedral. (119-121).
One of the most notorious works within the interior of the monument was the renovation of the floor in the Cathedral; precise wearing away tests had to be done in order to select marbles that substituted the former ones. (122-123).

Towards the end of 2007, restoration of the towers initiated, starting at the finish of the cross and sphere in the East Tower, which were designed and constructed by José Damián Ortiz de Castro in 1791.

While working in the inside of the sphere, a lead “Time Box” with the inscription: “May 14th. 1791” was found in the bottom of the lower hemisphere. Inside of this box, there were silver coins, golden medals, reliquaries and eighteenth century engravings. (124-125).

Another outstanding restoration work was the one carried out for the King’s Reredos\(^2\). This has been a major piece of work within the architectonic, symbolic and artistic organization of this religious building over 300 years. (126-128).

The upper shell on the roof was also reinforced. Central and lateral galleries, lateral reredos, and the main estípite\(^3\) or tapered columns were renovated.

\(^2\) A sculptural wall decoration at the back of an altar.
\(^3\) Square or rectangular columns wider in its upper part.
The successful completion of these restoration works was due to the joint collaboration of human and financial resources between the governments of Mexico and Spain, based on a Bi-national Cooperation Agreement, with the participation of the National Institute of Anthropology and History and the Spanish Institute for Historical Heritage. (129).

The monumental organs in this religious building are another piece of furniture with utmost artistic value, and were thus restored not only on the outside, but its instrument was renovated in Barcelona, Spain by Gerhard Grenzig’s studio. (130-132).

It is worth mentioning that smoke detection and CCTV (Closed Circuit TV) systems were installed inside the Cathedral, as well as an outside monitoring center. A substation was also constructed and an emergency power plant was set up. New power supply lines were connect-
ed to the electricity company in medium voltage, with their corresponding meters. This latter has benefited energy saving and will lower expenditure. (133-135).

![Images of electrical equipment]

Figures 133-135.

Although structural stability has been achieved, precision levelling and continuous monitoring have been ongoing concerns.

Finally, we must say that in order to guarantee the future decorous conditions of this heritage, it has been necessary to keep up-to-date regarding technology, as well as to carry out precise historical research before any restoration action takes place.

This being said, conservation of the Cathedral has meant a long term and permanent commitment that Mexicans are willing to keep. (136).

![Diagram of the Cathedral of Mexico City]

Figure 136.

4 STATE-OF-THE ART.

During the last three decades, there has been an increasing interest in the conservation of historic monuments; methods have consolidated, techniques have refined and the new developed solutions have exceeded the former ones.

Two major events have led the way: the first one was the great magnitude 1985 earthquake which, in spite it did not have a particularly destructive impact on the massive historic monuments in Mexico City, did leave an imprint and, over all, much concern. Earthquakes, such as those that happened in 1976 and 1991, had much greater effects on the built heritage within other parts of the country. The second major event was that of the conservation works carried out in the Cathedral of Mexico and specifically, yet not exclusively, the ones made for its geometrical correction.

We must as well point out the credibility a new standpoint has earned regarding the fact that the permanence of historic buildings constructed before steel was used, are resistant due to its shape. Hence, the stability and the conservation of the buildings’ equilibrium system are fundamental qualities of which their structural behavior and its permanence depend on. This is to say, the renewed value of geometry and proportion.
We may say that, nowadays, we have a well proved and assessed panoply of procedures that engineers and architects use with full knowledge based on successful experiences.

The following is a brief overview of the methods used to tackle structural challenges of historic monuments nowadays.

**Interventions:**

State of the Art interventions can address the subsoil, the foundations or the superstructure of a monument.

**Interventions in the subsoil.**

Among these kind of interventions, the sub-excavation is the one that has the objective of partially or completely levelling back a building.

The sub-excavation technique is a method used to counteract uneven settlements and reduce the sinking phenomenon of buildings. In the Cathedral of Mexico, this technique included a very significant operation that consisted in extracting soil from the less sunken areas. According to information provided by Enrique Santoyo, 32 concrete shafts were built beneath the basement level from where 4,220 cubic meters were pumped in order to diminish the difference in level from 2.42 m to 1.64 m. (137).

![Figure 137. Subexcavation in the Cathedral of Mexico.](image)

This method has proved its effectiveness in buildings such as the Pocito Chapel, San Antonio Abad, the Cathedral of Mexico, as well as in various modern buildings in Mexico City.

Strengthening soil in order to increase its capacity by means of injections or, nowadays, with inclusions, are both valid and dependable systems that have proved to be efficient.

Soil has been strengthened injecting mortar in several buildings such as the Cathedral of Mexico during its geometrical correction stage, in the Fine Arts Palace, in the front area of the National Palace, as well as in the Santo Domingo and La Santísima churches, and more recently in new buildings of concrete structure. (138-141).
Intervention in foundations.

The technique of control piles with casing was an invention developed by Enrique Santoyo. This method prevents the negative friction to take the effect of the piles when reinforcing foundations with the purpose of avoiding or reducing subsidence consequences.

This system was recently used to strengthening the areas of the Mariano courtyards at the National Palace. (142).
Micro piles, which first appeared in Italy during the 50’s, have the purpose of reinforcing foundations. In most cases, they are set diagonally, starting from the masonry foundations, with highly effective systems to increase contact area.

Micro piles have been increasingly used to strengthen the foundations of historic buildings such as the Old School of Medicine, the Old Corpus Christi Convent, and the Del Carmen church in Celaya, among other monuments. (143 -145).

Reinforcement of foundations with linear concrete elements joined firmly to each side of the masonry foundations is another technique that has proved to be highly efficient.

This system enables to increase the foundation’s section as well as its rigidity without altering it. La Conchita chapel restoration included this method. (146-148).

Interventions in the superstructure.

Walls and columns.

Consolidation by injecting mortar with fine aggregates is the most commonly used method for walls and columns. (149-150).
Floor and roof systems.

In several damaged roof systems, we have substituted one steel beam in place of a wooden beam, for example, one steel beam in four wooden beams.

On the other hand, positioning of hidden steel ties in the flooring system in order to bind the opposite end walls, has also been a technique with which we have been able to recuperate the original use in several historic buildings. (151).

Vaults and domes.

In the case of cracks in vaults, the most important issue is finding out what caused it, in order to try to repair it. If the crack is there because the material has given way, traditional methods such as injection or reweaving to consolidate the structures are used. In critical cases, we have proceeded to place ties.

In the very frequent cases where ascending cracks in domes appear in the areas subject to tension stresses, traditional methods are used. These consist in placing tension rings cased in concrete elements or carbon fiber strips in the lower area of the domes. The former solution proved its efficiency in the chapel of the College of San Pedro y San Pablo as well as in the Cathedral of Durango. The other option was useful in La Conchita Chapel in Coyoacán, an eighteenth century monument in Mexico City. (152-154).
Inclusion of reinforcement elements.

Some variations in the conditions can cause the masonry to be subject to traction efforts that it may not resist and therefore, it might be necessary to use steel reinforcements that take hold of these efforts.

A notorious example of this technique was the binding of the Cathedral of Mexico’s lateral crossing façades, by inserting stainless steel bars above the cornice with anchorage systems at the end hidden in sections of the stonework, within cylindrical perforations of up to twelve meters long. This was an initiative of A. Meli and R. Sánchez. (155-158).

Steel structures.

There is a significant amount of steel structures, constructed in the last decade of the nineteenth century and early twentieth century, such as markets, theaters, train stations and some churches. These buildings are currently needing major conservation works which include cleaning, passivation to avoid oxidation, local reinforcements and roofing sheets renovation. (159-162).
Introduction of contemporary elements.

In specific conditions, practice and regulations allow the incorporation of contemporary elements or complete sections to an old building or group of buildings. However, this needs experienced profession and talent.

Two examples of the aforementioned are the inclusion of a steel spiral staircase in the Museum of Popular Art and the extension made to the courtyard of the Old San Pablo Convent in Oaxaca. (163-164).
Ongoing projects.

**Annexes to the Old School of medicine: Conservation of a work of art.**

The magnificent Complex of the Palace of Medicine is one of the most representative historic buildings of the UNAM (National Autonomous University of Mexico). It accommodated the School of Medicine during one century, though it was constructed to house the Holy Office of the Inquisition during the Vice Regal period. (165).

![Figure 165.](image)

In order to guarantee the safekeeping of UNAM’s Heritage, the School of Architecture of this University was asked to work on an architectural restoration project of the annexes to this Palace, known as the “Escuela Secundaria” and the “Protomedicato”. (166).

![Figure 166.](image)

The historical background of this Complex dates back to 1569 during the Inquisition in New Spain, although the construction of the Palace as it is now dates from 1732-1736. Further, in 1854 the main part of the Palace was adapted to house the School of Medicine.
When the third level was demolished in 1968, the Palace recovered its original proportion. In 1982, all the buildings and houses that belonged to this Complex were destined to the service of the UNAM. (167-169).

Throughout the years and the several usages and modifications the “Escuela Secundaria” and the “Protomedicato” had, many of its original proportions and constructive materials suffered significant alterations that had as a result, among other issues that the load-bearing capacity and the mechanical properties of walls changed. Many areas of the buildings lost their original features when they were adapted to fit the needs of the new spaces. On the other hand, several low-quality interventions were made in an attempt to recover the formal appearance of façades. (170-171)

In addition to deterioration due to abandonment, lack of maintenance caused serious damage to structural wooden elements that lost their load-bearing capacity, suffered deformations, and so on and so forth. Some structures collapsed and minor details like loosening of paint and plaster left naked walls liable to humidity and saltpeter. (172-173).
Further, as drainage systems were unattended, there were floods that contributed to the appearance of parasitic flora whose roots broke up the materials of the walls and increased deterioration of the whole structure. (174-175)

Rehabilitation project.

Preliminary works included stratigraphic and structural test cuts in walls, floors and roofs. Non original materials in walls were removed and preventive shoring was carried out in areas which had a high risk of collapsing. (176-181).

After carrying out serious and detailed studies, the main façade foundation was reinforced by means of micro piles. Up to 28 meters perforations at both ends of the façade were made, then tubes were introduced, the reinforcement was prepared and finally, concrete was cast. (182-187).
Intervention inside the building initiated by repairing and demolishing non-original elements and extremely damaged aggregates in walls and mezzanines as well as in some flat roofs. (188-190).

Original stone walls were duly consolidated and re weaving masonry works were carried out in highly damaged areas with disintegration of materials. Fissures and cracks were injected. (191-196).
On the other hand, wooden beams in severely damaged mezzanines were restored and kept as testimony of the original constructive system. Conditions of each one of the beams were evaluated; some of the most damaged parts of several of these were cut and then returned to their original place, once the layers affected by woodworm were duly protected with the appropriate methods. As for the beams that lost their usable length, the hook-and-butt joints system was carried out before being able to place them back into their original position. (197-202).

To replace the collapsed mezzanine systems, IPR metal beams were placed in between the restored wooden beams, so the metallic ones bear the structural load. (203-205).
One of the stone columns of the “Escuela Secundaria’s” courtyard that was completely fractured was substituted with a new one with identical proportions and design. However, and in order to guarantee more resistance than the original one had, this new column was constructed with “chiluca” stone, which is a much more resistant material than the former one. (206-208).

During one of the multiple remodeling that the “Escuela Secundaria” building suffered, probably towards the end of the nineteenth century, two dividing walls were constructed in the first level. These did not meet with any wall in the first floor and were only supported by three wooden beams each. These latter had given way due to the weight of those walls and, as they bent, significant cracks in the first floor walls of “tezontle (volcanic soft rock) and “tepetate” (tuff), appeared. During the restructuring works, and as part of the substitution process of mezzanines in this gallery, these wooden beams were replaced by other IPR beams which bear the load of the walls in addition to being part of the group of beams that supported the steel-deck of the whole gallery. (209-211)

Walls had to be supported with an ingenious system created by the group of experts of the Engineering Institute of the UNAM. (210-214).

Non-original concrete mezzanines were demolished. Due to their excessive thickness, these mezzanines were tearing apart the walls in the main façade as well as in the interior one. In order to recover their use, these are being substituted by free-standing mezzanines of steel structure not attached to the original walls. (212-214).
As for the “Promedicato” building, cracked *voussoirs* in the central gallery were replaced and the arches were consolidated. A propping up system towards the nearby façades was a preventive measure prior to these works. The stone column in the interior façade was also reinforced and a new foundation was laid. (215-217).

![Figures 215-217.](image)

Further, corridors at the courtyard of the *Protomedicato* are currently being replaced with steel beams and glass. (218-220)

![Figures 218-220.](image)

Restoration works will be carried out in mural paintings in the staircase of the “Escuela Secundaria” building, plastering and wood panels of the decorated halls, carpentry of gates and doors, stonework in hallways and frames, as well as ironwork handrails of several periods in both buildings. (221-223)

![Figures 221-223.](image)

The main façade will be completely restored and all pertinent systems and architectural finishing will be concluded in order to provide the buildings with their new needs regarding academic and research activities, while recovering the magnificence they had in former times.
The old spinning and weaving mill in San Luis Apizaquito, Tlaxcala: From mill to Center for the Arts.

The first mill in San Luis Apizaquito, Tlaxcala, dates back to 1560. The spinning and weaving mill was established in the site and started to work in 1899 with only ten looms and ended working with 300. (224)

This mill closed definitely in 1961. In 1970, it was remodeled to allocate a familial residence. In order to make this place serve as a residence, some of its façades and architectonic spaces were altered, example, many original cast iron columns were covered with brick in order to give them a more rustic image. (225-226).

The building had as well several damages due to abandonment and lack of maintenance, thus, parasitic flora, humidity and filtrations were found. Moreover, part of the construction had lost wall coatings, mezzanines, and roofs. Some wooden beams and planking were also damaged. (227-229).
Constructive systems.

A detailed diagnosis showed the several types of constructive systems the building had. This served as a guide as to what the best intervention methods should be in order to protect the structural and historic integrity of the building. (230-231).

Figures 230-231.

Intervention.

In general terms, wall coatings were lost. Therefore, and in order to recuperate the composition and original structural work of the bearing walls, most of them were liberated from damaged material and consolidated by means of similar stone; cracks were injected with lime grout. (232-233).

Figures 232-233.

For the intervention in two different systems of roofs and floors, wooden beams and Catalan timbel vaulting were used. Wooden beams that could be recovered, were treated and revitalized with appropriate products. The hook-and-butt joints system was carried out in the beams that lost their usable length, and then placed back in their original position.

The wooden beams were replaced and kept as testimony of the original constructive system, and steel beams of a similar section were added in between. These latter are the ones that bear the structural load. A new planking was placed above the beams. On a case-by-case basis, these planking had the same characteristics such as the original one, or was made of clay squares. In all cases, a lightweight reinforced concrete compression layer was added. (234-236).
As for the Catalan timbrel vaulting ceiling systems with steel beams, the fill that made up the system and which had severe damages due to humidity, was substituted with a lightweight concrete layer with electro welded wire mesh. It is worth mentioning that shear connectors were welded to the upper flange of the beam, in order to increase the system’s load capacity. The clay finishing was renovated to restore the original image of the roofs in the whole complex. (237-244).
In the case of the covered columns, test cuts were carried out to find out if all the existing elements had casting columns. Once this was verified, these modules were liberated from the material they had been covered with in order to recuperate the original image of the mill and show the great beauty of these capitals. (245-246).

Metallic elements such as columns, beams, rails and tension rods were cleaned, passivated, and stabilized to prevent further corrosion caused by lack of maintenance and humidity. These will not be painted in order to show the original material and its characteristics. (247-248).

This is how what once was a weaving and spinning mill, will now be the Center for the Arts in Tlaxcala, which will be the most representative cultural space of the State, offering spaces with new technologies in accordance to the cultural historic process of development on education and specialization regarding art and culture. (249- 253)
Figures 249-253.