

STRUCTURAL EVALUATION OF HISTORICAL BUILDINGS USED AS A MUSEUMS IN TOLUCA CITY.

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ABSTRACT :

As part of the rescue of historical buildings in Toluca's Municipality program, the State of Mexico Government developed a historical building restoration plan. This program contemplates house buildings constructed from the 18th century to beginning of the 20th, with special cultural value. At present these buildings are destined for thematic museums.

In the present work the buildings structural evaluation is reported, which contemplates the construction classification according to its architectural and cultural value, the structural safety review both for gravitational actions and lateral seismic effects.

The evaluation process contemplates architectonic and cultural classification, as well as their structural evaluation and maintenance programs. For the structural evaluation the following stages were contemplated: Summary of geometric information, materials properties evaluation, gravity loads and seismic evaluations. The seismic building performance was estimated from base shear acting and resisting relation.

KEYWORDS:

Historical building, Toluca's Municipality, Maintenance programs.

1. INTRODUCTION

Toluca City, was founded in 1522, the constructions were based on the Toluca's Portales and houses around San Francisco Plaza. In this town, two kinds of architecture tendencies in historical buildings were identified, the first of them is the Colonial school and the second one is the Neoclassical tendency, in the first classification are contained religious buildings as churches for example: El Carmen and La Merced Churches as well as San Francisco Convent which only preserves the Capilla Exenta.

In XIX century the richest people were built their houses in Toluca's downtown even their haciendas were far away from there, this events gave to Toluca a Neoclassical French style.

Unfortunately the houses of neoclassic style have been disappearing as modernizes the city, giving passage to modern constructions. Today we can not say that Toluca maintains a defined architectural style, now is a mixture of historical and modern constructions.

A Toluca's typical house is described as a façade with columns and capitels in doors and windows, inside a big central open place and around there lines of rooms with front corridor, some of them used to have a interior garden with a central water fountain.

As part of the rescue of historical buildings in Toluca's Municipality program, the State of Mexico Government developed a historical building restoration plan. This program contemplates house buildings constructed from the 18th century to beginning of the 20th, with special cultural value. At present these buildings are used as thematic museums.

This effort is coordinated by the Instituto Mexiquense de Cultura whose actually is coordinating 27 museums from a total of 60 located in the entity. From these 27 museums, 16 are catalogued as historical buildings but only 8 of them are located in Toluca's downtown.

As a part of the collaboration agreement between the Institute Mexiquense de Cultura and the Research center in Structural Engineering of the Faculty of Engineering of the UAEM, the structural evaluation of the following buildings were developed: Watercolor Museum of the State of Mexico, Museum Felipe Santiago Gutiérrez, Museum Jose Maria Velasco and the Workshop Museum Nishizawa.

This collaboration project includes the description of each building, focused in historic information, structural system, geometry description, and modification and restoration works. Finally the evaluation of material deterioration and structural safety estimation were conducted.

2. DESCRIPTION OF THE ANALYZED BUILDINGS

2.1.- *Watercolor Museum of the State of Mexico*

The property is located on the Melchor Ocampo 105 Street, in Toluca's downtown, this is a one level structure, except for a small portion of two levels which is located at the rear of the property, and the construction area is approximately 1.368 m². The construction dates from the first half of XIX century and originally it was used as a house building. (Acosta 2005).

This museum is located within the historical area in Toluca city, and it is surrounded by buildings of great historical significance as well as museums and cultural buildings. For this reason its was acquired by the state of Mexico government in 2002 and it was destined to protect the artistic file of the watercolor museum of the state of Mexico.

According to available records, originally the house had a storehouse, and animal facilities, in the front of the construction, There were located different propose rooms as well as central open place, all of the structural walls were made of adobe on stone foundations. In the left wing, living room and the dining room were located. Inside the house, there were the lobby and the living room, alter the office was the snail and followed the bedroom. At the rear of the house there was a space, which was conditioned as stables. (Acosta 2005).



Figure 1 Architectonic plan, Museum of Watercolor State of Mexico

Within the main facade of the museum the great wood inner door is even conserved with great rings that allow access to the building, as well as headlights illuminating the façade. In its walls can be observed with aluminum

letters in gold color, the name of the museum. The facade is of a single level nevertheless is very high, all this is characteristic of building's construction practice of these time.

The house has a central court according to the colonial architecture. Inner corridors covered by roofing tile over wooden beams, supported by very thin columns that; interior wooden doors and windows with bevel glasses that they give inwards views with very high ceilings.

The rear part of the house is different in terms of its architecture, because in this part, there is a wood construction with roofs that served as stables in other times. This area is totally different from the construction overlooking the main access; one of its characteristics is the use of the lancet arch in its Windows.

2.2. *Felipe Santiago Gutiérrez Museum*

The structure is located on the Nicolás Bravo Nte. 303 street, in downtown Toluca City, it was originally designed as a house building; the construction has two levels and a construction area of approximately 1200 m².

This house, constitutes one of more notables architectonic monuments of the city, says that it was constructed at the end of century XVIII, (Acosta 2005). It served as house until December 1897, when it settled down like asylum of paupers; from 1929 to 1942 one became a neighborhood: from 1942 to 1969 it lodged a nursing home. The house was occupied as a student's house, from 1969 until 1978, when it was occupied by the religious congregation; from 1979 to 1987 it remained idle, the same year it was bought by the State of Mexico Government. (Acosta 2005).

Once acquired by the government, the house was adapted to function as the Numismatic Museum, which opened in 1987 and ceased its operation in 1992. On December of the same year the museum was inaugurated again. (Acosta 2005)

Like most artistic expressions of the nineteenth century, museum architecture is dominates within the current eclectic, which in turn brings together various architectural inclinations.

Inside the building, presents the central courtyard around corridors, which give access to the various rooms, These rooms communicate with one another, it is surrounded by thirteen arches supported by pillars decorated in metallic shaft and capital. Also, there are twenty arches of three centers, which rest on pillars; among the upper arches of the aisle are located wrought iron handrails on the wall of the west side there are six decorative arches of half a point to reasons for simulating stucco arches. In the rest of the building there is a more uniform design and sober. (Acosta 2005)

The facade of the museum is two levels and its composition tends to symmetry, there are 14 different shapes that meet some decorative functions and developed in mud, which reflect fruit and floral motifs. At the first level there are two wooden doors, windows have regular and ornate lintel. At the top of the building, there are iron balconies. (Acosta 2005)

There are many changes made in the nineteenth century. Some of its architectural details in the interior were made in its latest reshuffle that took place in the building, which was in the year 1987, to create the Museum

Several maintenance works were conducted in this property. The house was rebuilt respecting its original architectural structure, as well as construction materials, which can be seen in most of its extremely wide adobe walls.

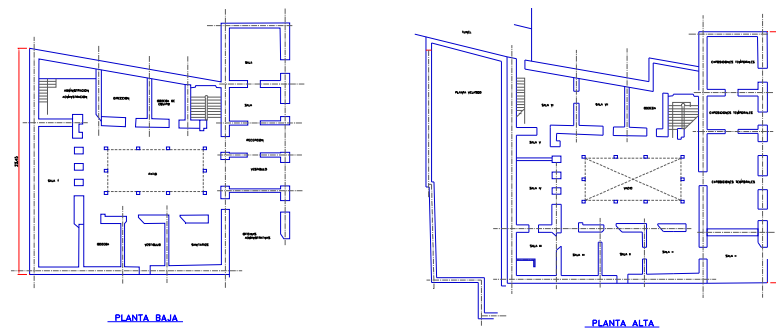


Figure 2 Architectonic plan, Felipe Santiago Gutiérrez Museum

2.3. José María Velasco Museum

This museum is located in Toluca's downtown in a flank of the Civic Plaza, the address is Av. Lerdo de Tejada No 400, and. Nicolás Bravo. It has two levels and a floor area of 1400.0 m².

This building has had various functions and since its origin in the eighteenth century and early nineteenth century, has undergone multiple renovations, it represents one of the most beautiful houses in the city of Toluca, originally was a home, subsequently in 1942 an Academy for ladies was founded, finally in 1992 the State of Mexico rescues for lead to the Museum Velasco.

In addition to artistic value that represents this construction, also has a historical value because was visited by the priest Miguel Hidalgo y Costilla on October 28, 1810 (Acosta 2005) in its passage through Toluca for the Monte de las Cruces.

The changes that have been made to the building have not been very significant, most changes have been adjustments to the museum and maintenance, in addition to having conducted a restoration of the whole building.



Figure 3. Interior view, José María Velasco Museum

The museum facade is designed at two levels, the top presents a cornice with Greco Roman elements, the span has escarzados arches, stone threshold and balconies with iron handrails forged with floral reasons, in the ground floor rectangular spans are presented including threshold and key of wrought stone and wood inner door.

This structure has 10 rooms, which are distributed in order to have circulation and thematic sequence. Inside the building there is large courtyard with corridors that allow access to rooms and a continuous movement, on the first floor corridors with wrought iron handrails exists that communicate to each showroom. Floors inside rooms and corridors are of floor mud in the central courtyard its floors are laja stone. The doors throughout the complex are wooden double discouragement.

The courtyard is covered with a dome, the columns around this are circular and made of iron with laja stone.

[illegible]

Actually the ancient wooden doors are conserved as well as the paved floor until the central courtyard, the corridors of the ground floor and first floor are made of mud floor.

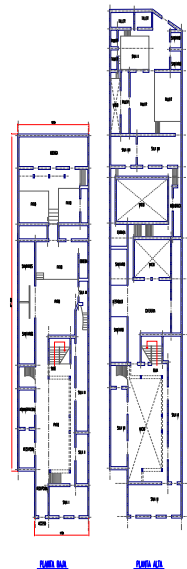


Figure 5 Architectonic plan, Nishisawa Museum

3. STRUCTURAL REVIEW OF BUILDINGS

Although these buildings have undergone several changes throughout their history, they all kept the original structural system, and only have been restored materials and elements that have submitted damage or loss of its structural capacity.

For the structural review of buildings were taken into account the following considerations: The walls are built in its entirety based Adobe, jointed with soil and brick mortar. The foundation is formed by a stone masonry jointed whit soil mortar, which follows the ground inclination. The thickness of the walls is variable, according to the time of construction and it was determined by field measurements.

The roofs are formed by a roof system consisting of wooden beams of 10 x 20 cm, tejamanil (thin wooden plates), and filling of earth with variable thickness to give outstanding drainage and finally mud tiles cover.

In the other slabs, there are two systems: the first one consists of 10 x 20 cm wooden beams with tejamanil and filling of earth, which supports a terrazzo mud, 28 x 28 cm, with a 4 cm thickness. This system is used in all the corridors outside and in some rooms.

The second system, used in some of the rooms located on the mezzanine floor consists of a 10 x 20 cm wooden beams system, supporting a wooden board. Table 1, shows the value of the dead and live loads employees in the review of the structural system.

Table 1. Considered loads in the structural review

Load		Roof		Weighty Slab		Light Slab	
Dead Load		3.0 KN/ m ²	300 Kg/ m ²	2.1 KN/ m ²	205 Kg/m ²	3.0 KN/ m ²	205 Kg/m ²
Live Load	Maximum Intensity	1.0 KN/ m ²	100 Kg/m ²	2.5 KN/ m ²	250 Kg/m ²	2.5 KN/ m ²	250 Kg/m ²
	Instant Intensity	0.7 KN/ m ²	70 Kg/m ²	1.8 KN/ m ²	180 Kg/m ²	1.8 KN/ m ²	180 Kg/m ²

Due to the restoration works conducted in all of these buildings, and its adequate maintenance works, we can

consider that there is no significant deterioration in the material in the whole structural system. This supposition is based in the fact of the replacement of damaged materials or elements, as wood elements and some sections of walls. For the foregoing, it is considered the typical mechanical materials properties, without impairment reduction.

The mechanical properties of adobe were obtained from the adobe pieces and scale walls tested in the laboratory. For handmade adobes from Toluca Valley region, the following properties are considered:

Table 2 Adobe Mechanical Properties

f^*m		E		v^*		G	
0.4 Mpa	4 Kg/cm ²	130 Mpa	1325 Kg/cm ²	0.05 Mpa	0.5 Kg/cm ²	17.5 Mpa	1783 Kg/cm ²

The wood elements were classified as B Class according to the NMX-C-239 official Mexico norms. The mechanical properties of the wood elements are presented Table 3.

Table 3 Wood mechanical properties

Elasticity modulus				Bending stress (ffu')	
E0.50		E0.05			
7848.0 Mpa	80,000.0 Kg/cm ²	4905.0 Mpa	50,000.0 Kg/cm ²	9.8 Mpa	100 Kg/cm ²

4. WALLS REVISION

The security level for the adobe walls was estimated as the ratio of nominal allowable stress that supports the material between the nominal acting stresses. The review focuses on the compression stress in walls, caused by gravitational actions as well as shear stress generated by earthquake actions; also bending moment slab system capacity is checked.

The vertical acting load on each wall was determined by its tributary areas, considering the floor as unidirectional system.

For lateral loads, the earthquake actions, were identified through a static analysis, determining the wall force proportional to its cross section area. For the seismic analysis, The seismic coefficient of $c = 0.2$ was used, (Ramirez 1996). Table 4 summarizes the most important physical characteristics for each structure and Table 5 summarizes the parameters considered for revision.

5. FLOOR SYSTEM REVIEW

The floor system review was made by comparing the acting nominal bending moment between resisting bending moment, The calculations were made for maximum span and considering 35 cm and 40 cm beam separation for intermediate slab and roof slab respectively. Table 6 presents the results of this analysis.

Table 4 Physical characteristics of buildings

	WATERCOLOR MUSEUM	F. S. GUTIÉRREZ MUSEUM	J. M. VELASCO MUSEUM	NISHIZAWA MUSEUM
Construction period	First half century XIX	End of century XVII	Century XVII	End of century XVII
Surface of construction	1368 m ²	1200 m ²	1400 m ²	1707 m ²
No. of levels	1 Level	2 Levels	2 Levels	2 Levels
Total weight	15865.6 KN	24023.4 KN	22499.5 KN	43260 KN
Unitary weight	11.6 KN/m ²	20.0 KN/m ²	16.1 KN/m ²	25.34 KN/ m ²
Area of walls	162.4 m ²	147.37 m ²	129.8 m ²	281 m ²
Density of walls X	0.05	0.05	0.06	0.07
Density of walls Y	0.066	0.07	0.04	0.09

Table 5 Review parameters of the buildings

	WATERCOLOR MUSEUM	F. S. GUTIÉRREZ MUSEUM	J. M. VELASCO MUSEUM	NISHIZAWA MUSEUM
Maximum nominal compression stress (f_{\max})	0.05 Mpa	0.08 Mpa	0.09 Mpa	0.07 Mpa
Maximum nominal shear stress (v_{\max})	0.011Mpa	0.012Mpa	0.01Mpa	0.009Mpa
f_r / f_{\max}	8	5	4.4	5.7
v_r / v_{\max}	4.5	4.1	5	5.5

Table 6 Review parameters of the buildings

	WATERCOLOR MUSEUM	F. S. GUTIÉRREZ MUSEUM	J. M. VELASCO MUSEUM	NISHIZAWA MUSEUM
Maximum Span	5.0 m.	4.5 m	4.75 m	5.2
Nominal resistant moment (Mnr)	6.6 KN-m	7.5 KN -m	7.5 KN -m	7.5 KN - m
Nominal acting moment (Mna)	4.4 KN-m	4.0 KN - m	4.5 KN - m	5.3 KN - m
Mnr / Mna	1.51	1.88	1.69	1.4

6.

CONCLUSIONS:

The historic buildings are an important cultural heritage of the whole society, thus assess their structural safety is an essential aspect to preserve them.

From the physical inspection conducted in the four structures presented, it appears that their conservation status is good and existing materials retain their original properties, the damaged materials have been replaced by materials similar to the originals.

Due to the structural features of the system used in this type of construction, resistance to gravitational actions is appropriate and does not represent a risk to global stability, but special attention should be paid to the walls that were changed, particularly when it reduces its cross section dramatically.

The lateral capacity in all the structures is suitable, There are not observed problems concerning the overall capacity of the structure, however it is anticipated that there may be vertical cracks at the intersection of orthogonal walls because the floor system does not form a rigid diaphragm.

The floor system capacity against gravitational action is certainly an aspect that should be monitored continuously, because the resistance of the system slightly exceeds the solicitations. It should be noted that this material change mechanical properties as a function of their deterioration status

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