

STRUCTURAL STRENGTHENING OF A TRADITIONAL ADOBE HOUSE IN CHIAPA DE CORZO, CHIAPAS

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ABSTRAC

This research paper presents an alternative to structurally reinforce the traditional houses of adobe from the historic town of Chiapa de Corzo, Chiapas, Mexico, with the purpose of increasing its seismic resistance capacity. Strengthening works were carried out in 2 houses of adobe, which were selected by the serious structural problems that record; also inhabited by low-income families, bedridden by their social status to make improvements to their homes.

In the development of the proposal was sought that it was economic, retain as much as possible the assets of origin and functional spaces, in addition, to improve the structural safety of the houses of adobe and ensure the safety of the people who inhabit them.

In a second moment, is scheduled to be aceleromtrica instrumentation to measure periods of fundamental vibration of operated dwellings. Thus the evolution of earthquake-resistant capacity will be evaluated to ensure that the proposal will serve as prototype of structural reinforcement in other adobe homes.

Also, it's offer a viable alternative to the relevant authorities seek mechanisms or financial funds that allow you to implement a collective strategy of structural reinforcement of houses of adobe in the city of Chiapa de Corzo, that due to its geographical location, is in an area of high probability of occurrence of certain magnitude telluric phenomena.

Keywords: *housing, adobe, reinforcement, structure, safety, earthquake-resistant.*

The historic town of Chiapa de Corzo, Chiapas, is characterized by the cultural richness of its buildings as historical monuments (OJ, 2000), including traditional creole, mestizo and indigenous houses. The buildings form part of a harmonious and pleasant urban architectural ensemble; however, over time the typical elements of the houses have lost their original values due to natural deterioration and neglect. Earthquakes have been the main cause of deterioration, such as the collapse of a significant percentage of traditional adobe houses by earthquakes in 1975, which caused the mass exodus of the population (Ocampo, et al., 2005).

Based on the accounts of major damage to buildings, it has been established that the seismic activity of the region where the city of Chiapa de Corzo is located is inevitable as a result of the subduction of the Cocos tectonic plate under the North American plate (García and Suárez, 1996), which warns the city that with its wealth of buildings and its inhabitants is located in an area of high probability of occurrence of a certain magnitude of earthquakes.

Additionally, the materials used in traditional dwellings: walls constructed of adobe (earth-straw) coated with lime-sand mortar and wood structures that support clay tiles on the roofs, do not guarantee the stability of the building due to the action of dynamic forces generated by earthquakes. The cause of this problem is attributed to poor structural containment of the construction elements.

A significant number of adobe houses have been maintained over time due to repeated episodes of damage and repairs done by the inhabitants, which often modify the original typological characteristics. An additional set of homes have not been repaired due to economic constraints of the low-income families that inhabit them. In this regard, the present investigation aims to develop a proposal for structural reinforcement to increase the seismic resistance of traditional adobe houses of Chiapa de Corzo. It is relevant that s that reinforcement is economical, and that the original design elements are conserved as much as possible along

with the functional spaces and, most importantly, that there is a scientific and technological assessment of the improvements in the structural safety of homes.

The work being done is part of the research project: “Proposal for structural reinforcement for the consolidation of the traditional home of the historic center of Chiapa de Corzo, Chiapas,” funded by PROMEP-SEP (2013); the team of researchers consists of academics from the Autonomous University of Chiapas and the Autonomous University of Guerrero, that form part of the academy of Urban Development (CADU-UNACH) and academy of Natural Hazards and Geotechnology (RNG-UAG), respectively. The beneficiaries of the project are low-income residents of traditional adobe houses, the National Institute of Anthropology and History (INAH) and the Municipal Government of Chiapa de Corzo.

PREVIOUS RESEARCH

In previous years, the researchers conducted a study in the urban area of the city of Chiapa de Corzo, to establish seismic zoning according to the fundamental period of ground vibration. The results allowed us to identify two areas; the first (Zone 1) range from 0.10 to 0.25 seconds and the second (Zone 2) with longer intervals recorded from 0.25 a 0.50 seconds of vibration, located precisely on the banks of the Grijalva River. Measurements were also taken of some behaviors of traditional houses (and Escamirosa Salgado, 2004), (Salgado et al., 2005).

In 2013 the inter institutional task force with the participation of students from the Faculty of Architecture of the UNACH and students of the Academic Unit of Engineering UAGRO, made a diagnosis of the problems of traditional houses located around the historic downtown section of Chiapa de Corzo, considering the type of housing, and social status of low-income residents according to Ocampo Garcia (2003). According to the diagnosis that was made,

2 traditional houses were selected as case studies to determine the structural dynamic properties and their vulnerability in a higher magnitude earthquake scenario by analyzing records of seismograms during the fundamental periods of environmental vibration done on site with acceleration sensors.

In this paper reference is made to one of the selected households, owned by Evangelina Aguilar Montero who noted that the property is more than 80 years old. The property is located in seismic zone 1, between Avenida Miguel Hidalgo and Calle Tomas Cuesta, in the San Vicente neighborhood, with geographic coordinates UTM (498673.62, 1847525.79) and an elevation of 433.78 meters above sea level. Its structure is formed by a stone masonry foundation, 40 cm. thick adobe walls, clay tiled roof supported with a structure of round wooden beams and planks. In the visual structural assessment, serious cracks in the walls and cracks in the corners we observed, which adversely affect the stiffness and cause an increase of the vibration period of the house (Figure 1).



Figure 1. Traditional adobe home owned by Evangelina Aguilar Montero

Subsequently the accelerometer was installed in the house to obtain the necessary measurements to determine the fundamental periods of vibration in the house and in the corresponding soil. According to seismograph records stored in 3 orthogonal dimensions of 30 seconds duration each, and based on the calculations of the Fourier spectra in each record, the transfer function, or spectral ratio was established using the Nakamura technique. The results indicate that the fundamental vibration period on average is high: (. Escamirosa, et al, 2013) at 0.2133 seconds in the soil to 0.1506 seconds for the house(Figures 2 and 3).



Figure 2. a)Installing the accelerometer on the floor, b) Installing the accelerometer inside the house

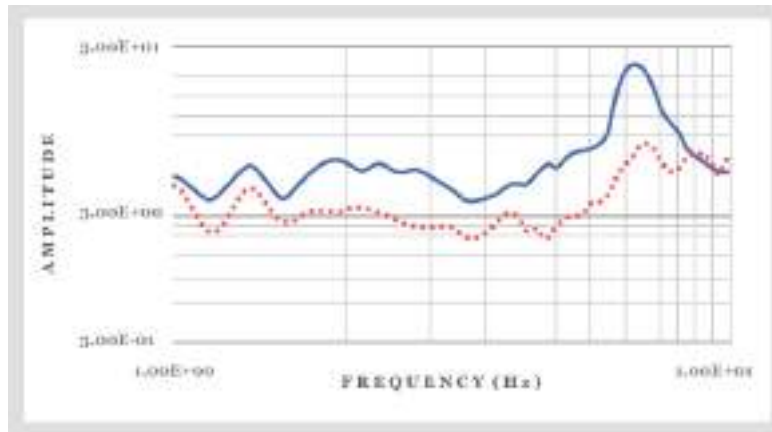


Figure 3. Fundamental period of the house with a vibration of 6.64 Hz that are equal to 0.1506 seconds

PROCESS OF STRUCTURAL REINFORCEMENT (INTERVENTION)

The intervention work began again with the identification of the geometric characteristics of the house, which included sizing and functionality of the spaces, and the conditions of existing structural elements: foundations, walls and roofs. With this, the team developed a proposal for an intervention for the structural reinforcement of the house, based on similar cases analyzed by Arroyo, et al., in 2010. The was immediately followed by a request for authorization by the INAH to conduct the intervention and request a building permit from the municipality of Chiapa de Corzo.

In early June 2014, the necessary materials were purchased to carry out the construction of the structural reinforcement of the adobe house. On Monday June 16th the work began , which was completed in August of that year. The procedure of the construction is described as follows:

1. Removal of doors: Frames and panels of 3 wooden doors were removed carefully to avoid unnecessary damage to the adobe walls.
2. Removal of mortar: On both sides of the existing walls the coating was removed, essentially made of lime-sand (Figure 4).



Figura 4. Removal of the existing mortar on the house

3. Cleaning and wetting of walls: before applying new mortar work.
4. Application of the first layer of mortar: cement-sand mortar was used with 1: 3 to cover the walls, throwing mortar by hand and then, with a wooden trowel spread to a minimum thickness of 1 cm . The mortar was applied according to the original shape of the wall; that is, no vertical leveling was considered for the walls.
5. Placing of steel mesh: On the walls welded steel mesh (6x6 / 10x10) was placed and on both sides were simultaneously anchored with wire anchors and annealed wire. The anchoring was previously carried out by drilling with a 5/16 “drill bit; the wire was placed forming a grid of

1.35 m. and annealed wire at a smaller lattice of 45 cm. Overlaps of mesh sections were performed at 60 cm. (Figure 5).



Figure 5. Attaching the wire mesh 6x6 / 10x10 inside the housing

6. Application of the second layer of mortar: The second layer of cement-sand mortar requires wet walls in order to obtain optimum concrete strength. Like the previous layer, the minimum thickness was 1 cm. (Figure 6).
7. Finished walls: a thin layer of putty produced from cement-lime with a 1:10 proportion was used for the final finish on internal and external walls, like the original caulking on adobe houses (Figure 7).
8. Placement of doors: 3 doors were hung and properly adjusted.
9. Replacement of damaged wood: The wood planks that support the clay tiles were replaced by 1 “x4” pine planks.



Figure 6. Application of the second coat of cement-sand mortar



Figure 7. Lime plaster with cement

10. Application of final finishes: The color of the paint on the walls and the roof structure was selected based on the type of the traditional houses in Chiapa de Corzo. The floor of the house was improved with 30x30cm ceramic tile.

On July 15, 2014, the research team decided to structurally reinforce another adobe house, located on Calle Tomas Cuesta No. 80 in the same neighborhood of San Vicente, whose owner Reyneria Moreno Cuesta said that it had been built by her father over 70 years ago. The house was built on a stone masonry foundation, with 38cm adobe walls on the main facade and 30 cm. on the rear façade. One of the walls butted against the fence that borders the neighboring dwelling. The walls were not coated with mortar, and had only a precarious layer of lime on the main facade that has served to keep the mud from the outside environment. The cover is constructed with clay tiles supported by a frame of round wood beams and planks (Figura 8).



Figure 8. Traditional adobe home of Reyneria Moreno Cuesta

As in the previous case, the conditions of the structural elements in the home were analyzed and it was observed that due to a lack of coating on the walls, the adobe had been exposed to climatic variations over many years, which has resulted in adobe in very poor condition. There were also serious structural problems found in the walls, cracks were observed, inclination (unplumbed)

and cracks in the head walls with interceptions in the main and rear facades. In the roof structure, two rotten round wooden beams were identified, and some planks supporting the tiles and the wooden lintel of the door located in the rear façade showed termite damage.

In this house the following actions were performed:

1. Removal of the existing layer of lime.
2. Strengthening the wooden lintel: At the door of the rear facade, an 8 cm. thick wooden pine plank was placed in the bottom of the existing lintel (Figure 9).



Figure 9. Strengthening the existing lintel with a pine wooden plank.

3. Placement of steel mesh (Figures 10 y 11).
4. Removal of the metal doors.
5. Cleaning and wetting the walls.



Figure 10. Attaching the wire mesh



Figure 11. Drilling the adobe to fix the steel mesh

6. Application of mortar: the first layer of cement-sand mortar was placed, ensuring a minimum thickness of 1 cm; After a long enough time for the mortar to set (2

hrs.), the second layer of a minimum thickness of 1 cm was applied., which was smoothed with wooden trowel. Similarly as in the previous housing, troweling was performed according to the level of the vertical walls (Figure 12 and 13)



Figura 12. Application of cement-sand mortar



Figure 13. Application of the cement-sand mortar

7. Inserting the metal doors.

8. Replacement of damaged wood: In the structure of the roof, 2 5 “in diameter round wooden beams and 5 1” x4 pine planks were substituted.
9. The walls were finished with cement-lime plaster.
10. Application of final finishes.

Monitoring and technical supervision of the work in general was done by the members and staff of the School of Urban Development (CADU-UNACH); José Adolfo Pérez Pérez and Francisco Javier Alvarez Roblero of the School of Architecture of the UNACH were also present to assist.

PRELIMINARY RESULTS

According to measurements taken before the structural reinforcement, the adobe house owned by Evangelina Montero had a fundamental period of vibration of the order of 0.1506 seconds, above the range of 0.08 to 0.12 second which is considered structurally sound by Hernandez, et al. (1979). Therefore, it was established that the structure of the house had high seismic vulnerability and therefore a safety risk for its inhabitants.

Regarding the adobe house owned by Reyneria Moreno Cuesta, although it was not analyzed in situ with accelerometers to record their fundamental periods of environmental vibration, due to the severity of structural problems posed prior to its structural reinforcement, it can be inferred that its seismic vulnerability and risk to the safety of the people were greater than the other home.

The structural reinforcement was performed in both houses during the months of June, July and August 2014. Following the completion of this work, it is planned in subsequent months the installation of accelerometric instrumentation to perform an evaluation and determine the new periods of fundamental

vibration. The new measurements made it possible to assess the evolution of the seismic capacity in both traditional adobe houses of the historic town of Chiapa de Corzo.



Figure 14. Result of structural reinforcement in housing.

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