Horizontal displacement of a catalogued house in Mexico City

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ABSTRACT
This paper describes the procedure used to move horizontally a catalogued heritage house in Mexico City. It provides an account of the preliminary actions carried out before displacing the structure as well as the equipment used during the process.

PRESENTACIONES TÉCNICAS
En este artículo se describe el procedimiento utilizado para mover horizontalmente una casa en la ciudad de México. Se explica la preparación previa y las actividades realizadas antes del movimiento de la estructura, así como el equipo utilizado para el proceso.

1 INTRODUCTION

Fondo Hexa is building Torre Reforma, the tallest skyscraper in Latin America, with 57 floors, nine-level underground parking lot basement and a height of 244 m (Fig. 1). The project is located in Mexico City along Paseo de la Reforma in a site with an area of 2788 m2, of which 600 m^2 are taken up by an old house built in the first half of the 20th century; therefore, is classed as national heritage by the Instituto Nacional de Bellas Artes (INBA).

To achieve functionality of the Tower it became necessary to optimize usage of the property area in order to comply with the number of parking spaces established in the building codes. On the other hand, it was also compulsory to leave intact the catalogued house that covers a large part of the job site. The solution was to displace the old house horizontally to release the space needed to build the diaphragm walls that would operate as retaining walls for the building basement and at the same time, take advantage of the area under the house to have a larger number of parking spaces. Upon completion of the diaphragm walls the house was returned to its original site to be subsequently integrated into the project as commercial and entertainment area (Fig. 2).

1.1 General characteristics of the house

The two storied house was built in 1932. It is catalogued by the Instituto Nacional de Bellas Artes (INBA) because of its artistic and environmental value since it represents the European architecture after Porfirio Díaz presidential term; the property style is eclectic and neo-gothic (Fig. 3).

It was built with brick bearing walls with minimum reinforcing steel and its facade is decorated with carved quarried stone; its foundation is based on masonry inverted beams supported by reinforced concrete strip footings at a depth of 1.5 m with respect to the street level. The boundary footings have an average width of 0.90 m and the central footings are 1.5 m width (TGC, 2007).

Figure 1. Torre Reforma (Courtesy of Fondo Hexa)

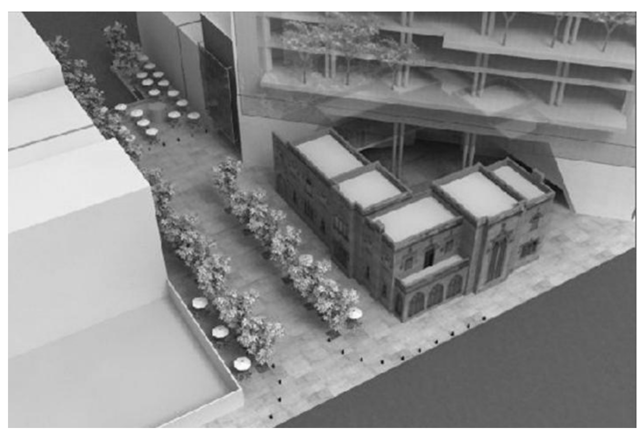

Figure 2. Scale model of the old classed house as part of the project of Torre Reforma (Courtesy of Fondo Hexa)

Figure 3. Detail of the classed house with its original architecture (Courtesy of Fondo Hexa)

1.2 Why to move the house?

Several options were analyzed to optimize the available construction area such as surrounding the house with a diaphragm wall, but this would make useless the area under the heritage house. Taking the old house apart as a jigsaw was also considered, as in the case of the former Pumping House at Tacubaya or the facade of the Palavicini Building, both in Mexico City (TGC Geotecnia, 1990). This procedure would allow using the full area as parking lot; the house would be reassembled in its original location after building the tower's foundation. This idea was not feasible because there was a very high risk of losing the original quarried stone. Another option was to place in the foundation a grid of post-tensioned beams with cables, similar to the solution applied in the cathedral of Montreal (TGC Geotecnia, 1999), but it was discarded because it was a very complicated procedure. Finally, the possibility of underpinning the house with micro-piles was also pondered, including a perimetral diaphragm wall outside of the property limits along the sidewalk of the lateral street of Paseo de la Reforma Boulevard and excavate under the house while the micro-piles and the diaphragm wall acted as supports.

At that time TGC Geotecnia joined the project to carry out the geotechnical study for the tower and to define a suitable underpinning for the old house. During a meeting attended by Arq. Benjamín Romano, designer of the Torre Reforma, as well as by officers from INBA, it was proposed to move the house to release the space to build the diaphragm wall around the perimeter of the property and therefore to use the full site as basement levels for the parking lot; subsequently the old house could be returned to its original position with no damages expected.

The possibility of moving the house to build the diaphragm wall caused a revolution in the original project because not only the tallest skyscraper in Latin America would be built but the most advanced technology was going to be applied to move a catalogued structure without harming it.

Around the world several structures have been displaced from their original locations, among others: buildings in Colombia in 1974 (Páez, 1975) and China in 2004 (Guinness World Record, 2010), a portico in the German city of Leipzig (City Tunnel Leipzig, 2006), and many other buildings in the USA.

In Mexico it is the second structure to be displaced; the first one was moved in 1950 in Guadalajara, Jalisco, where the Telmex building was displaced for widening a boulevard (Crespo, 2010); but the innovation in this case is that it involves displacing an old structure with scarce structural reinforcement.

2 PROCEDURE USED TO MOVE THE OLD HOUSE

In general terms, the procedure to move the house included: a) the house structural strengthening to prevent cracking; b) underpinning the house by means of a foundation slab; c) constructing a foundation for the rails and hydraulic jacks used for the displacement; d) excavating under the house to lift it from the ground to expedite the movement; e) installing sliding equipment (skid shoes); and f) moving the house. Each stage is detailed in the following paragraphs.

2.1 Strengthening the house

Being it a structure built at the beginning of the 20th century, the old catalogued house was quite susceptible to any deformation; therefore, to guarantee the minimum cracking it was necessary to reinforce it structurally and for this purpose turnbuckles and bracing were placed so the few centimeters of deformations expected would not affect the structure.

In addition, some of the internal walls were covered with a steel mesh plastered with mortar and others protected with a reinforced concrete wall (Fig. 4).

2.2 Underpinning the house

During the movement, the house was supported only in two of its ends, with a support separation of 19.0 m approximately. As the house is fragile, the main challenge was to control the deformations that could be experienced with a span of such dimensions. The solution consisted in placing the house on a sort of "tray" with enough stiffness to have only small deformations when the house was lifted and moved (Fig. 5).

This tray underpins the house and is a light-weight slab formed by ribs with a depth of 1.75 m and by other secondary ribs with a depth of 0.8 m, all of them poured in concrete with a strength, f'c= 70 MPa (Fig. 6).

The underpinning slab was also used as final foundation to integrate the house into the project, as well as to confine the original foundation of the house constituted by strip footings.

2.3 Foundation for the rails

The system used to move the house implied the use of hydraulic jacks mounted on rails. The rails had to be supported continuously so the house could slide without vibrations or vertical movements that could harm it. In addition, during the movement the house would be supported only by the hydraulic jacks, therefore transmitting high point loads; for these reasons, it was necessary to build a suitable foundation for the rails to be able to sustain the load concentrations without experiencing differential deformations.

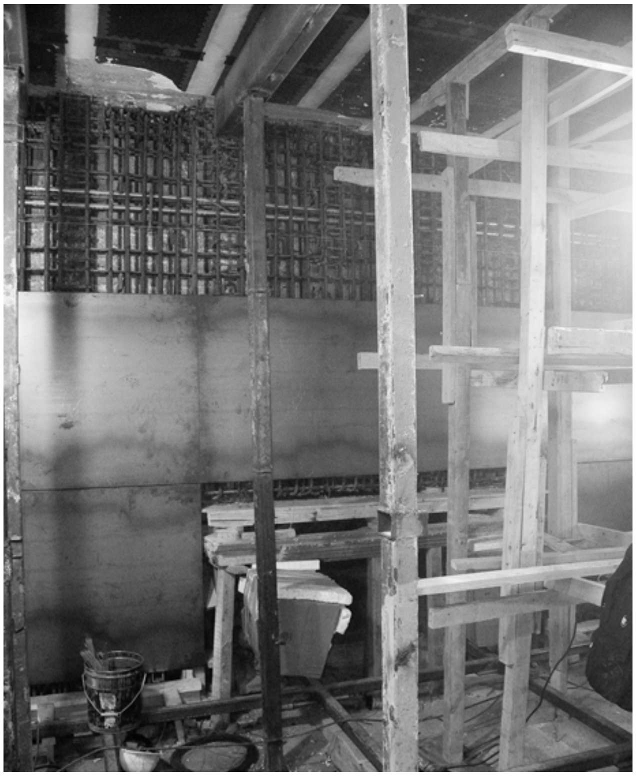

Figure 4. Strengthening of the house with reinforced concrete walls (Courtesy of Fondo Hexa)

Figure 5. View of the house prior to the movement

The tower diaphragm walls were used as supports for the rails. It was also necessary to place steel trusses among some of these walls, at zones where there was no slurry wall because they were part of the architectural and structural solution of the building basement, (Fig. 7).

The diaphragm walls used for the rails had thickness of 0.8 m and 1.2 m, resting at depths of 48.0 and 52.0 m on the deep deposits.

On the other hand, the location of the house prevented an accurate placement underneath of the elements designed to support the rails; therefore, some brackets embedded in the underpinning slab of the house were installed to serve as supporting points for the hydraulic jacks (Fig. 8).

Figure 6. Construction of the ribbed slab for underpinning

Figure 7. View of the truss placed between diaphragm walls after the hydraulic jacks had been positioned

2.4 Excavation under the house

The excavation under the house to separate it from the ground and to release the space to move it, started after completing the underpinning slab.

Initially, the excavation was made under Axes 3 and 4 where temporary hydraulic cylinders were placed to support the house while completing the rest of the excavation (Figs. 9 and 10).

Slopes and diaphragm walls were used as retaining elements to reach the required excavation levels, which ranged from 2.75 to 5.0 m.

Figure 8. Detail showing the hydraulic jacks (skid shoes) and the brackets embedded in the foundation slab

2.5 Placement of the sliding equipment (skid shoes)

Before mounting the house on the sliding equipment the upper part of the diaphragm wall was leveled with grout, to guarantee that the rails were perfectly horizontal. Two rows of modular tracks or rails were then installed, with a total length of 46.0 m per row, approximately. To prevent transversal displacements during the house movement, staggered stops were welded at the sides of the tracks.

Subsequently, six skid shoes were installed, three of them at each axis, as well as a pair of trust hydraulic jacks. The operation was accomplished by pushing skid shoes from the end of the line until reaching their final intended position.

After the skid shoes were properly placed, the jacks were pushed for the first time to support the house on them. Initially contact was made with all jacks placed at Axis 3 followed by those at Axis 4 (see Fig. 9). Subsequently, pressures in the jacks were measured and levels were verified to confirm that the theoretical weight of the house corresponded to the actual value.

To hold the structure, the skid shoes were attached to the foundation slab of the house by means of stops with Hilti type bolts.

The house weight was of approximately 2500 t, was transmitted to the jacks at increments of about 20% of the total weight of the house. Upon reaching 100% of the load, the performance of the whole system was checked and the condition of the structure was inspected at the supports of the sliding equipment to have an assurance that no anomalies had been found.

Subsequently, the house was raised to release it from its temporary supports and to reach the elevation established for the movement. It was lifted 10 cm at Axis 3 and 5 cm at Axis 4, approximately.

2.6 Moving of the house

After releasing the house from the temporary supports, levels were checked and the stability of the structure was also verified. The house was then moved, initially two meters to evaluate if the applied thrust was enough to move the house.

The first sliding took place on February 13, 2010 and it was continued in successive stages of expansion and retraction of the thrust cylinders, advancing one meter at each cycle until completing a total length of 18.0 m of structure movement.

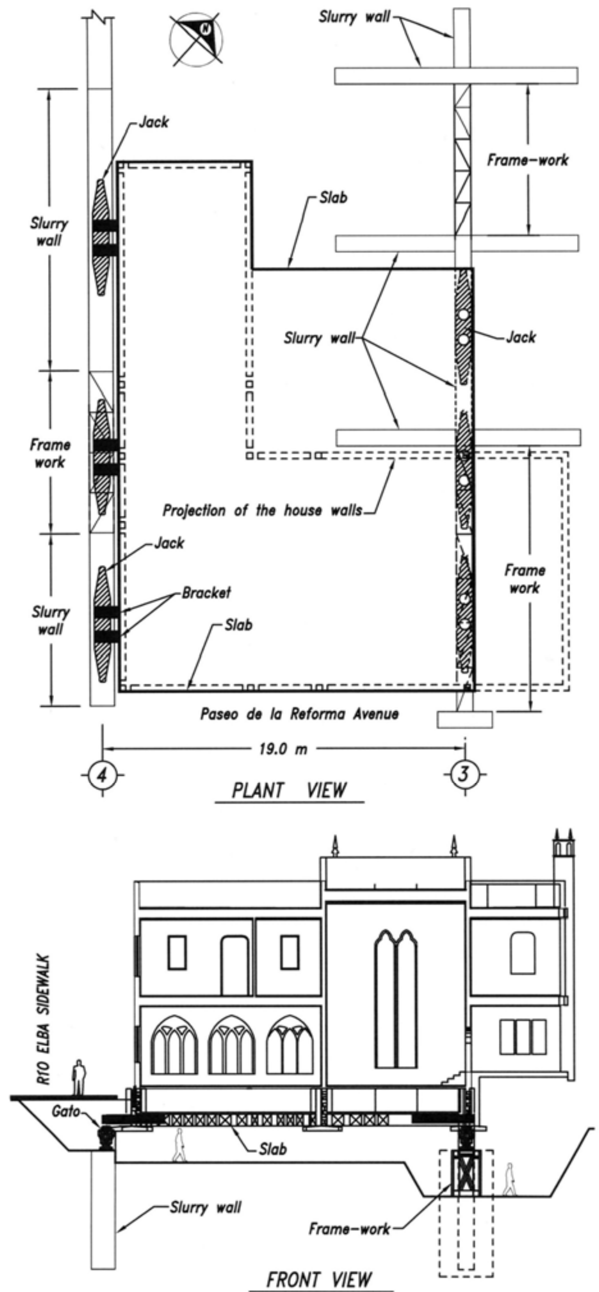

Figure 9. Schematics of the location in plan of the supporting foundation for the rails during the sliding

Figure 10. Panoramic view under the house foundation being supported by the hydraulic jacks prior to its moving

The house remained in its temporary location for two months, which was the time needed to construct the diaphragm walls at the zone of its original position. During this time the house was supported by temporary devices that withstood 50% of the total weight of the house, whereas the remaining 50% rested upon the hydraulic jacks of the skid shoes that were mechanically blocked to prevent any failure of the system. The return movement took place on April 18, 2010 using the same process.

After moving back the structure to its original site, the house was lowered until it was placed over its final supports. The load was gradually released following the same sequence of the loading procedure and checking the activities previously described.

3 EQUIPMENT USED

The equipment used to move the house, as well as the whole procedure was provided by the company ALE Heavylift that specializes in the lifting of heavy equipment such as vessels and nuclear reactors, among others.

A system SKS1000 was used for the movement, which included modular rails and sliding runners or skid shoes (Fig. 11).

Figure 11. System SKS1000 constituted by modular rails and sliding runners (skid shoes)

The six skid shoes placed were distributed between two axes, as shown in Figure 9; these sliding runners supported loads varying from 432 t and 782 t, depending on their location and on the loads transmitted by the structure. Each skid shoe was 5.5 m long and had a total capacity of 1000 t, distributed in two vertical hydraulic cylinders with an individual capacity of 500 t and a stroke of 30 cm each.

Four thrust hydraulic cylinders SS500 placed along two rows of rails supported by the skid shoes with an individual capacity of 64 t were used to supply the movement force (Fig. 12).

Figure 12. Detail of one of the thrust cylinders SS500

4 COMMENTS ABOUT THE MOVEMENTS

During the whole sliding process the loads applied to each of the skid shoes were controlled by the staff of ALE Heavylift, who were able to level and adjust the values on the vertical cylinders of each skid shoe, thus preventing the possible lack of compensating loads induced by small variations in the ground surface level.

As the house moved, periodic topographical surveys were performed every two to three meters, to check the behavior of the house and of the surrounding ground.

Figure 13. Sequence showing the movement of the house taking as reference one of the edges of Torre Mayor.

Figures 13 to 15 show the sequence of the first movement carried out. This initial movement lasted approximately 10 hours; the house only experienced some small fissures that, in general, corresponded to cracks that had been plastered at the beginning of the project but not represented any risk to the stability of the structure. During the time elapsed in its temporary position, the inside of the house was strengthened protecting its walls with steel mesh plastered with mortar. When the house was moved back to its original site no problems were found.

Figure 14. Original location of the house (Courtesy of Fondo Hexa)

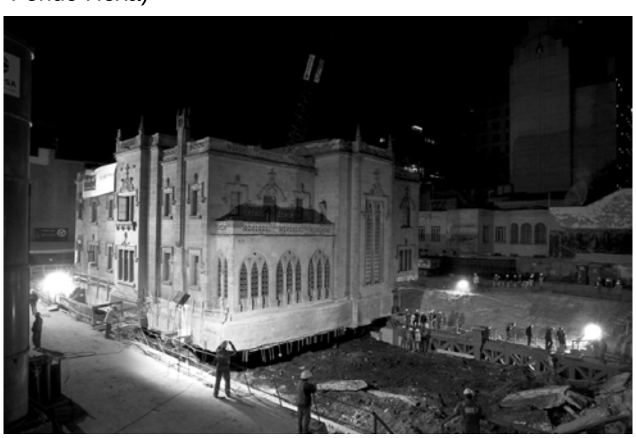

Figure 15. Location of the house after its moving (Courtesy of Fondo Hexa)

5 CONCLUSIONS

The possibility of moving catalogued structures is a feasible alternative that can be used for similar cases in future occasions.

Although the movement of this old house was not the first case in Mexico, it became an innovative procedure because it involved a catalogued structure reinforced structurally according to the prevailing building code at the time of its construction which was evidently scarce by present day standards and regulations. Additionally, advanced technology was used.

Team work among structural and geotechnical engineers and conservation specialists was of paramount importance in planning the operation and during the movement of the house.

Finally, the cost of the maneuvers was outweighed by the benefit of a better use of the very expensive land property.

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ACKNOWLEDGEMENTS

The authors are grateful to the corporation Fondo Hexa for the facilities provided to write this paper, particularly the help received from architect Benjamin Romano.

The companies and persons that were involved in the project are:

Architectural concept:
LBR&A
Structural consultant:
Instituto de Ingeniería, UNAM
Dr. Roberto Meli
Dr. Roberto Sánchez
Structural design:
DITEC Dr. Rodolfo Valles Mattox
VAMISA M en I Ismael Vázquez Martínez
Specialized equipment:
ALE Heavylift
Soil Mechanics:
TGC–Geotecnia
Diaphragm walls:
CIMESA
Construction Management:
Bovis Lend & Lease