FABRIC MEMBRANE STRUCTURES TO COVER COURTYARDS OF HISTORIC BUILDINGS

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Abstract. The aim of this paper is to show the advantages of covering courtyards of historic buildings with fabric membrane structures [1]. Two case studies, designed by the authors of this paper, will be presented: Fabric membrane structure for the main courtyard of the Palacio de Minería Building located in Mexico City and fabric membrane structures for three courtyards of the Museo del Palacio Building, located in Oaxaca City. As soon as the Spanish conquerors established their domains in the New Spain, starting from XVI Century, many stone constructions were built, which still remain and many of them are categorized by the Mexican Government as historic buildings. Most of these buildings obey to an architectural composition where a rectangular courtyard is surrounded by the different rooms of the construction. Originally, these courtyards were conceived as open air spaces, delivering light and air to the rooms of the building and in Mexico, as well as in many other countries worldwide, it is possible to find these kind of buildings all over the land, many of them belonging for instance to government offices, schools or institutions of higher education, although many of them still remain just as dwelling. Nowadays, it is necessary to use these courtyards for several different purposes such as meetings, official ceremonies, exhibitions, conferences, theatre performances and so on. Due to the lack of space and to the reduced budgets of many of the owners of the described buildings, it is needful to cover such spaces in order to be used to fulfil the requirements previously described. The two case studies presented on this paper will show the many advantages of applying fabric membrane structures to cover the courtyards against other more traditional structural systems, where all requirements demanded by the Mexican Government through the Instituto Nacional de Antropología e Historia – INAH, such as reversibility and non-permanent damage of the old buildings, were considered and fully respected. Special attention will be focused on the anchorage details of the fabric membrane structures with the old buildings.
1 INTRODUCTION

Due to the lack of space and reduced budgets on the one side and to the necessity of appropriate spaces in order to organize multipurpose events such as meetings, conferences, lectures, exhibitions, performances, ceremonies, etc. on the other side; many buildings all over the world have been transformed mainly by covering the available originally open air courtyards, which were originally designed and built in order to deliver natural light and air in all the rooms located surrounding these courtyards. Although all these buildings might be old or new, in Mexico, many of these buildings are historic and they are protected and supervised by the Mexican Government through the Instituto Nacional de Antropología e Historia – INAH (National Institute of Anthropology and History), which takes care of all buildings categorized as historic. This Institute has launched official codes to control any changes in the function or in the structures, fundaments, ornamentations or facades of the historic buildings. For this reason, it is not possible to undertake any change on these buildings without the official permission of the INAH. Some of the norms of the INAH state that any kind of change in the structure of the historic building must be able to be reversible and must not produce any damage in the structure of the old building. It is also prescribed that a new cover must respect the original architectural design of the old building and must not be seen by anybody standing on the streets surrounding the old building.

Other special condition in Mexico City, where one of the two case studies is located, is the bad quality of the soils. Mexico City was founded on a valley, which in 15th Century was a lake, thus the city sinks continuously and all constructions built on the lake area are specially affected in case of earth quakes. The authors of this paper consider that fabric membrane structures are currently one of the most suitable structural systems to cover courtyards of historic buildings and with the two case studies shown in this paper, they will try to proof this last statement.

2 BACKGROUND

Compared with other traditional structural systems, such as steel arches, reinforced concrete shells or timber trusses; fabric membrane structures offer many advantages in order to cover courtyards of historic buildings. One very important property is the lightness of the material. Due to the low own weight of the membrane, it is not necessary to consider adding large gravitational loads to the old structure. Of course, it is necessary to take into consideration the tensile and compression forces that will be transmitted through the cables and the masts to the old structure, as well as the anchorage points and building details, which are also very important and significant. Fabric structures are easier and quicker to install and also to dismantle, than other structural systems, when they are no more necessary or while renewing the fabric membrane. Even if the durability of the fabric is limited to 20 or 30 years, depending on the fibers used during their fabrication, usually polyester or glass fibers, and on the weather conditions or pollution of the place where they are located, and on the quality of the final coating materials; for historic buildings they are still more suitable proposals than other kinds of traditional structures, such as above mentioned.

When a new fabric structure is designed and built on a historic building, it is essential to analyze carefully the existing structure, in order to determine the design of the anchorage elements such as masts, arches, cables and any kind of new structural element. Special attention must be focused on the tensile forces generated during the pre-stressed process of the membrane as well as during the possible action of strong winds. As an example of a case where the above conditions reached a top level, the anchorage of the cables of a fabric structure in a historic building located downtown of Mexico City is shown. (See Fig. 1).
Figure 1: Anchorage of cables in a former Women’s Hospital, historic building located downtown Mexico City.

The old structure of the building built with brick vaults supported by iron I-beams at the beginning of the 20th Century, was very weak in order to grant the required rigidity to support the tensile forces generated by the fabric membrane. For this reason, the anchorage elements were fixed “down the floor of the upper floor” in such a way that the tensile forces are counteracted through the own weight of the whole upper floor. Steel I Beams supported on the structural axes of the building worked as “bridges” and allowed to fix anchorage elements along the beams according to the requirements of the project.

3 CASE STUDY “A”: FABRIC MEMBRANE STRUCTURE FOR THE PALACIO DE MINERÍA BUILDING

The Palacio de Minería building might be considered among one of the most important historic buildings in Mexico City [2]. (See Fig. 2). It was designed by Architect Manuel Tolsá and inaugurated in 1813. The Faculty of Engineering of the Universidad Nacional Autónoma de México – UNAM administers this building, which is mainly used for lectures, offices, library, exhibitions, auditorium, seminars and conferences. The old building was restored in 1973, when the roofs were substituted by reinforced concrete slabs supported on steel I-
Beams. The UNAM asked the contractors not to disturb the normal functions or daily working activities developed in the offices and classrooms of the building. Moreover, The INAH warned also the contractors not to affect the rich ornamental gypsum plaster on the ceilings of the offices. Because of the above reasons, special anchorage elements were designed and constructed in such a way that the requirements asked by the UNAM and the INAH were attended and respected.

Figure 2: Palacio de Minería, inside and outside views of the courtyard and the fabric membrane structure.

3.1 Anchoring elements

They were designed in such a way that they fix the masts and cables of the fabric structure by introducing just 7 cm; steel U-Rods, inside of the reinforced concrete slabs, according to the following diagrams and photographs. (See Fig. 3).
Figure 3: Anchorage details of masts and cables of the membranes structure on the top of the reinforced concrete slabs.

Each U-Rod was fixed every 30 cm with structural silicone to the reinforced concrete slabs embracing 6 inch. I-Beams. The I-Beams are long enough (Approx. 9 m) to guarantee that all forces (tension, compression or shear) acting on the anchorage points of the old building will be transmitted, as much as possible, on wide surfaces of the old structure.

In this way, all the requirements previously established by the UNAM and the INAH were fully respected.

3.2 Lantern

The lantern of circular plan and diameter 2.5 m is located in the center of the fabric membrane structure. (See Figs. 2 and 4). The lantern emphasizes the central point of the courtyard and allows the exit of the hot air at the top of the membrane structure. It is also an important and useful element during the montage process of the membrane.
Although this historic building was also restored at the end of the 20th Century, reinforced concrete slabs supported directly on the stone arches substituted the old roof structure. There were no beams available to fix the fabric structures on the old building and, for this reason, it was necessary to design and build a horizontal steel frame system on the roof to be used as fundament of the fabric structure. (See Fig. 5).
4.1 Fundaments on the roofs of the old building

This project takes into consideration the proposals developed in the project of the membrane structure for the former Women’s Hospital described in figure 1. The support and anchorage elements are fixed on a frame of steel I Beams which work once again as “bridges” between the structural axes of the historic building. Nevertheless, in this case the cables were fixed with steel plates joined with chemical anchorage elements in 68 different points located in the structural axes of the building.
4.2 Anchoring elements

The anchoring elements are supported on steel I Beams surrounding the courtyards. (See Fig. 6). They allow to counteract the compression forces generated by the posts with the tensile forces generated by the cables.

The posts have pin supports on the I beams to avoid bending stresses and consequently they required steel cables to keep in equilibrium.

The anchorage elements of the cables were designed in order to allow adjusting of the required position during the montage process. (See Fig. 7).
4.3 Lantern

Besides fulfilling the function of lighting the courtyard, the lantern allows the exit of the hot air accumulated on the top of the roof and as well as in the previous case, it was very useful during the montage process of the membrane structure. (See Fig. 8).
5 CONCLUSIONS

• The authors of this paper show that fabric membrane structures are more suitable structural systems to cover courtyards of historic buildings, than many other traditional structural systems, such as steel arches, reinforced concrete shells or timber trusses. This statement was demonstrated with the many advantages discussed on the two case studies shown in this paper.

• Due to the low own weight of the material, fabric membrane structures are highly efficient structural systems to build covers for courtyards of historic buildings, especially if they are located on soft soils with low mechanical properties and/or in earth quake zones.

• The montage- and dismantle process of a fabric membrane structure occurs quicker and easier than many other traditional structural systems, thus their application is highly recommended to cover courtyards of historic buildings; moreover to avoid damages in the original structure of the historic building.

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REFERENCES
