

## Preservation of Concrete Shell Structures

J. Mundo-Hernandez<sup>1</sup>, M. C. Valerdi-Nochebuena<sup>2</sup>, J. Sosa-Oliver<sup>2</sup>

<sup>1</sup>Associate Professor at Universidad de las Americas Puebla, Sta. Catarina Martir, Cholula, Puebla, Mexico, 72810,

<sup>2</sup>Professors at Universidad Autonoma de Puebla, Mexico.

**Abstract:** - This paper aims to analyse current people's perception towards concrete shell structures located in the main campus of the University of Puebla, in central Mexico. We are interested in knowing the perception of building academics and architecture and engineering students regarding the use, value and current conditions of concrete shells. This will help us to understand what kind of actions can be taken to preserve those structures, and what factors should be considered during the design of new spatial structures.

**Keywords:** - concrete shell structures, lightweight buildings, users' perception, building heritage, sustainability, 20<sup>th</sup> Century architecture.

### I. INTRODUCTION

Concrete shell structures have defined an important moment in the design of space structures during the 20<sup>th</sup> century. Concrete lightweight structures continue to impact in the design of new buildings. In Mexico there are still a great number of examples of concrete shell structures, mainly built during the 1950's and 60's, by Felix Candela. He and designers Fernando and Raúl Fernández-Rangel, established in 1950 a Company called "Cubiertas Ala" (that name translates as Wing Shells); which built around 800 thin concrete shell buildings until the company closed in 1976 [1].

Despite the architectural significance of thin concrete shells, some of them built in the city of Puebla in Mexico have been demolished, hence, the importance of finding and developing strategies to preserve them. This paper aims to analyse current people's perception towards those structures. We are interested in knowing the perception of building professionals and students regarding concrete shell structures located in the main campus of the University of Puebla in central Mexico. A broader project intends to develop a catalogue of concrete shell structures and other lightweight structures (mainly fabric structures) built since the construction of the University Campus in 1969.

The University campus in Puebla was built during the second half of the 20<sup>th</sup> Century, hence, an important number of concrete shell structures were built, for instance: the Cultural Centre of the Architecture Faculty designed by architect Miguel Pavón Rivero (Fig. 1), and a lab building of the Engineering Faculty (Fig. 2). There are also concrete hyperbolic paraboloid umbrella shells that cover exterior corridors for rain and solar protection (Fig. 3). Recently, some of those structures were demolished in order to build a new entrance to the campus, which has no architectural value. This fact raised concern among members of the Architecture Faculty, especially academic staff members, who have studied and worked for several years in that campus.

Knowing current users' perception towards those structures would help to raise awareness about the importance of preserving examples of fine architecture that could help us to understand the life cycle of buildings and consider certain factors in the design of new structures. Those factors are: lifetime, life-cycle analysis, interior environmental quality, users' role, climate, aesthetics, flexibility, comfort, building systems and materials. Valuable lessons can be learnt from past architecture examples. In addition, preserving usable buildings contribute to sustainability: avoiding the construction of unnecessary new structures or buildings, preserving land for other use, saving natural resources such as energy, water and wood, reducing waste; whilst decreasing the production of CO<sub>2</sub> and air pollution generated by the extraction, transport and manufacturing of building materials, and the use of construction equipment.



Figure 1. La Monja Cultural Centre, Architecture Faculty, BUAP (2012).



Figure 2. Lab building, Engineering Faculty, BUAP (2013).



Figure 3. Corridor covered by a concrete shell, University Campus, BUAP (2013).

## II. MATERIALS AND METHODS

A questionnaire with 16 questions was designed to answer the following main queries: **Do current users value concrete shell structures? How do they use them? And how those structures respond to present spatial needs? Are concrete shell structures worth preserving?** The questionnaire was distributed between February and April 2013, among students and academic members of the Architecture and Engineering Faculties of the University of Puebla (BUAP). In total, 117 answered questionnaires were received and analysed using the statistical software SPSS v18.0.

## III. RESULTS AND DISCUSSION

Respondents are mainly 5<sup>th</sup> year students (44%), 18% are 4<sup>th</sup> year students and 17% are 3<sup>rd</sup> year students, the rest are 1<sup>st</sup> and 2<sup>nd</sup> year students. Most of them (88%) are architecture students, and the rest are Engineering students (12%). Only 4 academic staff participated in the survey, therefore, their comments will be included in the discussion but not considered in the data analysis. 85% of respondents are between 17 and 23 years old, and 15% are between 24 and 30 years old. Hence, their use of the university campus and the concrete shell buildings is limited to 5 years.

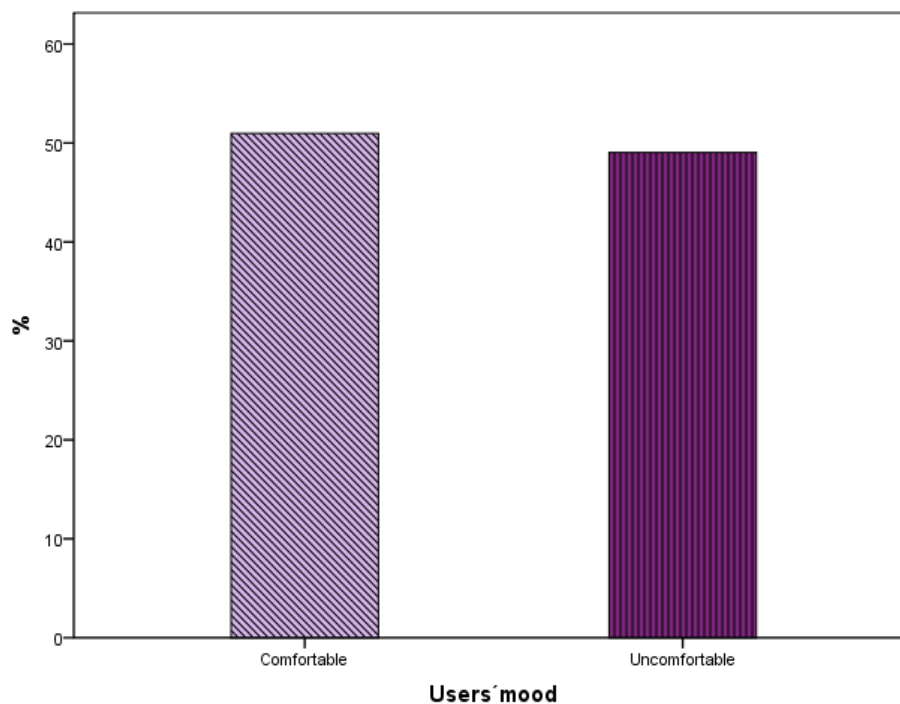
Respondents were asked about their general opinion regarding the university concrete shell buildings. People who have a positive opinion are 74% of respondents, they believe those buildings are useful, interesting and innovative in their design. On the other hand, people who believe concrete shell buildings are ugly, not

useful, boring and dated represent 26% of participants. Regarding the concrete shell umbrellas that cover the exterior corridors (Fig. 3), 82% of respondents think they fulfil their functional objective of solar and rain protection; and 77% believe they must be preserved. Reasons for that include: the structures are an icon of the Architecture Faculty and the University Campus, it is more expensive and not sustainable to demolish them in order to build new structures, they are part of the architectural history of Mexico and those structures are useful for sun and rain protection and to lit the corridors at night.

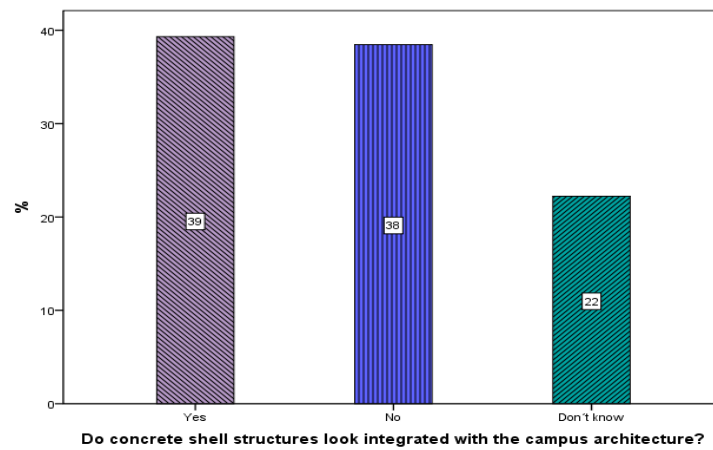
Figure 4 shows users' perception regarding their mood when using the university's concrete shell buildings. Their answers were grouped into two categories: comfortable and uncomfortable; however, people's responses included feelings such as being: warm, cold, bored, happy, distracted, active, etc. It is interesting to observe their opinions, 51% of respondents feel comfortable while the other half (49%) feel uncomfortable.

Users were asked if they believe the concrete shell structures look integrated with the whole campus architecture. 39% of respondents agreed that the concrete shells integrate with the rest of the university buildings, while 38% said they do not integrate, and 22% stated that they do not know (Figure 5). Moreover, people were questioned about their perception towards the level of maintenance of these buildings. The majority of respondents (almost 54%) said maintenance is fair, 12% answered maintenance is good and almost 34% responded maintenance is bad and very bad (Fig. 6). Open comments from people included:

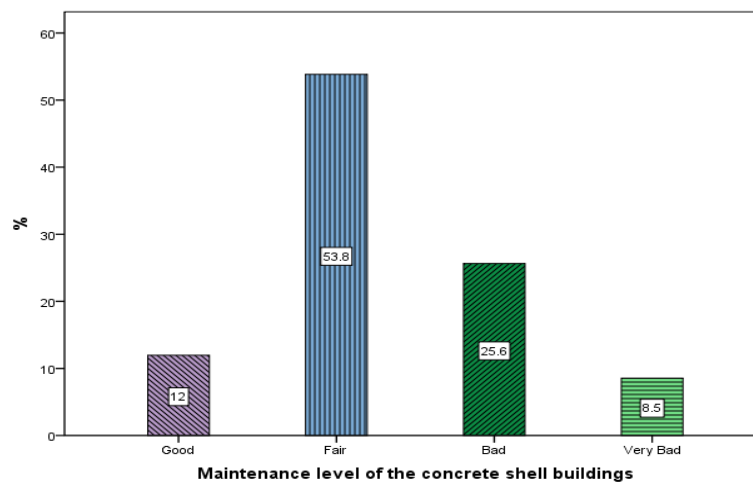
- "Maintenance to concrete shell buildings is poor;
- it seems that they are going to fall down;
- they are functional buildings but need good and continuous maintenance;
- they need painting, especially on facades;
- include green roofs and natural ventilation for thermal control in lecture rooms located in La Monja building (figure 1);
- some lecture rooms are flooded in the raining season;
- they need immediate attention and renovation;
- it is important to preserve these buildings for historical reasons;
- It would be better to restore them than to build new buildings".



**Figure 4.** Users' mood originated by using thin concrete shell buildings.



**Figure 5.** Users' perception regarding concrete shell integration with other Campus buildings.



**Figure 6.** Users' perception towards maintenance of the concrete shell buildings.

When users were asked about the value of concrete shells and the importance of preserving those structures, students pointed out that they look dated and poorly maintained. They also mentioned that it would be necessary to restore them in order to preserve them. Some people mentioned the need to demolish them in order to build new and modern buildings. Staff members value more the architectural significance of concrete shells, and the importance of preserving them as part of the university's architectural heritage.

#### IV. CONCLUSION

We believe the key to preserve thin concrete shell structures relies mainly on the education of future building professionals. If they recognise their architectural value and engineering advantages such as lightweight, minimum use of materials and the ability to cover large span buildings, those shells could be saved from demolition. According to Draper et al [2] one of the reasons for rarely finding today designers building such structures is the lack of technical expertise to properly understand their structural behaviour.

In addition, few approximations to study thin concrete shells environmental behaviour have been carried out. Previous research developed at the University of Puebla was focused on studying the interior environment of La Monja building [3, 4]. Results of that project pointed out some major environmental problems of the building: lack of natural ventilation, elevated interior temperature and the presence of glare. Those factors have made people to leave the building and even to suspend lectures or conferences being held in there.

Preserving functional concrete shell buildings would allow future generations to use, see and admire space structures designed and built during the 20<sup>th</sup> Century. Concrete shell structures represent an important contribution to engineering, technology and architecture. Recently some researchers have proposed and tested

the use of fabric and pneumatic formwork for the construction of thin concrete shells and other type of concrete buildings [5, 6]. These procedures could make possible to design and build innovative and modern building shapes, without the stiffness and flatness of traditional wood or steel formwork. Moreover, they could contribute to reduce building costs since the construction would be simpler and more efficient. Cauberg et al [5] have done a review of the possibility of replacing traditional steel reinforcement for textile reinforcement, allowing to build the same double curvature and elegant concrete shells with more flexible and lighter materials.

Moreover, preserving existing buildings is a sustainable approach of the building industry. Reusing buildings avoids the construction of new ones, and this contributes to preserving farm land, forests and natural habitats. It also avoids the use of water and energy necessary to build new structures. The quantity of construction material used to build new buildings is far greater than the amount of material used to restore an existing building. The same can be said about the production of waste in building sites, and air pollution with CO<sub>2</sub> and dust generated by construction machinery and other demolition and construction activities.

Particularly to this case study, it is recommended to take the following actions:

- To introduce topics related to the design and construction of concrete shell buildings in Mexico and the rest of the world in the contents of Architecture and Civil Engineering courses.
- To organise university study trips to visit concrete shell buildings and other innovative structures.
- To make emphasis among university students and building professionals of the design possibilities and construction advantages of thin concrete shells, their current use and building technology and materials available.
- To encourage the preservation of existing concrete shell structures with the University planners and central administration.
- To propose innovative and energy efficient lighting systems to be integrated into the umbrella type concrete shell structures, in order to enhance their shape while illuminating the university corridors.

#### REFERENCES

- [1] Garza-Usabiaga, D., *Félix Candela*, (Ed. Del Cueto, J. Spain: Acción Cultural Española, 2011, pp. 10-17).
- [2] Draper, P., Garlock, M., and Billington, D., Optimization of concrete hyperbolic paraboloid umbrella shells, *Proceedings of the 6<sup>th</sup> International Conference on Computation of Shell and Spatial Structures*, Ed. Abel, J. and Cooke, J., IASS-IACM, Acapulco, Mexico, 2008, pp. 16-32.
- [3] Mundo, J., Valerdi, M., Sosa, J. and Romero, E., Iluminación y confort ambiental: La percepción de los usuarios del Centro Cultural La Monja, BUAP, Puebla. *Revista Legado de Arquitectura y Diseño*, No. 7, Year 5, pp. 63-74.
- [4] Mundo, J., Valerdi, M., Sosa, J. and Arenalde, B., Occupants' environmental perception of a concrete shell building: a case study in Mexico. *Book of Abstracts and Proceedings of the IASS-SLTE Symposium*, Ed. Oliva-Salinas, J., IASS, Acapulco, Mexico, 2008, p. 189-190.
- [5] Cauberg, N., Tysmans, T., Adriaenssens, S., et al., Shell elements of textile reinforced concrete using fabric formwork : a case study. *Advances in Structural Engineering*, Vol. 15, No. 4, 2012, pp. 677-689.
- [6] Lusi, V., Production technology for concrete shells using pneumatic formwork with variable elevation. *Scientific Journal of Riga Technical University*, Vol. 12, 2011, pp. 35-39.