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Lightweight Structures and Architectural Archives: The present living of past heritage knowledge

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Abstract

This paper aims to showcase the view of other designers and projects beyond the must-know, the basis for research, conservation, use, reutilization, and new challenges of the architectural living heritage. It also underscores the unique and significant role of the Faculty of Architecture at the UNAM in shaping the future. The faculty's approach is distinct, balancing and feeding back three axes – historical research, experimental laboratory, and teaching- thereby contributing to the progress and future of shells and spatial structures. The historical research, starting with original documents of some Mexican architects, engineers, and builders such as Félix Candela, Juan Antonio Tonda, Alberto González Pozo, and Enrique de la Mora, is a testament to the faculty's commitment to preserving architectural heritage [1]. The Lightweight Structures Laboratory (LSL) implements this historical knowledge by analyzing, solving, and performing with innovative technologies, methodologies, sustainable materials, and cutting-edge procedures. The resulting experimentation is based on the Specialization Course on Lightweight Structures. This one-year Course has graduated students working in Mexico and abroad whose knowledge lies in implementing the future based on understanding the still-alive past. The faculty's efforts to disseminate this knowledge through cultural expositions worldwide further underline its dedication to the cause [2].

Keywords: Architecture archives, concrete shells, historical research, experimental laboratory, teaching lightweight structures

1. Introduction

The state of conservation of the shells and lightweight structures that put Mexico at the forefront of construction during the decade of the 50s of the last XX century is an example to follow around the world, mainly because of the shells, paraboloids, and reinforced concrete umbrellas of the company *Cubiertas Ala* headed by Félix Candela [3]. The valuation of the built heritage is recurrent and not secondary. Nowadays, the past is still present in our daily activities and cities: factories, wineries, churches, markets, auditoriums, and restaurants. On the one hand, these require clear conservation policies, appropriate methods, in the case of damage, for its restructuring and safeguarding, and an adaptation of continuous learning from the past to project it into the future. The Mexican Architecture Archive, a part of the Faculty of Architecture at UNAM, plays a crucial and global role in this conversation, ensuring that the past is not forgotten and its lessons are applied in the future. Its global impact is evident in disseminating this complementary knowledge, allowing citizens worldwide to protect the recognition and valuation of a heritage asset.

In the face of existing buildings, the issue of safeguarding and heritage protection requires historical knowledge from documents and plans to recognize the processes of design, geometry, calculation, construction, methods, procedures, and materials, and everything that allows us to understand, from the foundations to the solution of lightweight structures, its raison d'être. This knowledge is complemented in two ways. First, the study of structures' material, geometric, and stability behavior over time, and second, experimentation to enhance this knowledge with alternative solutions or varied materials. In the laboratory of lightweight structures, through the implementation of specialized subjects, in parallel to the training of professionals, this knowledge arrives to all kinds of public. Research, experimentation, and the professionalization of the constructive experiences of the past make it possible to recognize the value of a living heritage that is good for all.

2. Research experiences from the collection of Mexican architecture

Mexico City concentrates the most significant number of buildings built with shells, umbrellas, and paraboloids that architects and engineers built nationwide. It is a question of numbers because the policies concentrate on services and benefits in large modern cities. The heritage with these examples of lightweight industrial building structures is in danger of disappearing. On the one hand, human agents, such as the lack of maintenance and real estate speculation, together with the requirement of already urbanized land and infrastructure, provide housing and services to the inhabitants of the ever-growing Mexico City. On the other hand, the natural and environmental phenomena that deteriorate these buildings, such as earthquakes and weather, affect the buildings.

Knowing and acknowledging is the first step and challenge to new architectural and design requirements for integration and reuse within an ever-changing urban structure. One second aspect, protection, adequacy, and safeguarding, requires research from documentary sources. In this sense, the documents conform to the collection of Mexican Architecture. They are an invaluable primary source for getting historical and constructive knowledge, design processes, materials, systems, and technical solutions that were the most right in their historical moment. Knowing them allows us to create the proper tools and strategies for their restoration, restructuring, and adaptation that enable them to continue their useful life. Some reinforced concrete shell safeguarding examples were based on analog, manual, and even artisanal data, calculations, and procedures. Significant are the documentary collections of *Cubiertas ALA* by Félix Candela, Alberto González Pozo, Enrique de la Mora, and Juan Antonio Tonda.

They were clear examples of technological innovation, experimentation, and teaching, following a constructive tradition still in force today, 70 years apart. What can we learn from them? Are these shells still relevant, or can they be improved? Thanks to the Experimentation Lab, these questions are constantly being discussed.

Based on this, some exhibitions of Candela's works have been made and have traveled worldwide [2]. The historical and original plans and documents of the projects that make up the exhibition were fundamental to feeding the data for elaborating the models made in the Laboratory of Lightweight Structures.

3. The Lightweight Structures Laboratory (LSL) and the LSL Research Group

The LSL was founded at the beginning of the 1970s by the Mexican architect José Mirafuentes Galván. After two European stays with Stephan Du Chateau in France and Frei Otto in Germany, Architect Mirafuentes started the LSL at the Faculty of Architecture at *UNAM.* The objectives of the laboratory were to research, promote, and teach the ground knowledge for developing lightweight structures, mainly tensile membrane structures and grid shells. The fabric structure for the central yard of the Palacio Nacional (main Government Building) was a remarkable project constructed in 1972 to cover a 70 m X 64 m surface. (See Fig. 1.). José Mirafuentes developed other projects in Mexico for more than 20 years, mainly on tensile architecture. Unfortunately, he died in 1991.

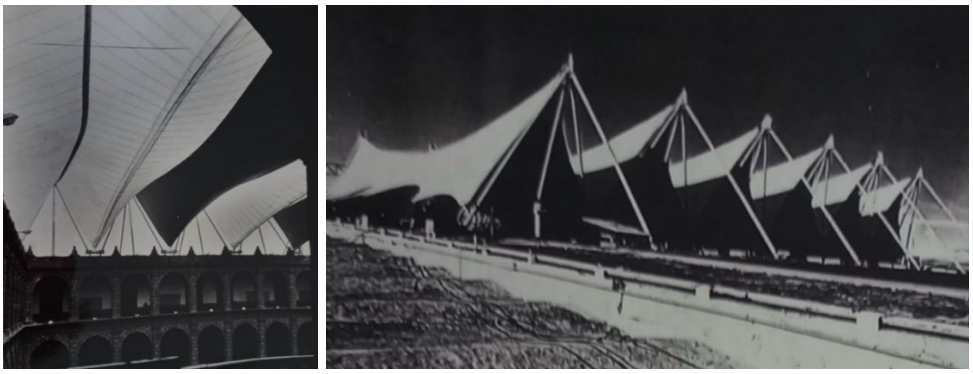

Figure 1: *Tensile membrane structures for the central yard of the Palacio Nacional building in Mexico City 1972. [Photo: https://revistaconstruye.com.mx/jose-mirafuentes-el-artifice-de-las-velarias-en-mexico/]*

Juan Gerardo Oliva restarted the LSL in 1995, and this lab has since become the seedbed of young architects and engineers involved in the conception, design, and construction of lightweight structures in Mexico and abroad. (See Fig. 2.)

Figure 2: *Students of the LSL Research Group working on constructing the experimental pavilion PabUNAM and preparing the exhibition of Candela`s Legacy.*

The LSL Research Group has been able to conceive, design, and build dozens of lightweight structures in Mexico. In addition, considering Félix Candela's legacy and the contributions of several Mexican architects and engineers to the present living of past heritage knowledge, the LSL Research Group has performed several projects of lightweight structures in existing UNAM buildings. The tensile membrane structure for the central yard of the *Palacio de Minería* building, located in the historical downtown of Mexico City in 2000 (See Fig. 3a,) and the bamboo gridshell at the campus of the UNAM in 2011 (See Fig. 3b) are two examples of the implementation of the historical knowledge to the present development of lightweight structures in Mexico.

a)  *b)*

***Figure 3**: a) Tensile membrane structure for the central yard of the Palacio de Minería building. b) Bamboo gridshell at the UNAM Campus.*

Looking for sustainable architecture and considering Mexican building traditions and procedures, the LSL Research Group recently constructed freeform brick vaults on the central yard of the Faculty of Architecture. (See Fig. 4.) This experimental pavilion, PabUNAM, was built in 2022 using the Mexican "leaned bricks" technique with pitched 20 X 10 X 5 cm bricks and steel edges.

***Figure 4:** Constructing the experimental Pavilion PabUNAM and the finished brick vaults at the central yard of the Faculty of Architecture, UNAM.*

4. The Specialization in Design of Lightweight Structures (ECL)

The ECL forms a critical component of the Unique Program of Specializations offered by the Graduate Program in Architecture at the Faculty of Architecture of the *Universidad Nacional Autónoma de México (UNAM)*. Its primary objective is to train specialists who can efficiently respond to the professional field's specific demands in the current social, environmental, and technological context [4].

The Specialization in Lightweight Structures was established in 1984 through Fernando López Carmona's initiative, with Juan Gerardo Oliva Salinas's integration as a researcher. Oliva Salinas had recently returned from obtaining his Doktor-Ingenieur degree at the *Universität Stuttgart*, Germany, under the direction of Frei Otto in 1983. Other academics who contributed to the development of the program include Carlos Chanfón, Ricardo Arancón, Jorge Sánchez, and Porfirio Ballesteros.

The program's curriculum emphasizes the practical application of knowledge to train specialists who possess in-depth knowledge and practical skills in the analysis, calculation, design, and construction of lightweight structures. These structures must be characterized by their lightness compared to traditional structural systems and their rigidity, which is based on geometry rather than the mechanical properties of the materials used.

Mexican architectural history boasts a rich tradition of using reinforced concrete shells with synclastic and anticlastic curvatures to construct religious temples, markets, gas stations, industrial complexes, and housing. Architects such as Félix Candela, Fernando López Carmona, and Enrique de la Mora have contributed significantly to this tradition. Their mastery of the technique and the availability of highly qualified and economical workers made this possible.

New materials, prefabrication, and digital design tools have been developed, and these must be considered in the design of lightweight structures. The economic and demographic conditions of the country have also changed. Nevertheless, optimizing available resources is still essential; therefore, it is necessary to continue training professionals interested in these structural systems. The specialization in the design of lightweight structures, offered over two semesters at the Faculty of Architecture, trains professionals to innovate theoretical and practical knowledge in architectural proposals. The structures they design must respond efficiently to climatic, thermal, and acoustic insulation demands while being cost-effective and aesthetically pleasing. Specialization is a means of transmitting the experiences and knowledge generated in the past to create new technological solutions that are projected into the present and the future.

5. Conclusion: knowledge contribution

It is important to emphasize that it is through the configuration and linking of the three significant areas of knowledge expressed above that the Faculty of Architecture fulfills the substantive tasks of a public university such as UNAM. It contributes internationally by reinforcing universal knowledge about shell solving and encourages research into similar examples elsewhere and by other authors [5]. On the one hand, the historical research from the sources, plans, memories, and calculations that are carried out within the facilities of the Mexican architectural heritage allows us to understand how the most emblematic examples were built and how they were made; secondly, in the laboratory, this knowledge is put to the test and taken to the limit to propose new forms, solutions or methods, and finally in teaching, as a binding element with the latest generations that will specialize and live with these buildings. Through historical research and experimentation, new forms can be projected into the future. The dissemination of knowledge is essential since, based on simple language, explaining draws and models, it is possible to reach a non-specialized audience to enter the world of lightweight structures, to know their value, and to recognize the buildings in their territory to protect them. That is why it is essential to highlight the tangible contribution of the traveling exhibition on reinforced concrete shells and the projects of the roof room in front of Félix Candela that are currently in the country.

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