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Towards a future in sustainable structural design

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Abstract

Architects and engineers are responsible of conceiving, designing and building efficient structures with a minimum use of energy and materials, taking care of the natural resources, where functional and beautiful buildings emerge to develop functional and beautiful cities and landscapes. They are responsible of creating a sustainable structural design.

Nevertheless, the aim of many buildings in the contemporary architecture has turned into an obsession of creating unique and different works that pretend to obtain *trademarks*, without taking any care of the quantity and kind of materials. Structure has become into a slave of the form: Nothing counts but the form. No matter how expensive it is, no matter how many tons of steel, concrete or any other material are required to materialize those unique forms, let us impact the masses, even if the natural resources are reduced and damaged. If architects and engineers are looking for a real sustainable future in structural design, this is not the right way to keep on working. It is very important to consider these facts, otherwise the future generations will pay a very high bill because we have ignored and disrespected the available natural resources of our world today.

Keywords: Sustainability, environment, natural resources, structural design, morphology, concrete shells, membrane structures, lightweight structures.

1. Introduction

"A straight line is the shortest link between two points".

Maximum and Minimum principles like the one mentioned above appear in our daily life and we have to choose between the biggest and the smallest, between the better and the worst. The current development of the civilizations around the world obeys to schemes of inequality, of richness and poorness, of abundance and deficiencies and due to the fast development of the computers, the communication and the globalization, many cultures worldwide have changed, decreasing their own identities and accepting imported aspects

from other cultures of the world, where the natural environment has started to demand the bill of the damages caused to the natural resources. Nevertheless, among this unequal system, many people and cultures are looking for a sustainable world.

How should a structure be nowadays or in the future in order to be considered the best one?

Which would be the values to take into consideration in the contemporary and future structural design?

Which are the responsibilities of architects and engineers in the conception, design and construction of structures?

We will try to find possible answers to these questions, with the support of the ideas of some well known architects and engineers.

2. Description

There is no doubt that the form and the conception of the living space are closely linked to the design and construction of a structure. We can find different values in a building, where we commonly recognize the aesthetical ones in the form and in its expressive potential. All possible values obey to social, cultural and economical conditions, furthermore of the scientific and technological developments. All the previously announced aspects constitute the styles.

We can find styles defined through formalism, based on the understanding of the Architecture just as a sculptural piece of Art, where the form becomes an aim in itself. On the other hand, there are styles in which morphology, mechanics, materials and structural behavior are taken into account during its creative process, getting out furthermore than only pieces of Art, forms that obey and respect the laws of nature, where the relationship between form and structural behavior is strongly considered and where a beautiful architecture and engineering emerges.

Some architects from the last century and today are obsessed with the creation of unique works, trademarks born in modes. The wave increases and covers specially the social groups with high incomes, where most of the rest of the people will be able to live just through the virtual reality.

"Not everything which is technically possible to build, should be built", these are some words from the German architecture professor Jürgen Joedicke. He remarks: *"Structure is a mean for the Architecture, not an aim in itself."*

The scientific and technological development has always influenced architects and engineers. The creation of new materials and the computational evolution, which offer new possibilities for analyzing forms -either geometric, or the so called free ones-, attract the attention mainly of architects eager to prove their creative skills, forgetting any aspect of sustainability, outside any circumstance of healthy living and economics.

Let us remember some thoughts of Félix Candela published in 1954: *"The styles determine the way followed by the collective mental inertia and only a "genius" is able to live in an environment with complete liberty in order to create it. The danger of the case happens when the genius devotes to produce works which -even if they show the unmistakable talent*

and being plastically strong enough to pull along the common mass- are not based on authentic architectural values, creating in this way a new formalism without any sin and consequently, more damaging…"

Figure 1: Large dome over Manhattan. Richard Buckminster Fuller, 1960 – 61.

Figure 2: Mexican Stock Market. Enrique de la Mora, Fernando López Carmona, Félix Candela Outeriño, 1955.

Any structural designer, architect or engineer, has the liberty to propose a solution to a specific challenge. Ethics in each person play a very important roll and the scale where it moves goes from good to bad, making impossible to identify where are the borders, where to start or to finish. Despite the liberty to decide from each human being, there are natural laws which always remain -so as the Newton´s law of gravitational attraction-, and the architect or engineer must adapt his proposals to these conditions.

Professor Frei Otto, the well known German architect wrote:

"Good architecture is more important than beautiful architecture. Beautiful architecture is not necessarily good. The ideal is ethically good architecture that is also aesthetic… Our times demand lighter, more energy-saving, more mobile and more adaptable, in short more natural buildings, without disregarding the demand for safety and security…The search for the natural in architecture does not restrict the possibilities, it extends them...the resulting products are more energy-saving, lighter, more flexible and closer to human beings."

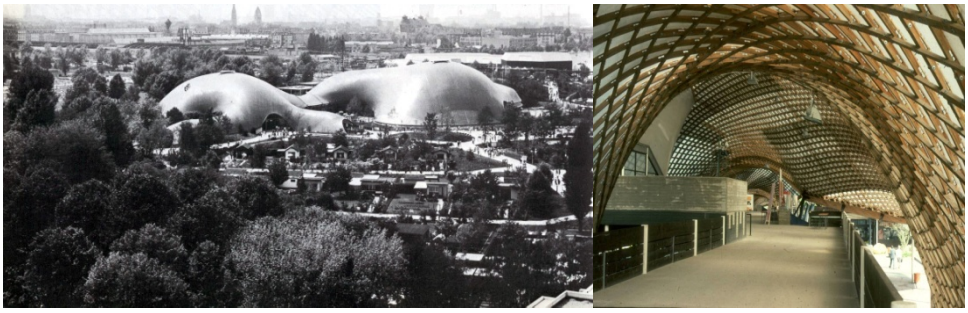

Figure 3: Multihall in Mannheim, Frei Otto & Partners, 1975.

Lightweight structures are clear examples of sustainable structural design. Some of the leaders in this particular field in the middle of the last century in Mexico were Félix Candela (1910-1997) and other ingenious Mexican architects and engineers. Due to social and economical conditions of a Latin American country, where there is plenty of cheap handwork; Félix Candela and other Mexican pioneers showed their outstanding skills conceiving, designing and building extraordinary reinforced concrete shells, featuring to the world a legacy of a real sustainable structural design.

Stimulated by the Lambert-St. Louis Airport Terminal, 1956 by Anton Tedesko, Minoru Yamasaki and William Becker; Candela demonstrated with the reinforced concrete shells of the Bacardí Rum Factory, how to make an elegant and simpler structure. Instead of the intersecting cylindrical vaults designed in St Louis, Candela designed intersecting hyperbolic paraboloid vaults, nearly three times thinner that the ones in St. Louis and with the wide span nearly one and a half time less. The reader should not forget that the Bacardí shells are not exposed to the same conditions of the St Louis shells, where a wide range of temperatures or snow loads had to be supported.

The project was entrusted in 1958 to the Cuban architects and engineers SACMAG -Sáenz, Cancio. Martín, Álvarez and Gutiérrez- with headquarters in La Habana, and to the Mexican engineer Luis Torres Landa, who asked Candela through his enterprise "Cubiertas Ala" to design and construct some of the buildings. Candela reconsidered previous projects developed by this group of professionals, which were drastically modified ruling out what did not seem logic and presenting new proposals, looking for a closer approach to a sustainable structural design.

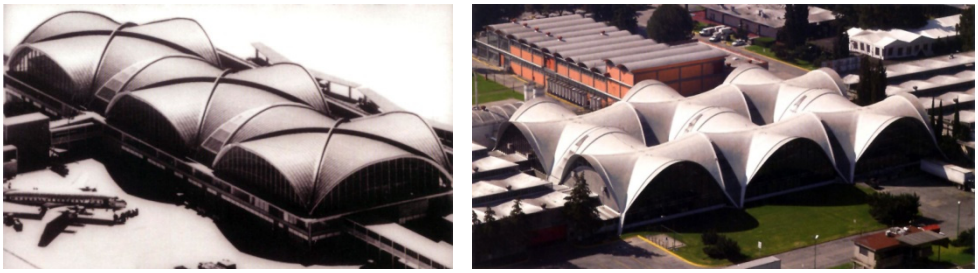

Figure 4: (Left) Lambert-St. Louis Airport Terminal, Anton Tedesco and Partners. 1956. (Right) Bacardí-Mexico Bottling Plant, Felix Candela & Partners. 1958.

The bottling plant represents a sampler of the concrete shells built in Mexico in the fifties and the sixties, because it has several buildings of folded plates, cylindrical vaults, umbrellas and other types of light weight structures of reinforced concrete.

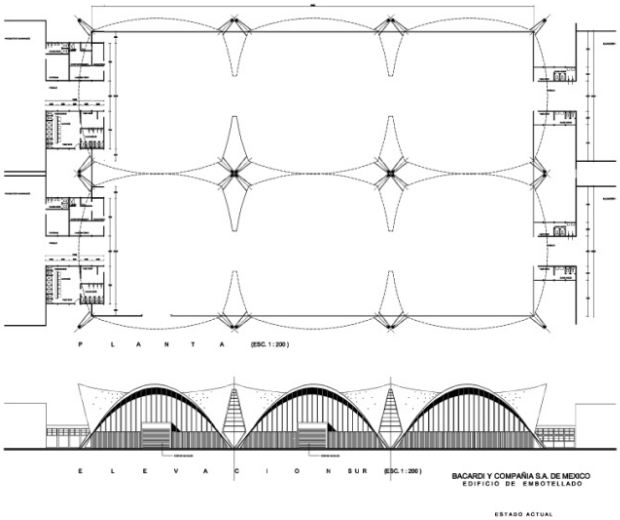

Figure 5: Bacardí-Mexico Bottling Plant, Felix Candela & Partners. 1958.

Mexico -as many other countries in Latin America-, is constituted by a society with low income rates, where the architecture and engineering have to adapt to pre established budgets. This specific phenomena, more than a restriction, becomes a mobile which promotes the creativity. For the architect and the engineer, it becomes a challenge to conceive, to design and to build structures where the natural and human resources must be ideally applied: a sustainable structural design.

Following this legacy, in the Laboratory of Structures of the School of Architecture at the Universidad Nacional Autónoma de México, several projects of light weight structures have been developed and realized, mainly on grid shells and tensile membrane structures. The aim of these projects has never been to look for admiration because of an outstanding form based in the creative skills of the designers. Beyond these objectives, the aim has always been to give an answer to a social necessity, adapting the proposals to limited budgets and trying to use a minimum of materials, where the relationship between form and structural behavior is strongly considerate and all premises of sustainability are respected.

Figure 6: Grid Shell. Mexican Arts and Crafts Museum, Mexico,
Juan Gerardo Oliva & Partners, 2007.

Figure 7: Tensile Membrane Structure. Palacio de Mineria, Mexico,
Juan Gerardo Oliva & Partners, 2002.

Jörg Schlaich and Knut Göppert prestigious German engineers wrote in the paper "The essence of Lightweight Structures" presented at the Widespan Enclosures Symposium in Bath/U.K.: *"With lightweight structures the engineer is able to award the adequate visual expression to an ingenious and efficient structures thus contributing to building culture…Any structure designed intelligently and responsibly aspires to be "as light as possible". Its function is to support "live loads". The dead loads of the structure itself are a necessary evil. The smaller the ratio between a structure´s dead load and the supported live*

loads, the "lighter" the structure… From an ecological, social and cultural perspective lightweight structures have never been more contemporary and necessary than today…lightweight structures are material-efficient because the materials strengths are optimally used. Thus no resources are wasted…"

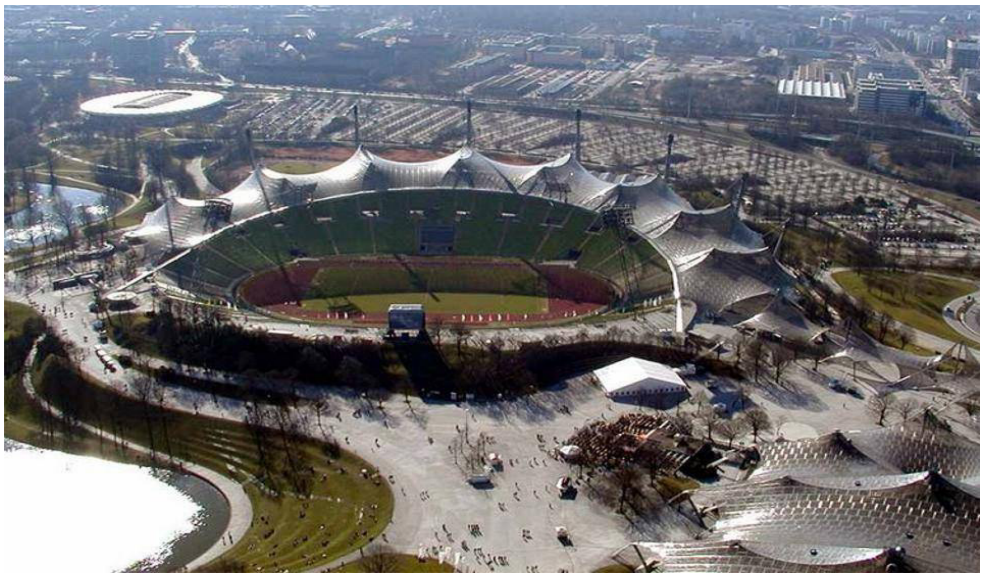

Figure 8: Olympic Stadium Munich, Germany. Frei Otto, Behnisch & Partners, 1972.

Finally, let us show a Sport Stadium located at Ciudad Universitaria, in Mexico City. It was designed and built by the architects Augusto Pérez Palacios, Raúl Salinas Moro and Jorge Bravo Jiménez, between 1950 and 1952. Originally a Sport Stadium, in 1968 it became - after some adaptations- the Olympic Stadium. Initially there were two projects: one proposal with a reinforced concrete structure, and the other one, based on the artificial configuration of terrepleins.

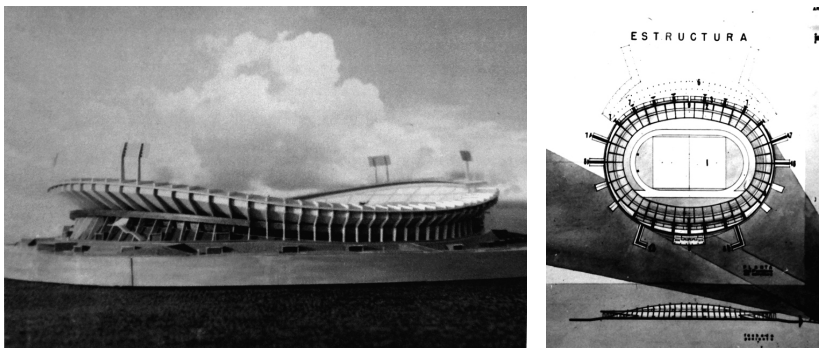

Figure 9: Project 1: Olympic Stadium in Ciudad Universitaria, Mexico.
Augusto Pérez Palacios & Partners, 1952.

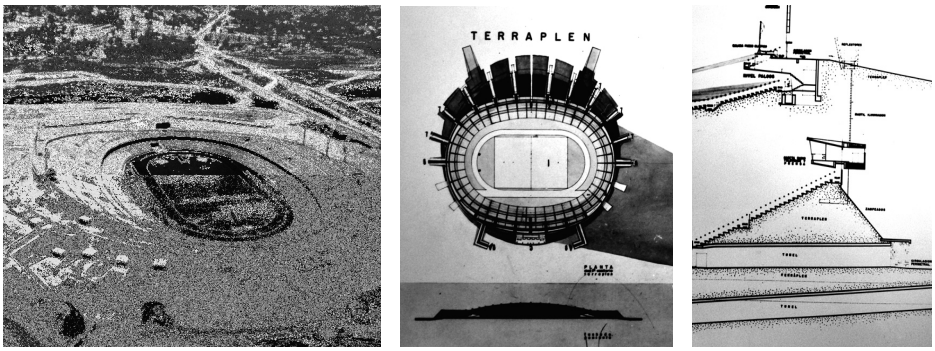

Figure 10: Project 2: Olympic Stadium in Ciudad Universitaria, Mexico.
Augusto Pérez Palacios & Partners, 1952.

After an evaluation of both projects, the second proposal was chosen due to economical reasons: the building prices were much lower. Besides this reason, there were other important ones: the building time would be shorter and the use of reinforced concrete decreased considerably. Finally, a beautiful building of modern architecture was built, and declared –together, with other buildings of Ciudad Universitaria-, cultural heritage of humanity. This Olympic Stadium became an example of sustainable structural design.

Figure 11: Olympic Stadium in Ciudad Universitaria, Mexico.
Augusto Pérez Palacios & Partners, 1952.

3. Conclusions

Sustainability -more than a term-, has become a new way of thinking nowadays. There is no doubt that Economics play a very important roll to decide the best project to carry out. In the last Olympic constructions built in Beijing, the Chinese people tried to show the world their potential power, and so the Olympic Stadium in Beijing (2008) -designed by the architects Jaques Herzog and Pierre de Meuron-, has become an important reference in the modern architecture. Many tons of steel were improved in order to carry out the construction of an inverted bird net, where many structural elements had to be constructed exposed to big stresses caused by the great amount of bending moments. Its structural design remains far away from being an example of a sustainable structural design.

Figure 12: Olympic Stadium Beijing, China. Herzog & De Meuron, 2008.

Experimentation in structural design must not be avoided, but promoted. The use of new materials and technologies must be encouraged to the students of Architecture and Engineering and the challenge for any structural designer is to conceive, design and build innovative structures inside an environment, where taking care and respecting the natural resources and the future of the world, a contemporary and future sustainable structural design will emerge.

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