Design and development of a public leisure centre made up of tropical garden and an indoor swimming pool in the city of Valencia [Spain]

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Abstract
This final year project proposes the building of a public leisure centre, which consists of a tropical garden and an indoor swimming pool, (see Figure 1), both within the same enclosure, so the installations can be enjoyed all through the year. In order to define a unique and compact volume, an organic form with its own identity was chosen during the enclosure's conceptual design phase. This volume needed to meet several requirements as the enclosure's configuration should adequately integrate the different uses for which the enclosure is projected (garden – hall - swimming pool), It should be structurally and economically feasible, there should be enough light in the garden and it should be singular and efficient in its structure.

Keywords: organic form, space steel structure, tubular profile, swimming pool, tropical garden, low form factor, peanut shell, steel - glass surface, greenhouse, reticular metallic structure, diaphanous.

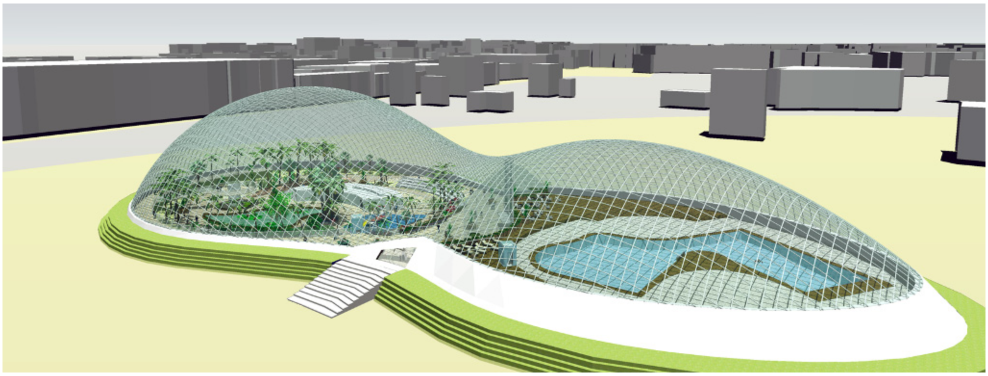

Figure 1: Main view of structure and complex

1. Introduction

1.1. Location, origins and reasons

At long of 1950 - 1960 years, Valencia and another similar cities near the coast, experimented a hard economic growth. It generated high migratory flows from rural areas to the city, which produced a quick urban development without adequate planning and a lack of social resources. The government and local administrations covered primary services, as public health, education, transport, etc.

At this moment, primary social services are full covered, but there are new social demands, as weekly leisure: culture, deports, relaxation. It produces a new lack of secondary social resources like sports facilities and green zones.

This final year project proposes the construction of a public integrated leisure center witch alternative uses as concert hall, classrooms, exhibitions, inside of a unique closed and conditioned enclosure, made by a steel - graced spatial structure.

1.2. Conception and development

The design of this structure is based on three basic criteria. Conceptual criteria: Structure with own entity and personality, open / clear and innovative construction and organic form inspired. Construction criteria: Structurally efficient and economically feasible and low form factor (energy and steel saving). Function criteria: physical division between zones, keeping group philosophy, independent climatic control of greenhouse / swimming pool, public zones + services / installation / maintenance areas and alternative uses (classrooms, culture associations), and fully accessible for handicapped person.

After several trials, a shape was found which met all of these requirements: a peanut shell. As will be explained the resulting form allows the different uses to be continuously independent one zone for the garden, a different one for the swimming pool and an intermediate one which serves as exchanger between them.

Large steel - glass surface would allow the light into the garden, creating the proper microclimate; a relationship would be established between the external environment and the other spaces. Building the structure is technically feasible. The solutions are known. After actions identification, effort calculation and profile assignation optimization, the resulting structure turns out to be very light and with remarkably. The dimensions of the full diaphanous space structure of roof are 161 m. long, between 73,65 m and 44,47 m of span length and a coronation height between 24,52 m. and 13,25 m, the cover has a surface of 11.290 m^2. The structure leans discretely on a perimeter wall which also serves as foundations and container of the enclosure's different areas. The inner space includes approximately 9230 m^2 in plant, in 3 levels: 3290 m^2 for the swimming pool zone, 1441 m^2 for the hall and access walkways and more than 4500 m^2 for the garden.

For the structural resolution of the surface, it is decided on a continuous reticular metallic structure, completely diaphanous, closed, glazed and made in its totality by CHS tubular steel profiles.

2. Modelling

2.1. Profile-type obtaining

To obtain a parametric model, from an original peanut shell, diverse simplifications were made in order to synthesize the shell surface. First, it was impossible to obtain a useful model. Second, in order to reduce the surface's complexity and achieve a clean form which nonetheless can be identified with its natural counterpart. A series of profile-types which will serve as a basis for surface generation were obtained from several peanut shells (see Figure 2).

Figure 2: Peanut shells

Several elevations, some of which are shown in the enclosed images, were obtained through longitudinal section (see Figure 3).

Figure 3: Peanut shape cuts (raster)

A vectorial curve interpolated using NURBS was obtained from these profiles to get a digital and parametrical model (see Figure 4).

Figure 4: Peanut shape cuts (vectorial)

Two parallel methods for surface formation were tried. In the first one, surfaces were interpolated among different profiles which caused results with little coherence. However, the use of a single profile, and the generation of surfaces through revolution gave rise to much more satisfactory results. There-fore, this last method was finally chosen (see Figure 5).

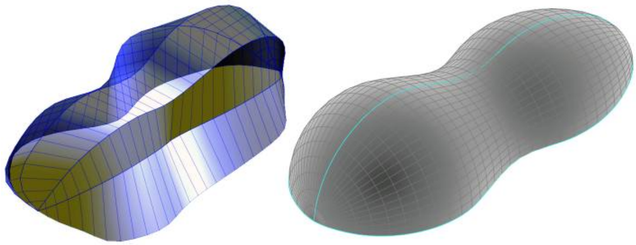

Figure 5: Preliminary surface shell models

2.2. Discretization

The next goal was to go from a non-dimensional surface to a discrete one, in order to obtain a bar model and thus to get a model for calculation. There-fore, a density and orientation for bars would have to be selected. In order to reduce the number of bars and crystal cuts as much as possible, a quadrilaterals mesh was used, only resorting to triangle forms for the border close. In order to reduce costs, the surface cover should be generated through flat crystals. This forces the use of crystals with a defined maximum shape, which is established by the surface curvature. Length should be as regular as possible in order to simplify the implementation.

The last attainment was the most crucial as it brings the three together. The translational surface method was used to obtain it. The surface's convergence in the directive curve surfaces forced the use of increasingly small bars and crystals, producing a highly heterogeneous mesh in some surface regions. Therefore, a cut line over the rotation baseline was set (see Figure 6).

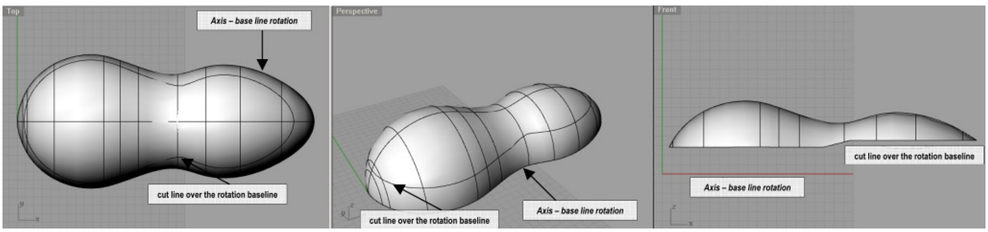

Figure 6: Surface digital model

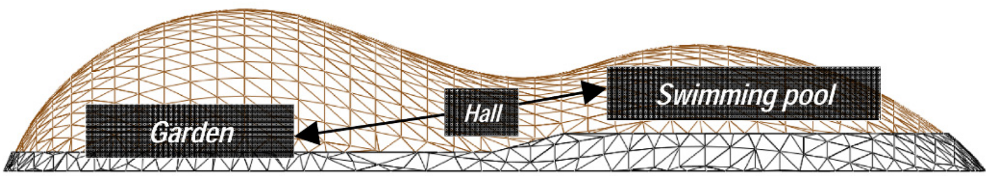

Figure 7: Uses and zones

A guideline curve was divided by a hundredth of the original total length, which resulted in 1600 mm segments. The form which the surface then takes is obtained through small relative turns between the grid squares. The surface produces then 3 types of modulations: Quadrilaterals with parallel sides which are perpendicular to each other two to two, with all its vertexes in a same 1600x1600 mm plane. Quadrilaterals with parallel sides, not perpendicular to each other, with all their vertexes in a same plan of variable dimensions. Triangles of diverse sizes in the zones of covered encounter - laying of foundations. In this way, a highly homogeneous reticule is obtained. Master modulation (1600 mm) gets the highest score at model histogram, which has 8732 bars (see Figure 8).

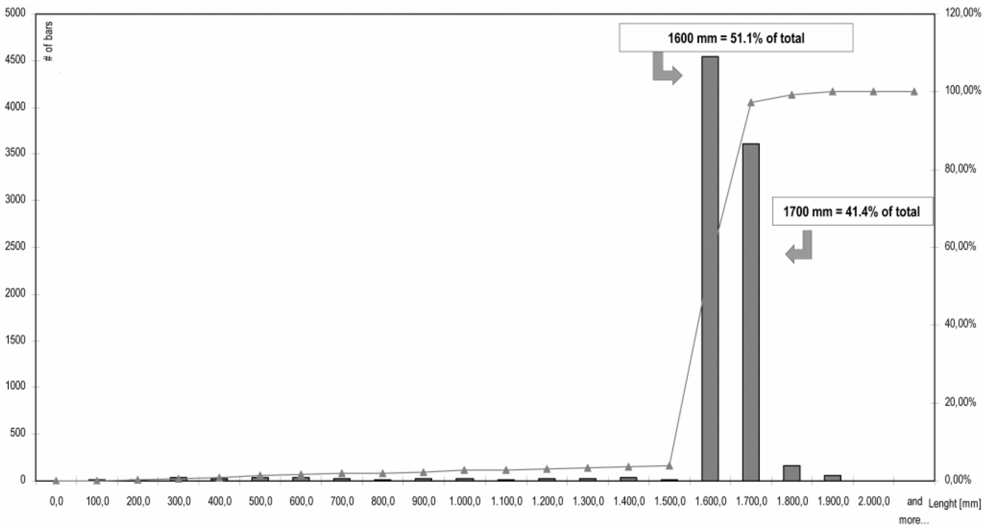

Figure 8: Bar model histogram

3. Calculus model procedure

Calculations for the structure were carried out following a 3-dimensional bar model, through the use of non-lineal matrix models. The used regulations of reference have been the Eurocodes and its national transcriptions (CTE - action and structural design) along with internationally recognized design guides.

Taking into account the surface's singularity, this method will provide the most reliable results. A simplified flat model would result in conclusions far removed from reality. The use of a 3 dimensional calculation model al-lows making efforts compatible with the deformations produced by them. The structural typology (from top to bottom) of the set is a reticular steel mesh like main lifting element of the closing , altogether with an orthogonal shared in common mesh wiring to each one of the reticules, acting like bracing element (see Figure 9). The global behavior can be assimilated to a laminar structure that at local level works like a bi-directional Vierendeel beam. Effective buckling bar lengths take values around 1.

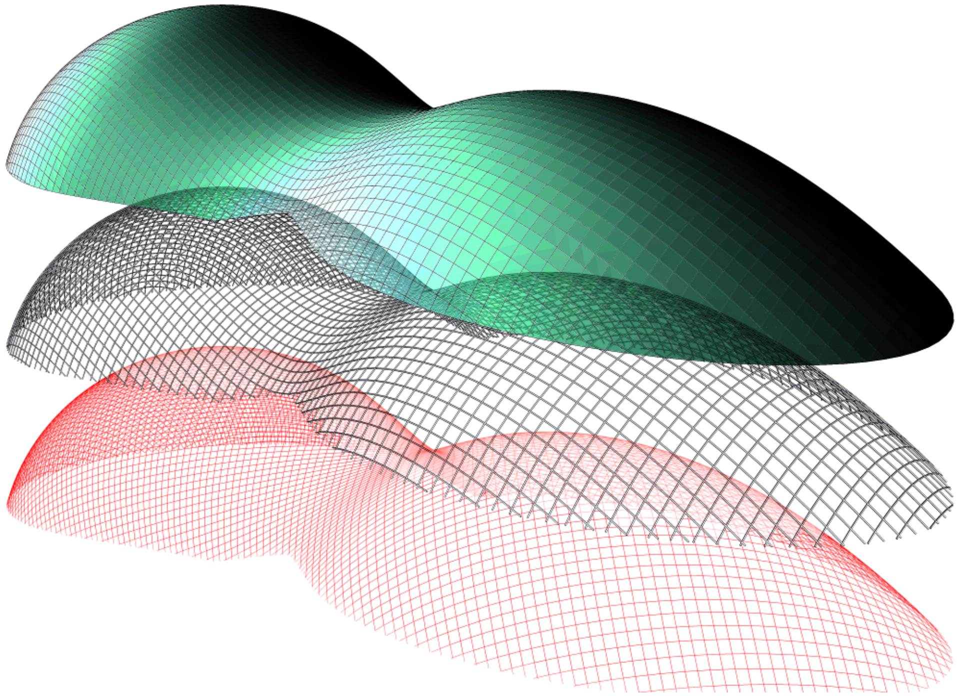

Figure 9: Structural typology

To make calculations, an iterative process was implemented (see Figure 10).

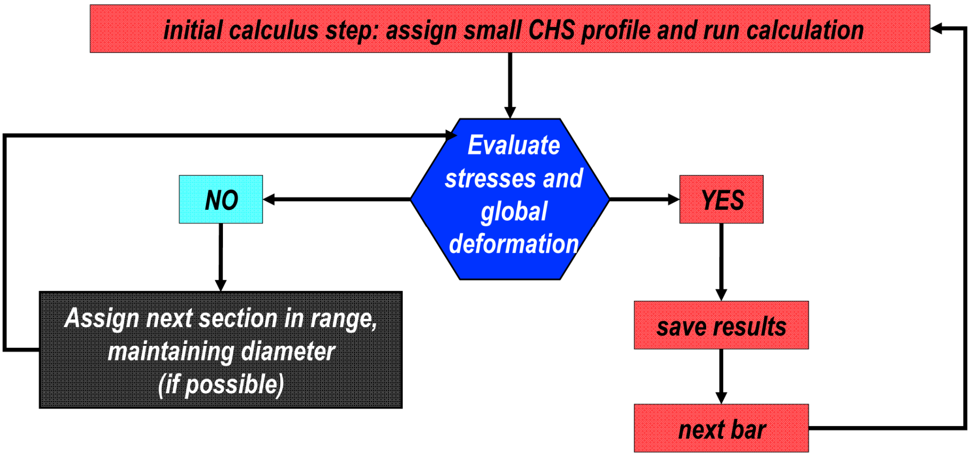

Figure 10: Calculus procedure

4. Steel profiles

In order to build the enclosure, only hot formed tubular profiles (CHS) were used. The use of that kind of sections is the solution for several needs. On one hand, the selected profile will have to face efforts in any direction of the plane. Therefore, pro-files with remarkable mechanic properties with regard to one of its planes are discarded (I, T, H sections). Circular and square sections were candidate profile.

By avoiding the use of stiffeners, a tubular profile greatly simplifies manufacturing. Unions are made directly and continuously either in the workshop or in the construction site, substantially simplifying the building process. This kind of building allows for the manufacturing of big structure blocks which are situated in their final position once they are built in the ground. This kind of sections offer greater resistance to fire, and a smaller quantity of products are needed for its protection, especially important in swimming pool zone, due to a smaller form factor.

Being a structure that works through compression, materials and section are optimally profited. This makes the use of steal with high elastic limit (S355) competitive. Tubular steel sections makes possible simplify mechanisms of specific supports in the structure's nodes, to be used for load transmission. This allows the installation of low-emission glasses in the upper side of the profile. It also allows placing the cable web for bracing in the lower side (see Figure 11)

Figure 11: Node and modulus detailing

5. Conclusion

A tubular section, in particular circular profiles, allows obtaining an extremely slight structure, with an optimal advantage of profiles. The resultant structure is made of (See Table 1): 8732 CHS tubes segments, with a total length of 13,789 meters, 19.417 meters of steel cable and 4576 glasses, with a total surface of 11.290 m^2. The resultant ratio steel/surface in plant results less than 18 Kg S355 / m^2.

Some additional figures can be found below.

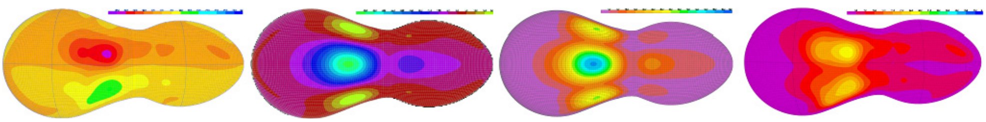

Figure 12: Deformed shape of roof structure (color contour) at different load cases

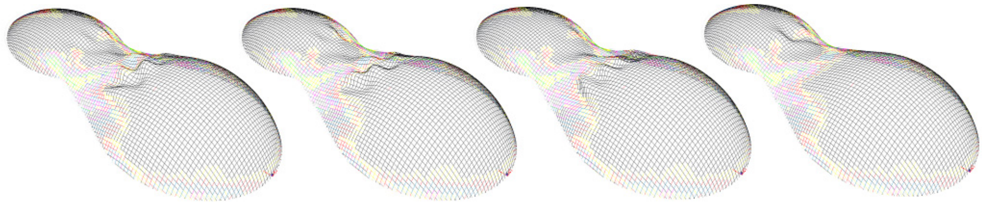

Figure 13: Deformed shape of four first buckling modes

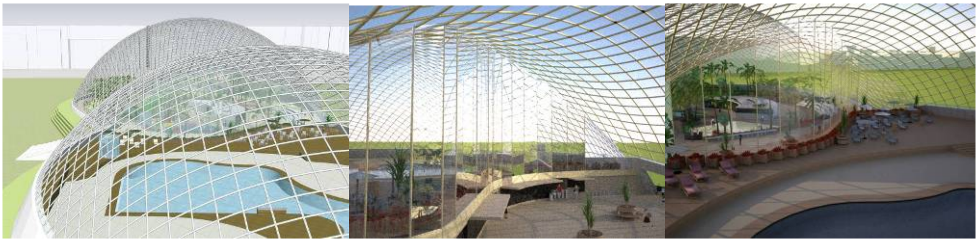

Figure 14: Interior and exterior view of complex and structure

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