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Extreme Water and Architecture Building without joints

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Abstract

The objective of the design was to formalize an aggressive natural phenomenon and then use it to imply a complex geometry. The structure needed to be aligned with the edges of this arbitrary form and was to be modulated so that it could be dismantled and mounted elsewhere. To this end, we proposed triangular faces connected only by the edges and not by means of nodes. Maybe the real innovation of this solution lies in the fact that it can be conceived as an origami design. The final result has been a spectacular mass of glass and steel sheets of great transparency.

Keywords: Space structures, Glass walls, joint transmission, fractal geometry, expo architecture.

1. Introduction

This project was intended to formalize and define an idea in order to enable its construction. The idea consisted of a pavilion which simulates the form that an enormous wave could take, similar to one produced by a tsunami, with a series of contents inside the pavilion which show the devastating effects that this water could produce in a particular habitat and in nature. It was then the architects' concern to formalize the model in order to give it geometry and constructive possibilities.

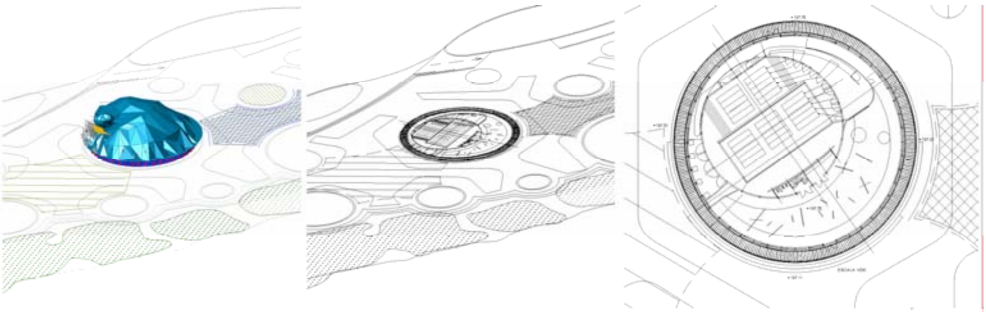
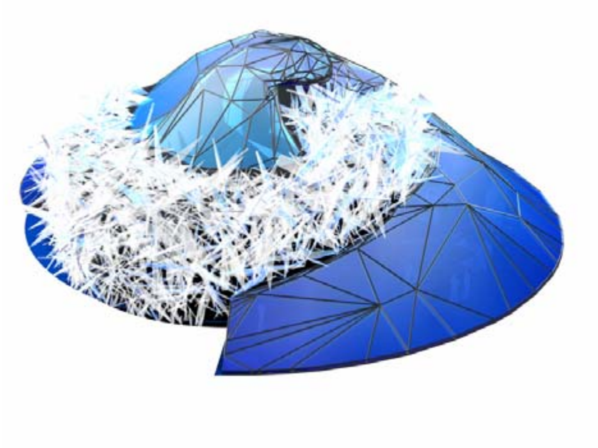
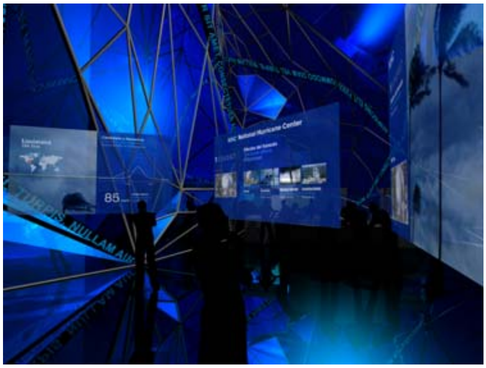


Figure 1. Location and general plan of the pavilion.



Figures 2 and 3. Matrix idea winner of tender.

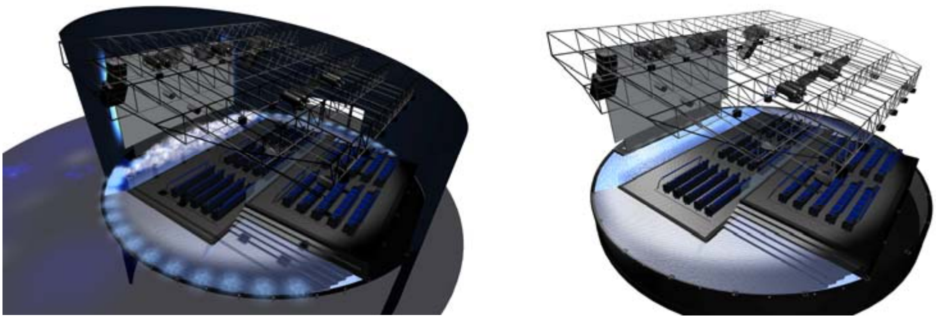
Formally, the intention was to create an exterior image of a potent mass of water which was rising up threateningly and breaking on a regular element in the form of surf. On the inside, this regular element comprises a room for special effects.



Figures 4 and 5. Projected images of the interior with aquatic appearance.

The interior should also simulate the life that can be produced inside the belly of this mass of water broken into facets, with a bluish penumbra, in which projections and models illustrating the above-mentioned special effects would be exhibited.

On a special site, which on the outside would have the appearance of drifting wreckage, or a buried construction, experiences would be created with effects similar to those created by this “tidal wave”. This site is referred to as the “sensory zone”, in contrast to the other section, designated the “reflection zone”.



Figures 6 and 7. Design of the sensory effects room.

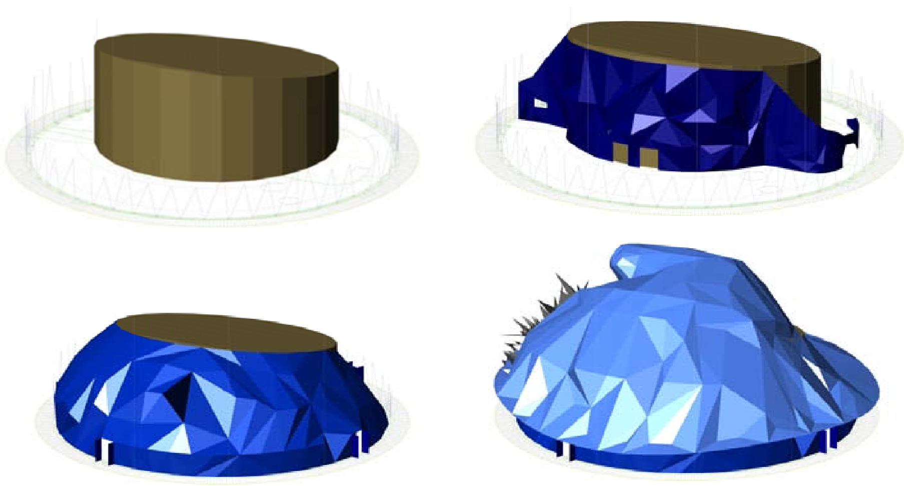


Figure 8. Sensory enclosure and growth of the three skins of the project.

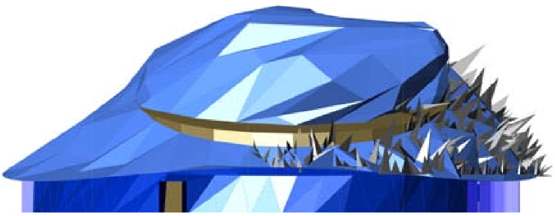
In order to achieve these aims efficiently and effectively, it was decided to create a skin of coloured glass which would delimit the "sensory space". Another skin, also of glass, would surround the "exhibition space" and completely enclose the sensory drum, like a kind of completely isolated black box.

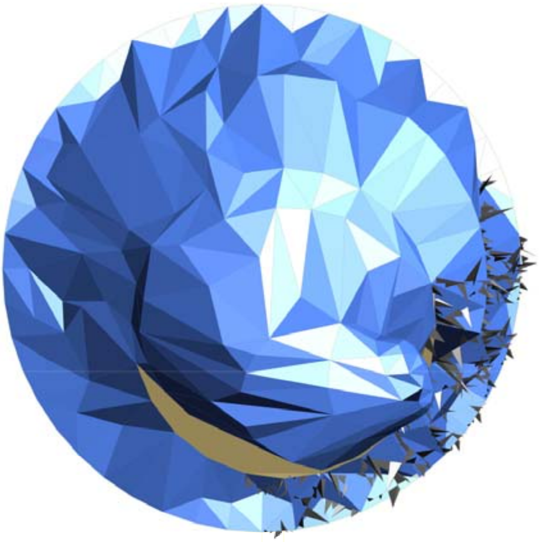
A further skin, perforated and rough, would be spread out over this second glass skin, which is airtight and impermeable. This third skin consists of deployed sheets, which simulate the foaming and vibrant surface of the great wave.

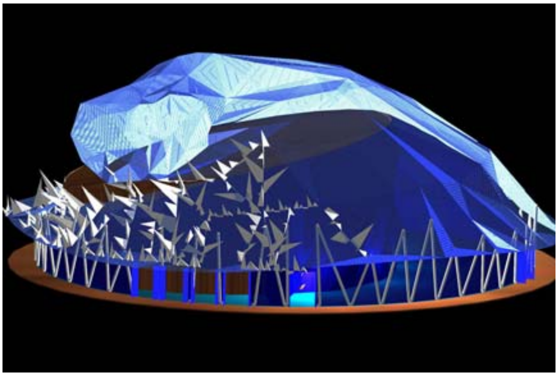
The only openings to be permitted would be the entrance, the exit and the fire escapes.

The public waiting to enter would be able to enjoy the shade of a canopy running around the perimeter of the building, 2m wide and at an average height of 3m.

Architecturally, all these effects are created by means of a multi-faceted surface in the form of irregular triangles, in order to produce random and, in a way, chaotic shapes, both on the inside and on the outside. Constructively, all of these triangles are autonomous forms which are bolted to each other along the length of their edges in order to give structural monolithism.







The perimeter of the "sensory zone" is comprised of 24 supports which bear the interior and exterior roofs.

The location of this architectural unit in a privileged position, near the exit of the Bridge Pavilion by Aha Hadid, would make this uniquely-shaped structure stand out, especially if the tongue of the wave was facing the visitors, raised up above a base of surf.

The light plays a decisive role in the appearance of the pavilion, as during the day it filters the outside light to create a soft bluish half-light, and during the night it shines like a marine surface agitated by the lights and reflections of a shore lit up by a town or city.

One of the principal conditions of the architectural design is the fact that it can be dismantled. Consequently, this pavilion would be reusable elsewhere after the EXPO. This would be quite simple to do and without the need to replace more elements than those which get damaged during the moving process, and those which it is easier to replace than to make mobile. The latter include the roof of the "sensory space", due to problems of the loads of the installations, and part of the cover and waterproofing.

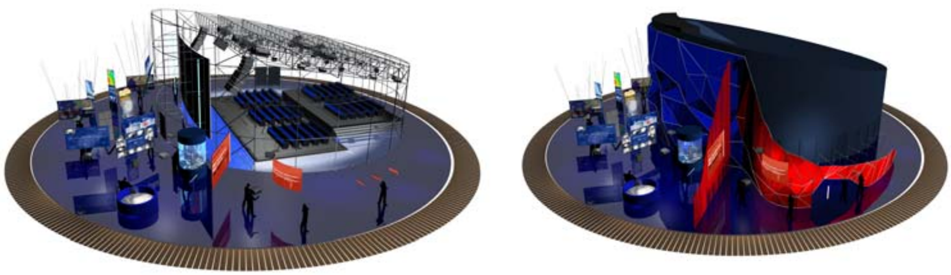
Figure 9. Elevation and plan.

Figure 10. Nocturnal image proposal.

We would have liked even the foundations to be reusable, but in the light of the poor characteristics of the ground, which obliged us to use monolithic foundations, this part of the construction cannot be reused and needs to be demolished. We simply guaranteed that the foundations were not deep and that we would facilitate reinforcing arrangements which make demolition easy.

As far as the installations are concerned, given that we wanted to take advantage of the entire plot, they would be situated, as far as possible, in the roof of the "sensory space" and the pipes would be reduced to a minimum, as there would be an entrance to all sites from this roof. When the installations have to come up from the floor, they go down through the technical rooms, situated behind the screen.

Constructively, the planned approach was an exhibition site surrounding a small, circular enclosure of sensory activities, with a spectacle based on water and the forces of nature which develop around it. This site is designed to be dark and hermetic.



Figures 11 and 12. Approach to the exhibition site.

The exhibition site should simulate a sea bed with a transparent colour similar to what would be experienced at a depth of fifteen metres. It would therefore be a site composed of glass, in blue tones, where even the walls appear as sheer cliffs with greenish vegetation.

At the exit it reddens due to the effects of climate change, creating a distressing sensation.

The general appearance of the exterior is effectively that of a wave, accentuated by the existence of the crest of the wave breaking into foam.

The basic materials to be used would therefore be coloured glass, textured panels and plasterboard panels for the enclosure and steel for the structure.

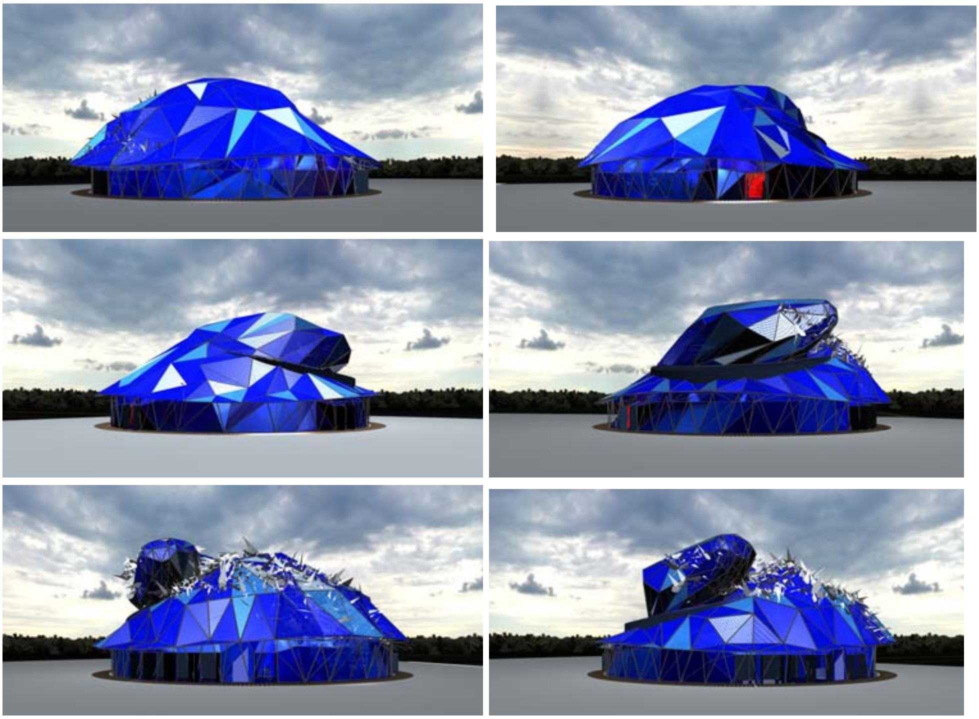


Figure 13. Collection of exterior images of the final project

Figure 14. Interior images of the final project.

The basic materials to be used would therefore be coloured glass, textured panels and plasterboard panels for the enclosure and steel for the structure.

2. Structural and constructive approach.

So far, we had formally defined the building and what now remained was for us to develop and implement it as a final design. We proposed that the enclosures were themselves structural without the need for a complementary system, that is to say, that the triangular panels that comprised the structure were resistant as if it were a system of irregular bricks, an "opus incertum". And the same as the structure, its elements would not be joined by the vertices but rather by the edges. Each triangular element would be joined to adjacent triangles by bolts spaced 50 cm. apart and the node would not have to be a structural connection. Despite this solution being so obvious, it has turned out to be an authentic innovation and very few important projects have applied it. The complexity of the shape of the Extreme Water pavilion, the need for it to be a modular structure and therefore capable of being dismantled, and the difficulty of performing on-site welding made us consider a system of joining struts which, unlike traditional joints, would be based on the transmission between edges and not the transmission between nodes. One way or another, the components under consideration were rigid triangles, with rigid corners and joined along their edges.

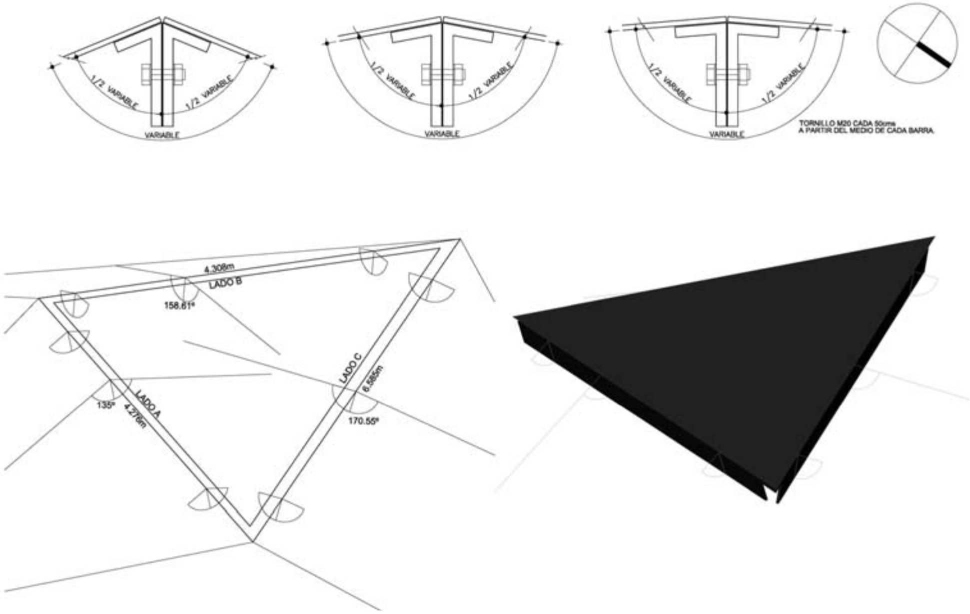


Figure 15. Detail of the triangles which define the glazed interior roof.

In a way, we are making triangular elements bolted together, a typical solution in the construction of large domes which has already been tried out and put into practice by other preceding designers. Buckminster Fuller, for instance, used this system profusely in his large roofs.

In these cases it is very difficult, if not impossible, to take the connection as far as the vertex itself due to its own complexity and due to the confluence of a great number of elements.

Figure 15 shows the solution of the meeting points and the joints defined. As can be seen, we are dealing with a set of triangles with their edges made up by means of L200x200, which are covered on the glass face by the panes, which are stuck on, and on the exterior face by stamped sheets with no structural function.

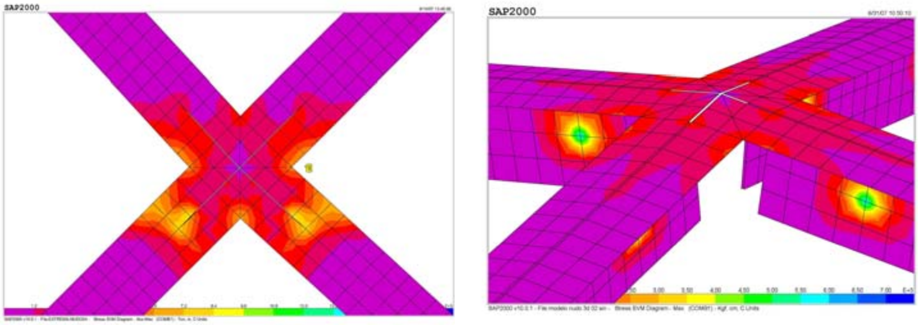


Figure 16. FEM model for the study of the node.

Figure 17. Additional structure between layers.

The mathematical model is therefore a grid which considers the nodes as articulations and the edges as double Ls as described above. The constructive problem lies in the fact that it is very difficult to take the flanges of the sections right to the end due to the difficulty in assembling them, as the corners can clash. For this reason, it was decided to eliminate the continuity of the flanges. In fact, the calculated stresses seemed to allow for this decision and we did not hesitate to adopt it. So why adopt this simplified model for a structure whose nodes have a doubtful continuity? A FEM analysis revealed that the stresses in these non-existent nodes could be diverted via the wings (Figure 16). Nevertheless, we also used an analysis where the struts were considered to be divided into three parts with the real inertias in each one of them. In this case it was necessary to reinforce some of the longer struts.

In any case, the proposal turned out to be controversial and, in spite of the reasoned defence we made in favour of this solution, the organisation decided on a conventional response in the way of some large-section profiles situated radially between the two roofs and which both were attached to by means of hooks (Figure 17).

The constructive solutions in this building are extremely complicated and all of the components need to be prefabricated in order to be bolted together on site.

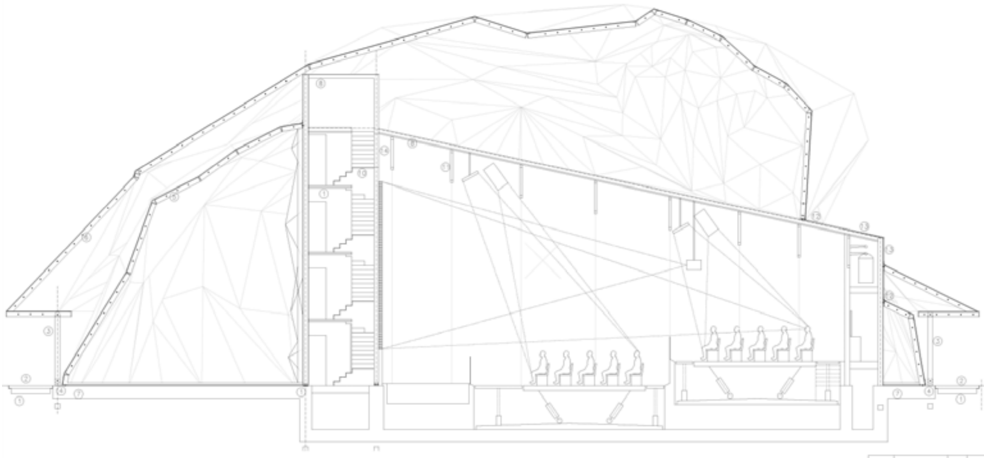


Figure 18. Constructive section.

3. Final formalization

The final result coincided with prior expectations despite the modifications made while executing the work. In fact, it has become one of the most outstanding pavilions contributing to the image of the exhibition site. In the images of figure 19, beautiful shots of the final result can be seen.

Figure 19. General aspect of the exterior of the finished pavilion.

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