Funicular shell

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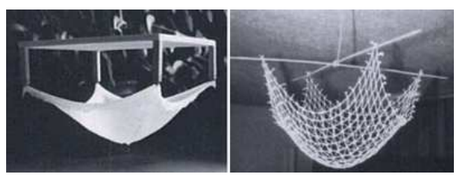
Abstract

The project consists on the research of the behavior of forces on funicular shells. Starting with the use of a simple shape such a self loaded square and observing its deformation depending on the way its hung, whether we use pickpoints or catenaries. Furthermore, simulating the behaviour computer wise, differences concerning the grid used appeared.

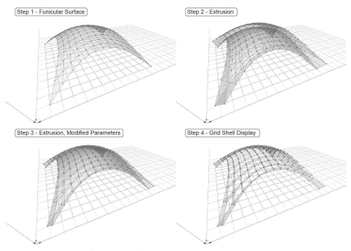
1. Introduction

Researching on different topics, like cable nets and fractals, we found that the research of new ways of designing funiculars was inexistent. Thus we intended to get to something new or different to those well known examples, like Heinz Isler's.

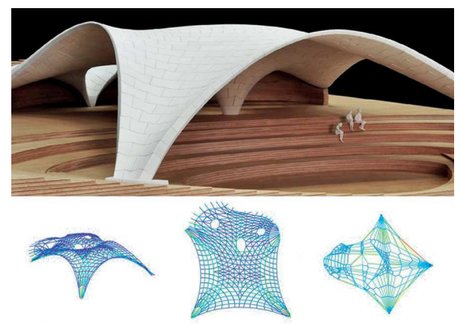
2. Background



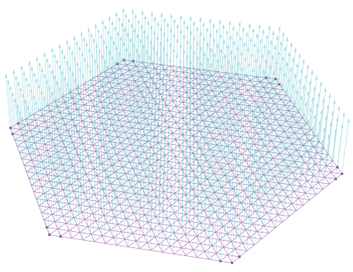
First experiments of Frei Otto and Heinz Isler consisted on the hanging of a cloth or chain system, getting a full tensile system, meaning that once turned upside down it turns into a full compression structure.



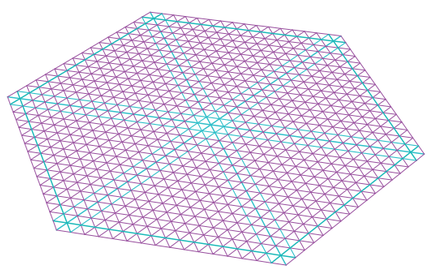
More recently these experiments have been done digitally, with software such us Kangaroo, Catia or Karamba. In the drawings we can see the process from a bare mesh to a final optimised structure.



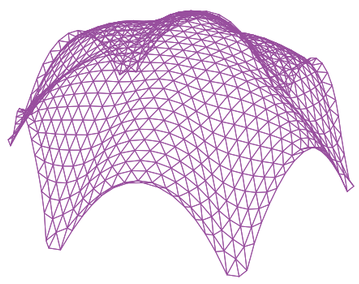
3. Form generation



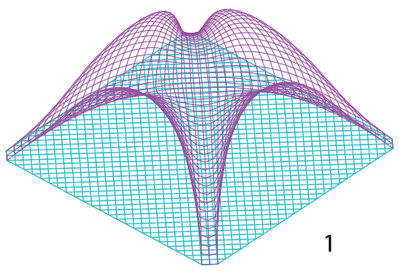
Starting with a mesh, anchors or fixed points are applied together with the points that will move up.



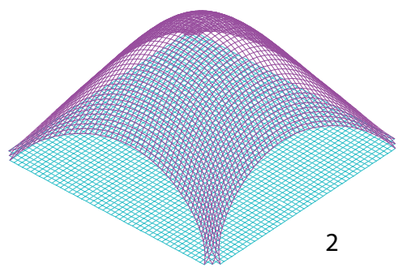
We define several tensors which define the valleys and montains for the final shape.



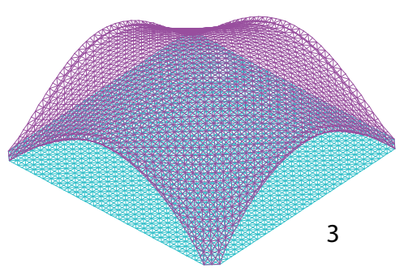
Final shape, converged mesh in kangaroo.



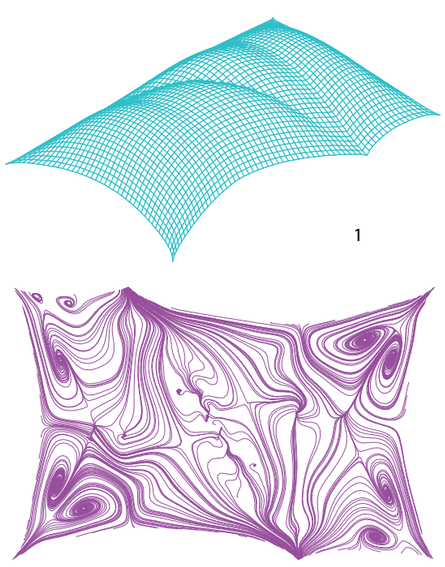
At this point we analysed how different mesh patterns produce different final shapes. For

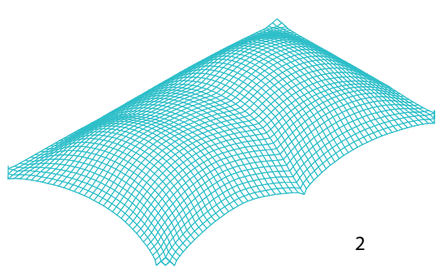


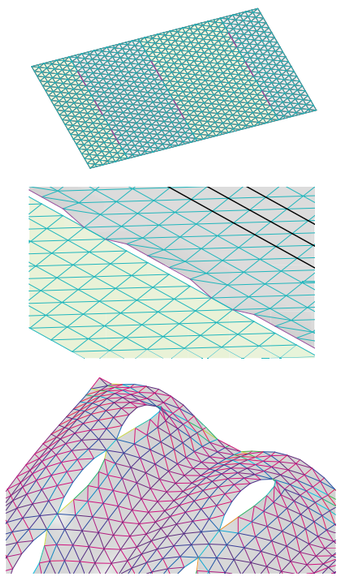
this evaluation we used a simple form like a square in which we applied different patterns:



1.diagonal grid
2. quad grid







During the formfinding, with the purpose of creating some wrinkles on the surface we tried:
1.Putting a cable under the model while taking shape.

2. Increasing the number of pickpoints, which resulted to be the smoothest.
Also we jumped to the conclusion that crosswise lines collide with the grid resulting on an unoptimised shape.

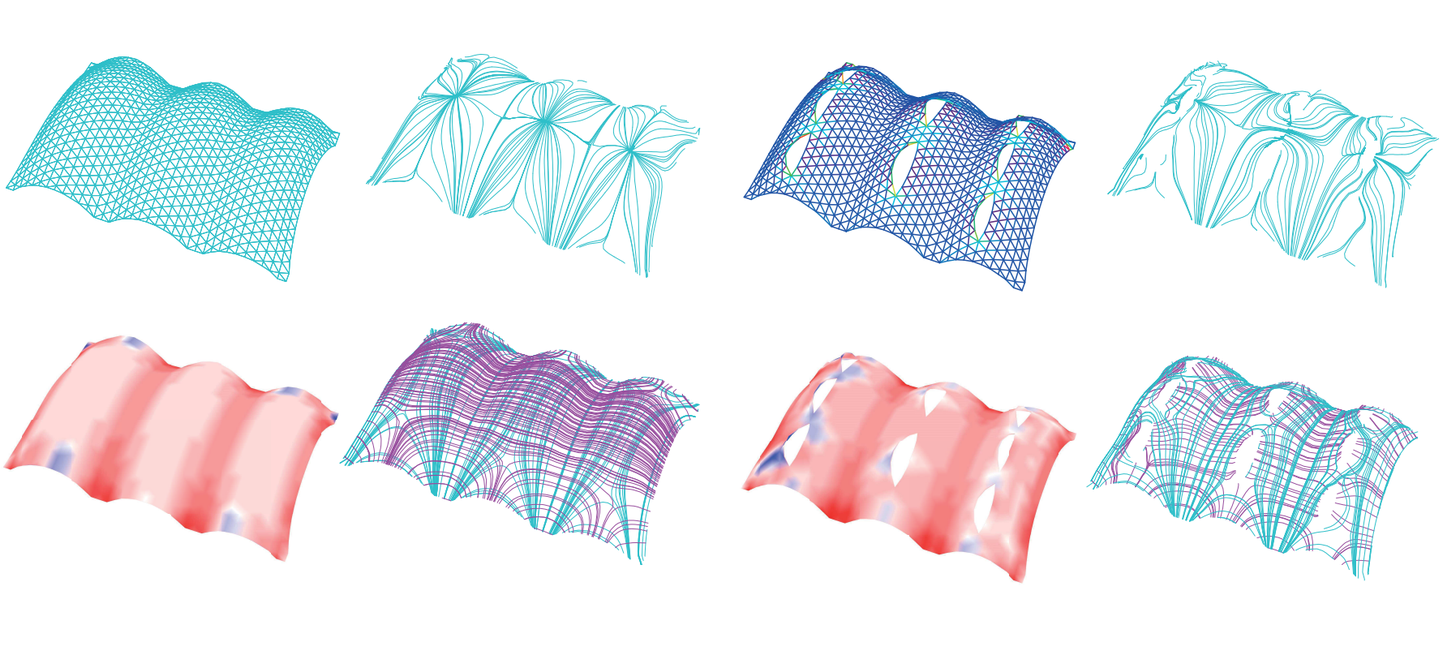
To make the apertures on the vault, we followed the procedure below:
1. Split the mesh through the aperture planes and weld it with the aperture points separeted.

4. Tech implementation

2. Assign different strenghts to the edges. In the graphics above, represent the interpretation of the forces given in the previous operations, in order to get a clearer or better ordered structure, and also an optimization of the material.

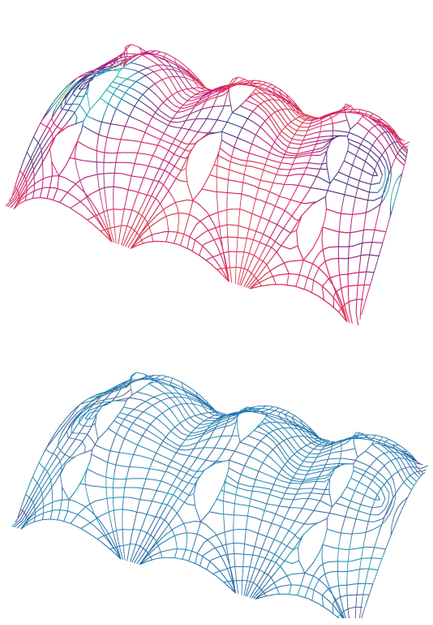
First representation, on the left represents the principal stresses. On the right secondary stresses.

5. Performative analysis



Comparison of the vaults with either continuous and uncontinuous (with openings) structures.
We compare how the edges of the mesh change, the forceflow, the utilization, and also principal stresses.

The results of both the stresses and the forceflow were used to place the openings in the less harmful location.
In conclusion we observed that the openings do not affect the structural behaviour too aggressively.



Doing the reinterpretation of the stress graphics , we reparametrized in order to get a beam structure out of the original approach.

6. Conclusions

Based on the classical structure a funicular shell is (also very characteristic through Catalan architecture), the purpouse was to create a new modern structure out of the main characteristic of these buildings, the pure compression efforts.
After our first approach with continuous meshes, we realised that we could add some new qualities to these kind of buildings as using a beam structure to get the same efforts also we found out that we could add apertures without getting important tensiles.

7. References

Thomas Herzog, Julius Natterer, Roland Schweitzer,Michael Volz & Wolfgang Winter.*Timber Construction Manual*. Heinz Isler and Frei Otto experiments.

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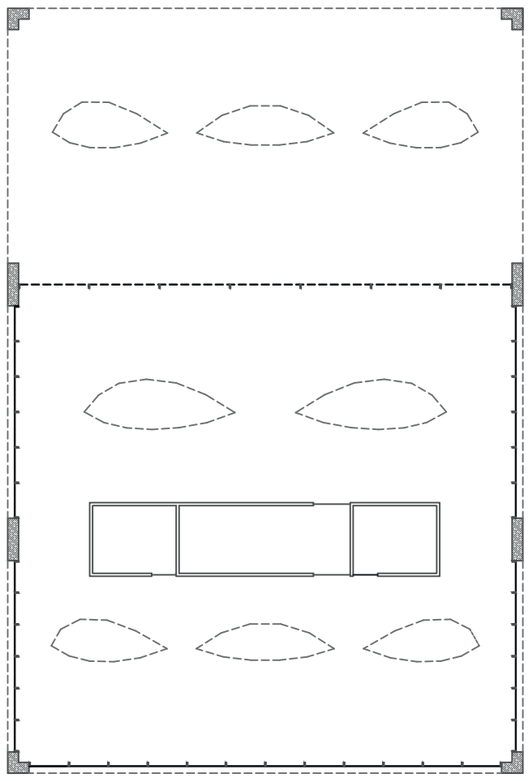
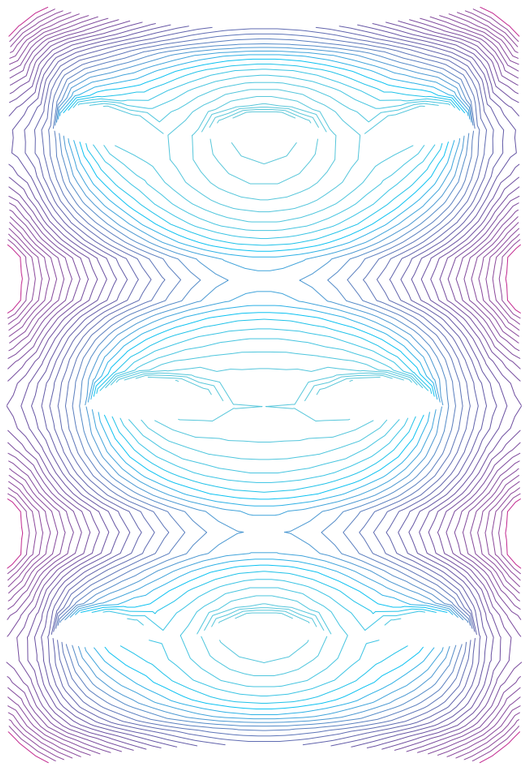
1. Documentation

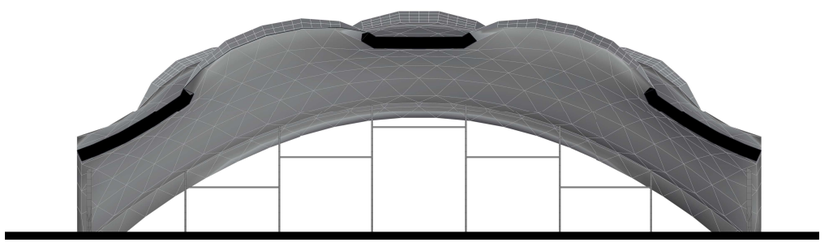
The project proposed consists on a wood work lab. For its construction we used a shell composed by a wood structure, as a metaphore for the work which is going to be developed inside, also we used curtain walls to close the space without claiming for attention and finally a white aluminum skin, to protect the structure behind, as well as the machinery inside.
Geometrically we divided the shell into three parts, meaning it has eight supports. In between the three different parts the enclosure as well as spaces needed (like office,storage). On the other hand we have a third of the structure unclosed, so that the workers can work on some pieces outside, or use it as an exhibition area.

Plan

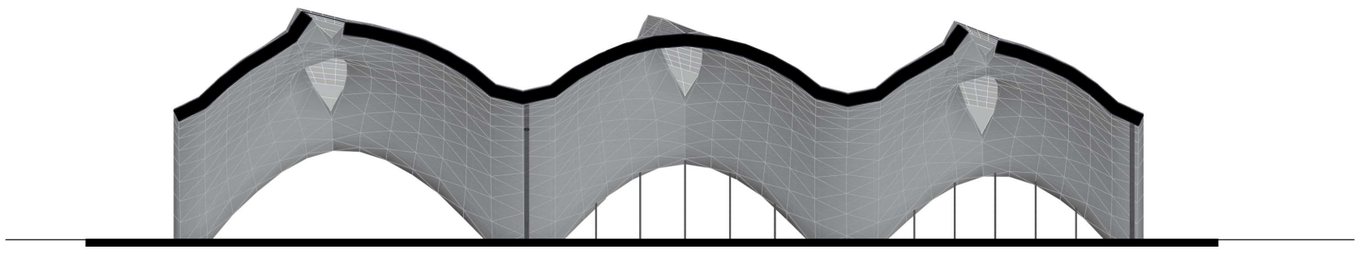




Transverse section

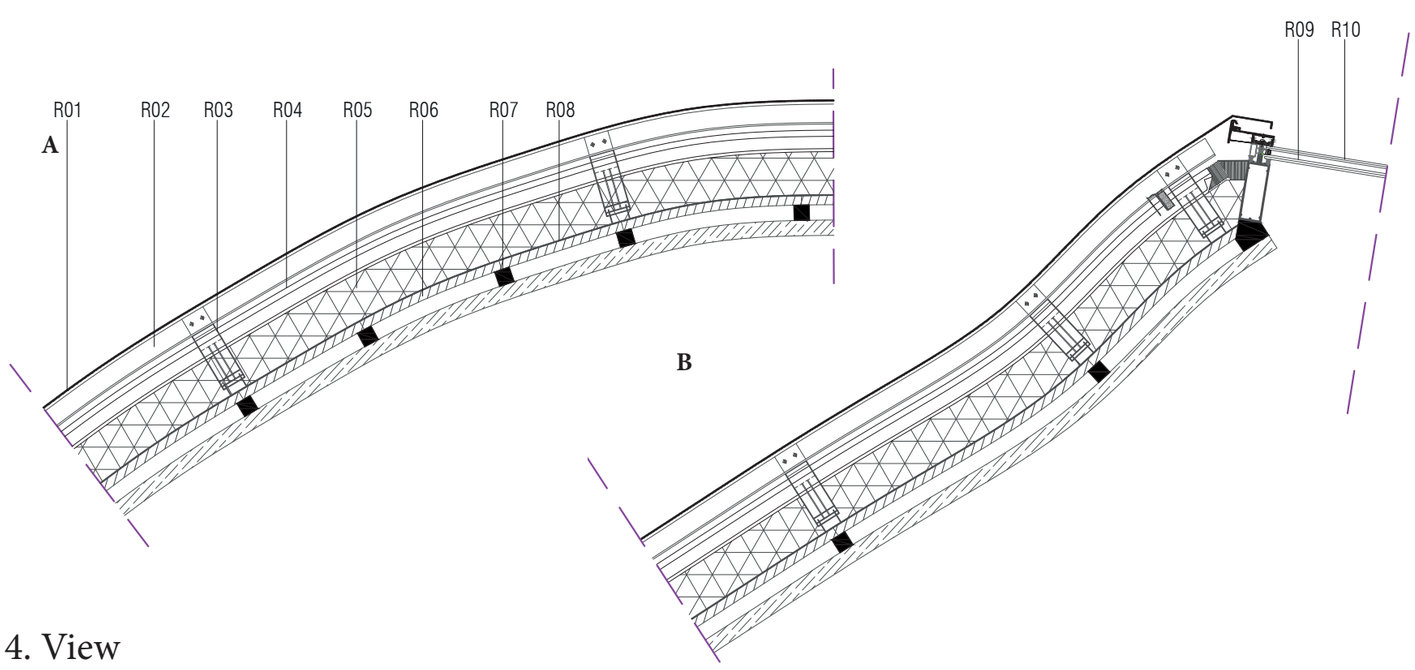


Longitudinal section

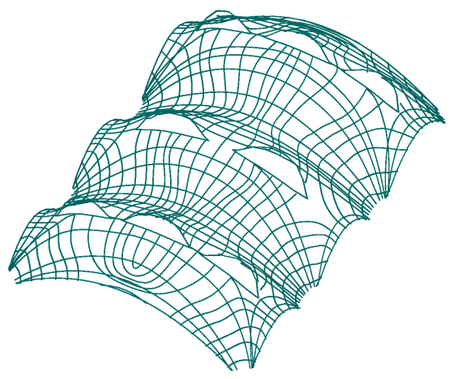


2. Elements

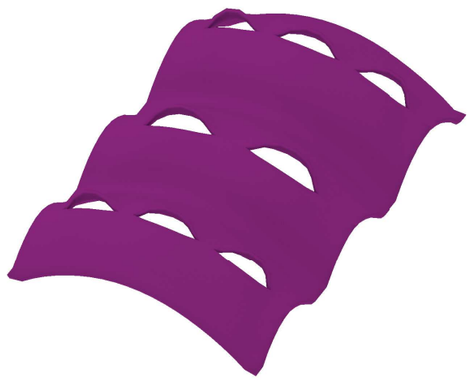
R01_ Two layer aluminium with mineral central nucleus, ALUCOBOND paralel to the direction of the roof 7,6Kg/m²,blanco metalizado.
R02_ "U" section profile to support the finih of the roof.
R03_ Polyamide clip to fix the aluminium panels, 65mm, KALZIP.
R04_ Aluminum panels finish 1mm thick, with standing seam and clips.
R05_ Rigid insulation panels, 140mm thick. Fire Protection EUROCLASE A1, noise αw = 1.
R06_Table boards for roof supporting.
R07_Wood profiles variable section Pynus sylvestris, E:1050KN/cm²
R08_vapor barrier
R09_Skylight with profiles compressing the glass vertically while fixing it to the main structure. Horizontal sealing between glasses to avoid water to accumulate. EPDM joints. 30mm PVC profiles for Thermal Bridge breaking
R10 Double glazing, climalit (6+6/16/6+6). Clear glass.



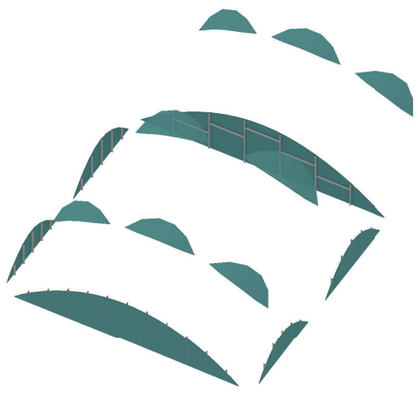
3. Construction sequence



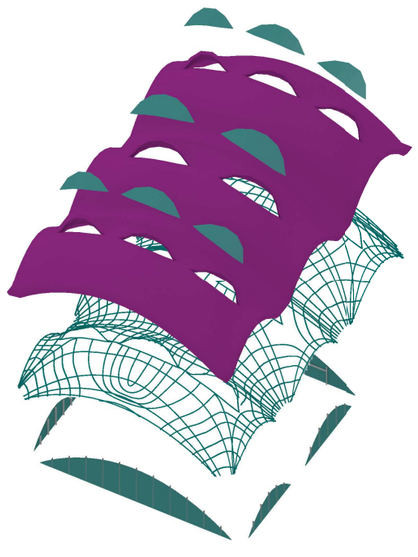
1.The main structure is composed of wooden beams, reinterpreted from the forceflow of a continuous mesh.



2.Over the main structure we have a proper aluminium shell, with its own supports and insulation, which conforms a proper shell.



3.The carpentry is the last thing added (both skylights and curtain walls).



Exploded axonometric view of the construction sequence.

4. View