From NURBS to Textile Architecture

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Summary. NURBS models are used in the architectural design to develop new geometries. This document describes the process from the pure geometry to a feasible membrane shape, which is still compatible with the design intend of the architect.

1 INTRODUCTION

More and more design tools like Rhino are used in the development of geometry driven architecture. Very often the intent is to use textile materials to realize these shapes. Especially monolithic geometries modelled as NURBS surfaces have typically synclastic curvature, while the use of textiles, unless they are not inflated, requires typically anticlastic curvature.

But even anticlastic shapes, generated with NURBS surfaces have typically less restrictions than membrane shapes generated with a normal formfinding process.

2 TUBALOON, KONGSBERG JAZZ FESTIVAL

Since 1965 in July, one of the most important Jazz festivals in Norway takes place, in Kongsberg, 80km west of Oslo.

The shape of the stage roof is inspired by the inner ear and by wind instruments. In the initial design the perimeter beam of this structure was made as Tensairity beam. Due to the shape of the beam high bending and torsion moments occur, so that a slender steel arch was used for the final concept. The pneumatic ring was kept in the design, and helps to prestress the closure flaps.

The shape was developed with geometric design tools. The structure is sitting on 2 nodes, has one big arch over the stage, one small backstage arch and a "flying ring" sitting on the small arch.

Based on the architectural design we have started a first formfinding, assuming a reasonable stress ratio in the prestress stage. This led to a much wider neck and a higher saddle. In an iterative process we have adjusted the shape to be best fitting with the architectural concept.

Figure 1: Initial design

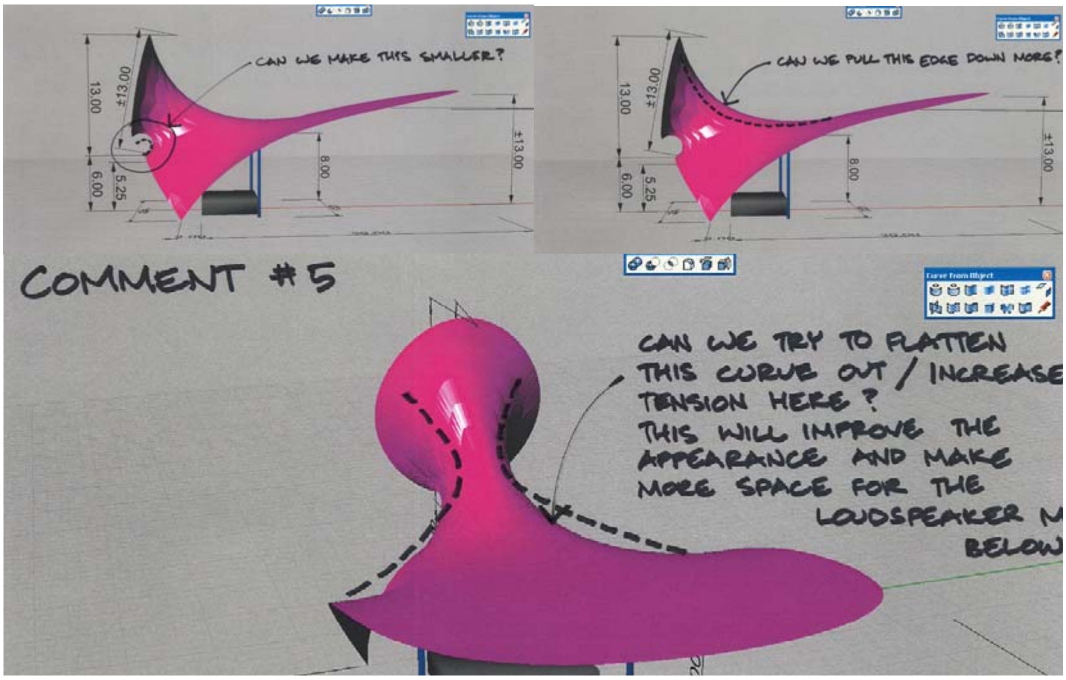

Figure 2: First formfinding commented by the architect

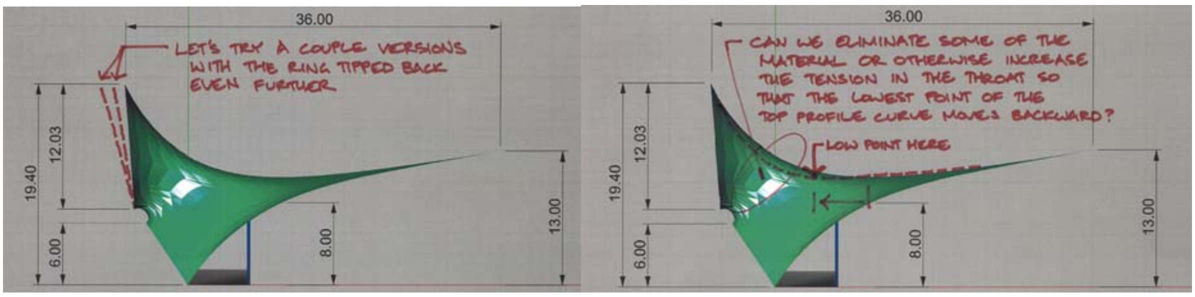

Figure 3: Improved geometry with further comments

It was then decided to vary different parameters in the formfinding process to obtain a shallow neck and a low saddle. The ring inclined backwards led to a high saddle, so that we checked also different ring inclinations and their impact

Within these parameter studies we ended up with a satisfactory shape. The stress strain ratio is varying over the whole structure to allow the slender neck, but we had still enough width to realize the structure with continuous membrane strips.

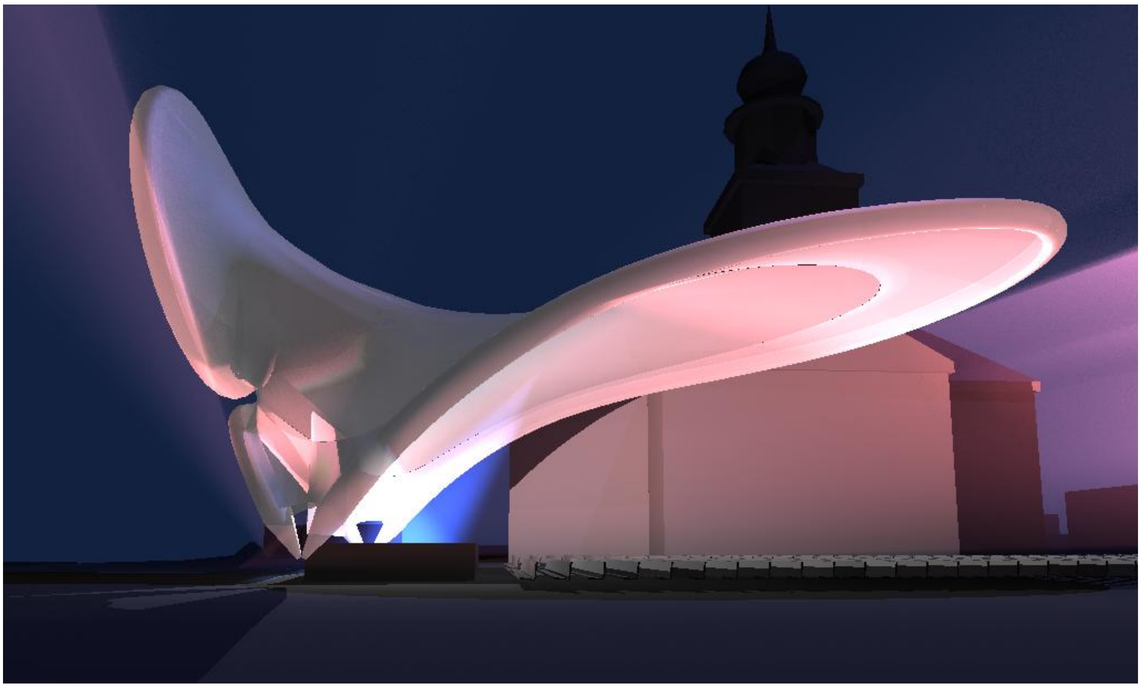

Figure 4: Rendering with the final membrane shape

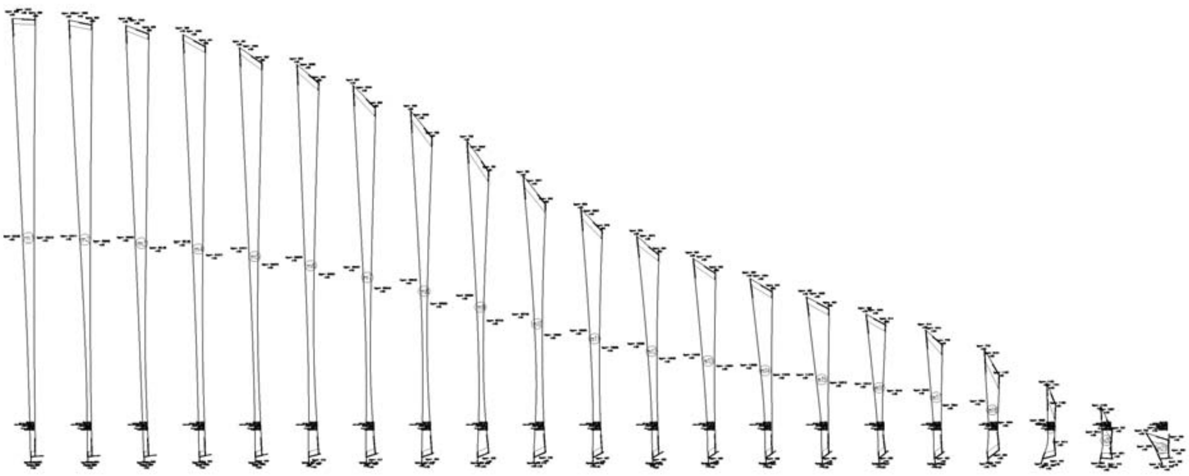

Figure 5: Cutting Pattern of the main membrane

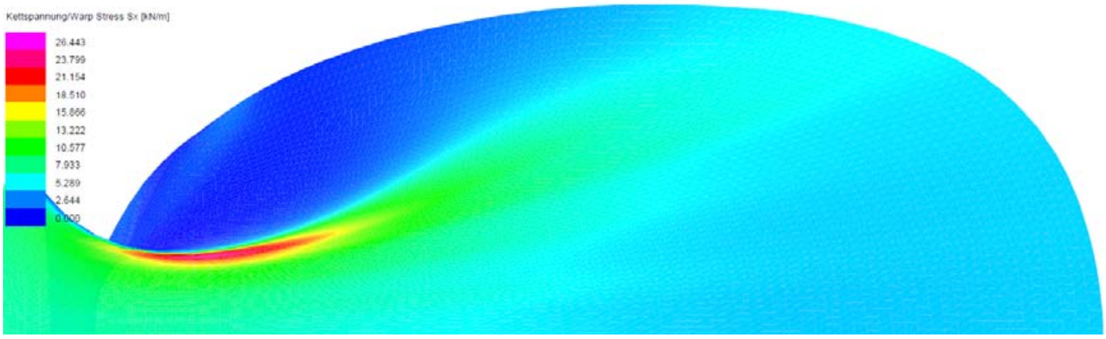

Figure 6: prestress in warp direction

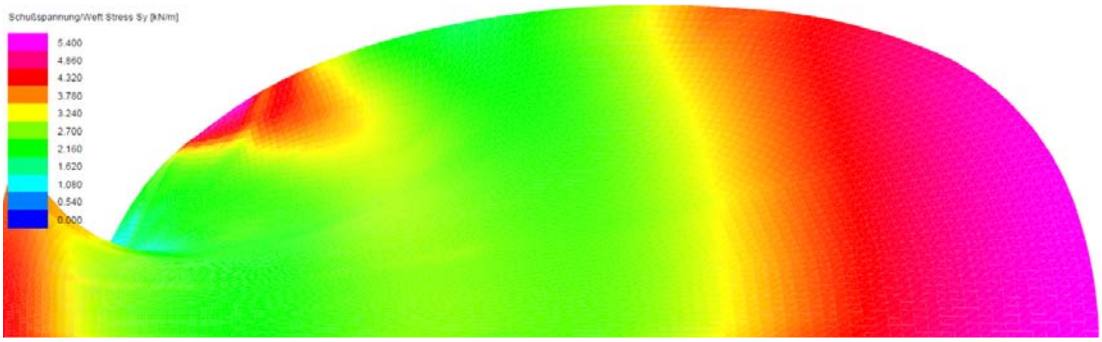

Figure 7: prestress in weft direction

Figure 8: installed structure

3 ZÉNITH DE STRASBOURG

Close to Strasbourg the 18th Zénith of France is situated. The Zéniths are concert halls for «musique populaire» from rock to pop up to musicals.

The inner part of the building is not disclosed at first sight. It consists of 30 cm reinforced concrete which is formed by the lines of different curve radii to achieve an optimization of maximum capacity and best view. The reinforced concrete was selected to have the best possible control over the acoustic.

The oval form was chosen as sculptural element, its monumental volume gets some easiness by the ellipses of the steel structure. 20 steel girders form a sort of access balcony around the massive core and build the primary structure for the façade structure which carries the membrane. 5 horizontal steel rings with a tube diameter of 50 cm enclose the whole building. Like the orbits of the planets they have different distances and inclinations. This leads to a dynamic appearance which is also emphasised by the displacement and rotation of the ellipses.

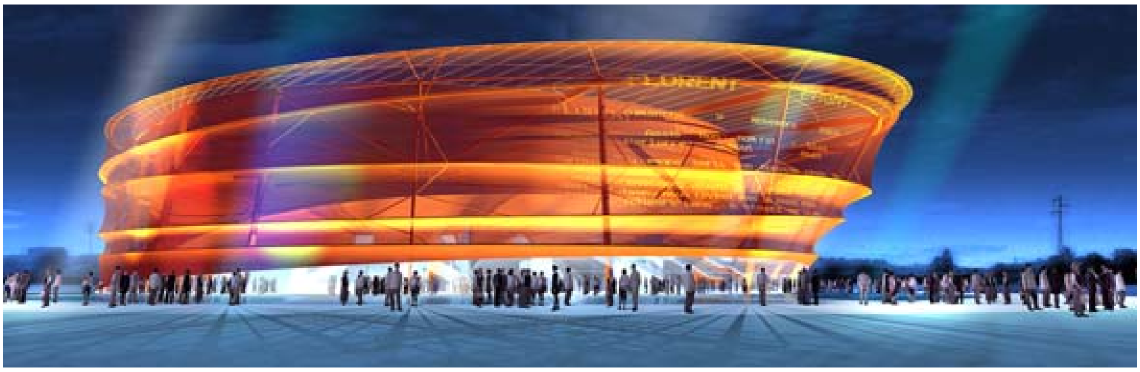

Figure 9: Rendering by the architect

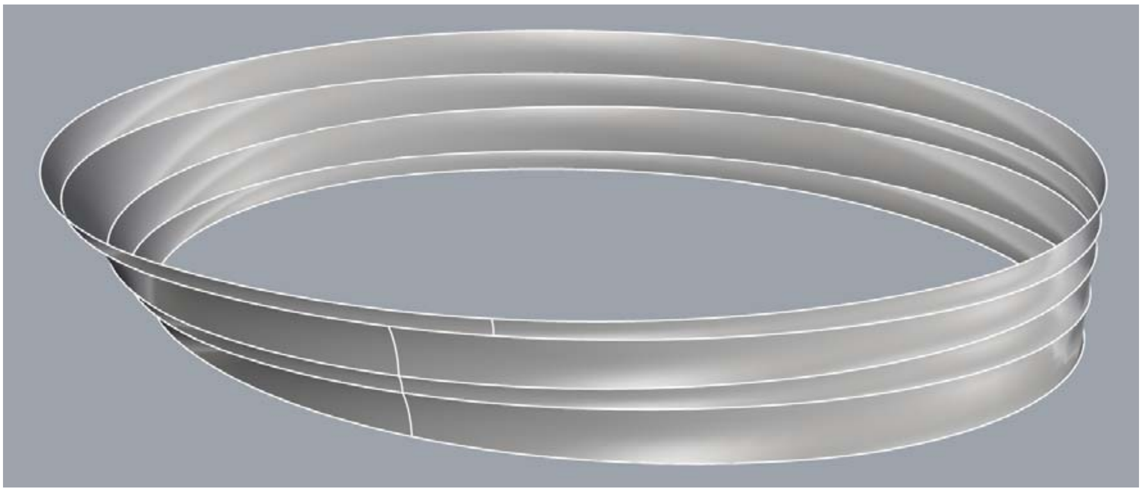

Figure 10: Rhino model

The geometry developed by the architect was based on the idea of having the same membrane length at every point between two rings, so the wide areas were flat, and the small areas were curved.

In the wide areas this would give a reasonable shape, but in the narrow areas the difference of the two radii was approximately 90 m to 2 m. To get an equilibrium, we would need the same ratio, this means if for example the pretension in warp is 1 kN/m, the pretension in weft would be 45 kN/m.

All generated saddle shapes looked very flat and completely different to the architects idea.
Together with him, we defined a solution with additional valley cables, to get a comparable overall shape, but this solution ended up with a very sharp geometry for an even stress distribution, so we increased the pretension in weft to keep the faces slightly curved.

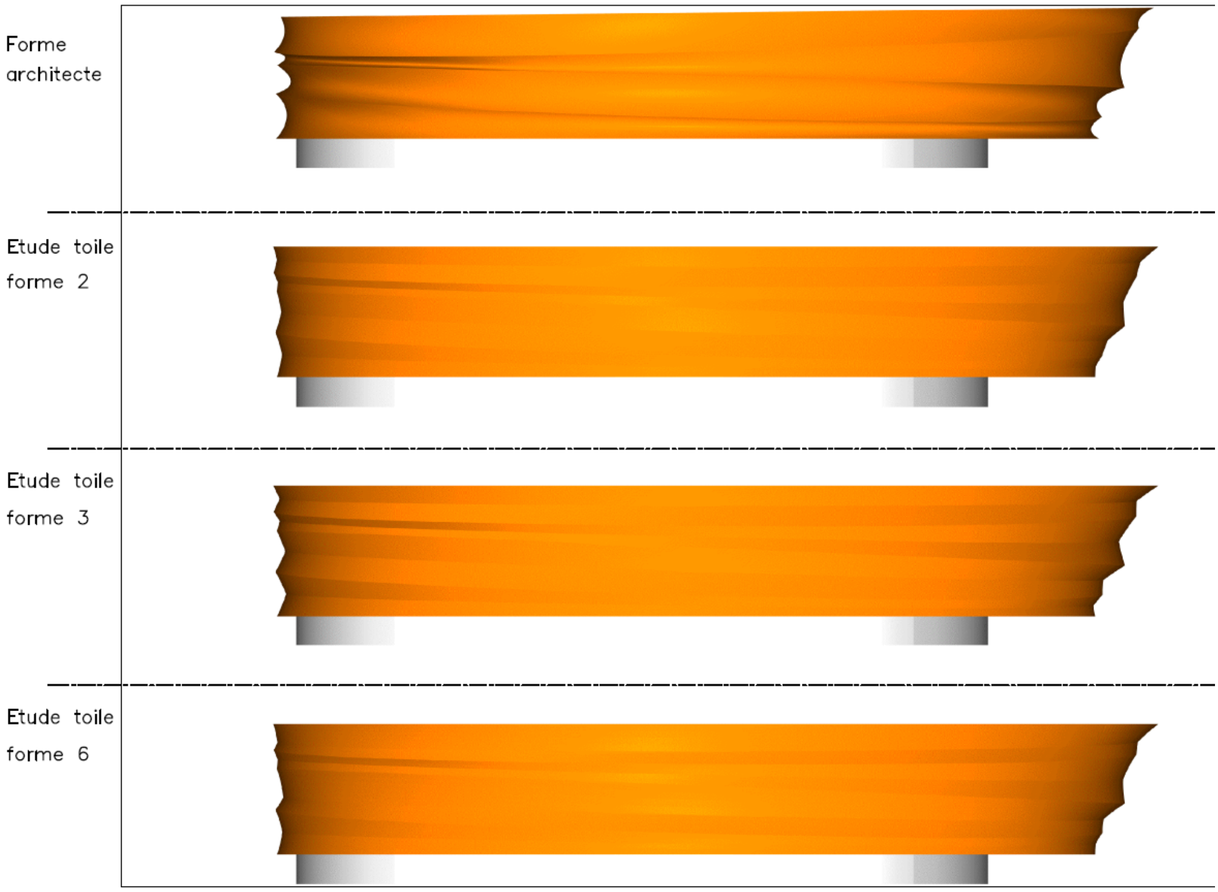

Figure 11: Shape development

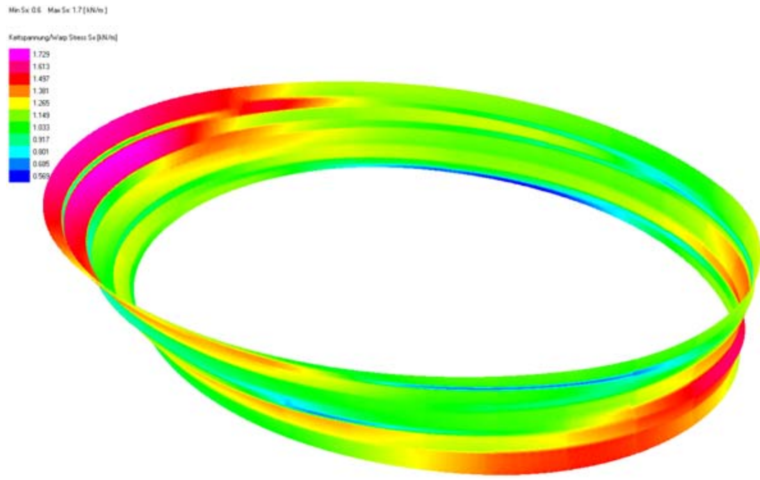

Figure 12: prestress in warp direction

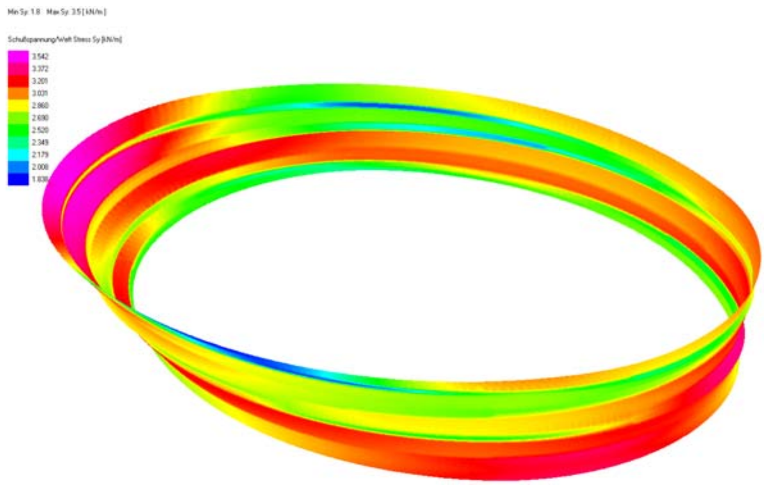

Figure 13: prestress in weft direction

Figure 14: result of the structure at night

4 NUVOLA, CENTRO CONGRESSI, ROME

The project Centro Congressi will become Rome‘s new congress centre. The 200 m long and 75 m high cube is partially sitting below floor level.

Almost floating, fixed with only few points to the ground a cloud, in Italian Nuvola, is dominating the inner space of this huge glazed cube. The Nuvola is a 126 m long and 65 m wide organic shaped object. Inside is a cafe, foyers, conference rooms and an auditorium for 2000 spectators.

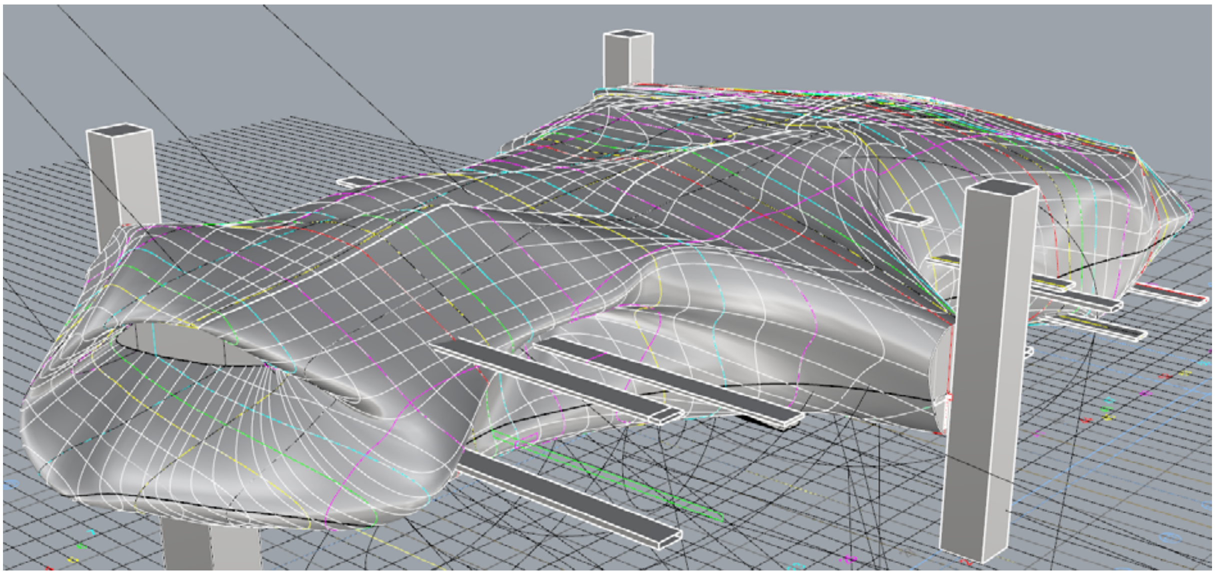

Figure 15: Rhino model from the architect

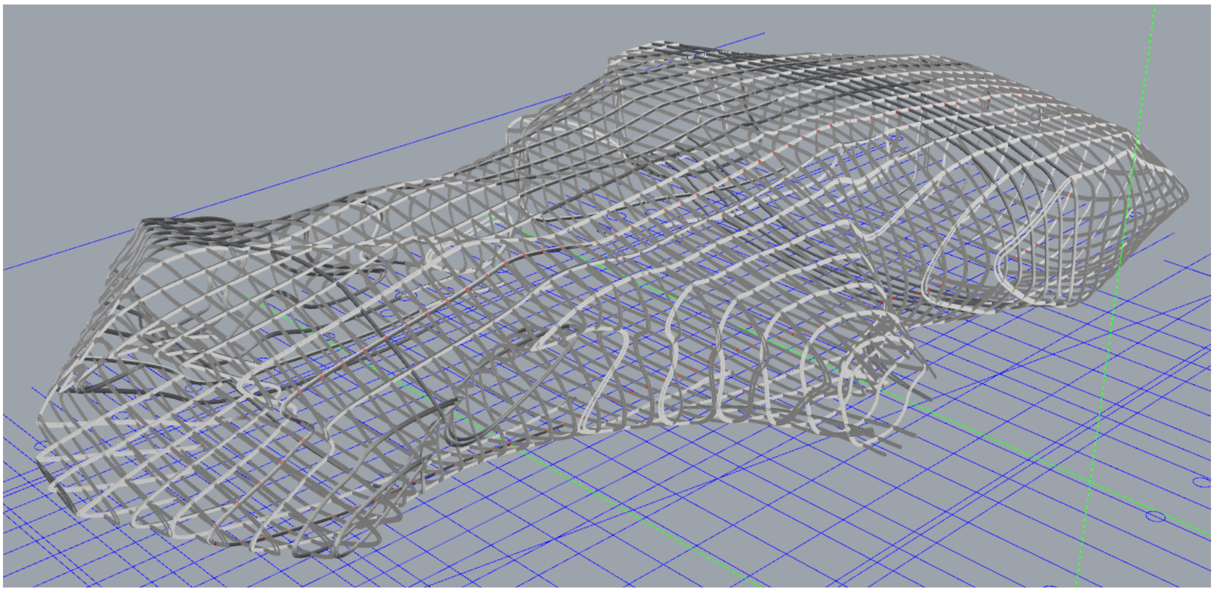

Figure 16: Rhino model steel grid

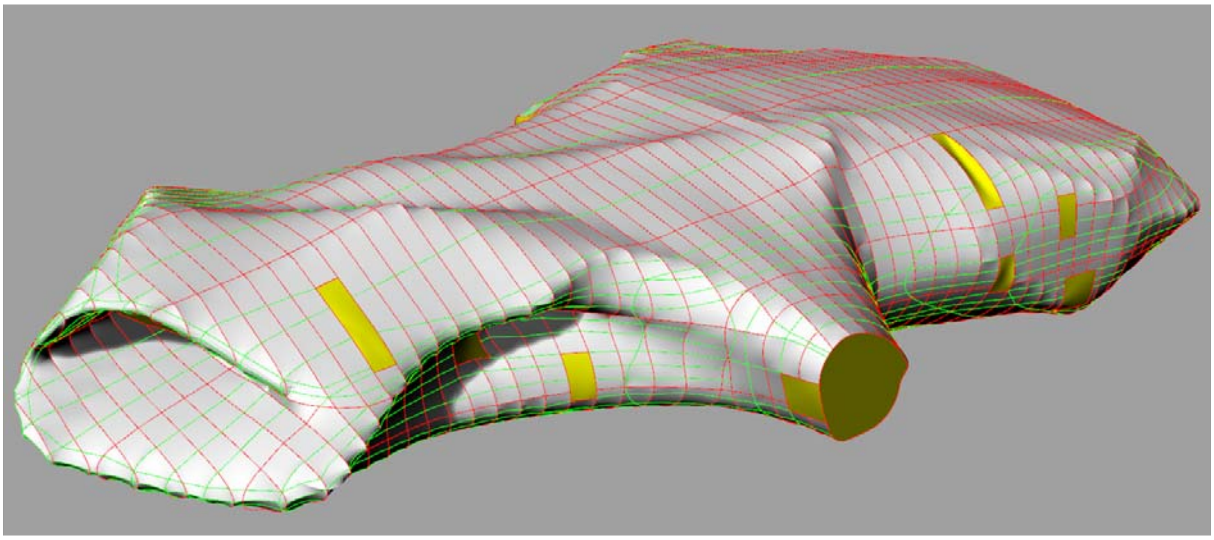

Figure 17: membrane shape (red lines = panel edge; green lines = seam)

The supporting steel structure was developed by cutting parallel planes through the outer surface of the Nuvola. Different possibilities how to cut these planes were checked. The steel consultant decided for orthogonal planes through the surface.

This steel layout simplified the steel production, but at the same time it created many problems for the membrane cladding. Our task is to cover the heavy steel structure with light white silicone coated glass fibre fabric. In curved areas the steel sections were typically not in the perfect location so that we got sharp edges predominating the appearance of the Nuvola.

The initial geometry was smooth and mainly with synclastic curvature. In-between the main sections the membrane formed saddles depending on the curvature of the axes. With the modification of the prestress ratio, only a slight reduction of the saddles was possible.

Figure 18: steel grid and first panels

5 CONCLUSION

Software tools available on the market offer new possibilities to designers in the development of free form shapes. This leads to a wide range of interesting structures and enriches the today architecture.

In a close collaboration between designer and engineer feasible membrane shapes can be generated fully satisfying the architectural intend. Essential in this process is the understanding of each other. Sometimes it is necessary to turn the wheel back in the design process, as if the involvement has been from the beginning.