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THE NUVOLA FOR THE NEW CENTRO CONGRESSI IN ROME STRUCTURAL MEMBRANES 2017

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Key words: membrane, mechanically tensioned, nurbs geometry, formfinding, analysis, silicone coated glass, cutting pattern, extrusion profiles, parametric process

Summary: In Rome's EUR district, a new congress centre has opened recently, designed by the Italian architect Massimiliano Fuksas. The project consists of three main elements, which the architect calls „Teca“ (theca), „Lama“ (blade) and „Nuvola“ (cloud).

The central element located inside the Teca is the Nuvola. Almost floating only with few points fixed to the floor and to the building, it dominates the huge glass box. The Nuvola is a membrane cladded steel structure with a length of 126 m, a width of 65 m and a height of 29 m. It contains a café, foyers, meeting rooms and an auditorium for 2000 spectators.

The paper is about this central element, the Nuvola from the geometry driven design process to the installation. It describes the design process, especially the very complex formfinding process in order to achieve the defined geometry derived from a nurbs shape. The analysis process with mock-up installations is presented, as well as the detailing and the automated process for the workshop design and the cutting pattern.

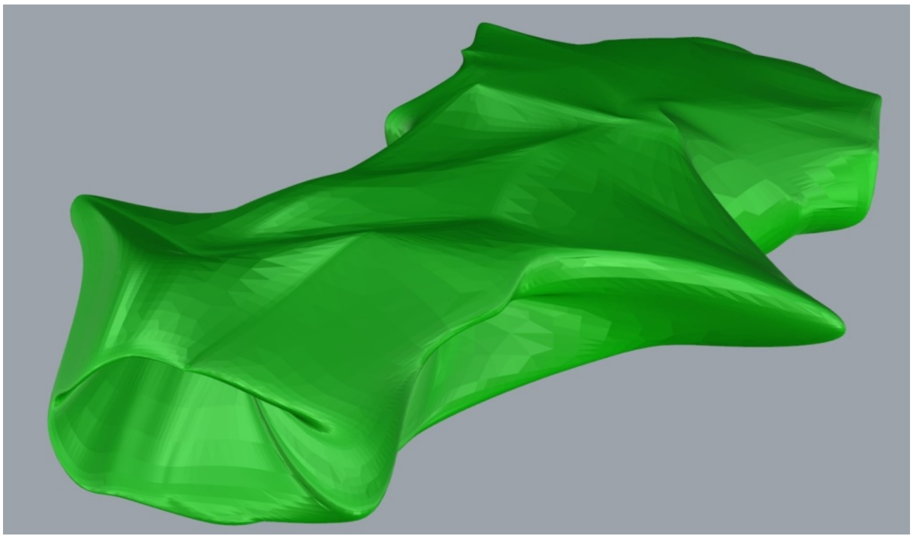

Figure 1: Nurbs model of 2004

1. INTRODUCTION

In 1998 the city of Rome together with the future owner EUR launched an international architect competition, which was won by Massimiliano Fuksas. In 2004 we have received the first inquiries together with a 3D nurbs geometry. The surface was smooth all over the Nuvola.

We made first suggestions for the orientation of a supporting grid, for the details and we tested different seam layouts. We tried to convince the client to start with the membrane engineering and to do a large scale mockup of a critical zone in order to test the different ways to create the shape with a tensioned membrane.

The client decided to continue with a steel consultant, who developed in the following a concept that allowed an easier way to produce the steel, which was then basis of the tender documents. The concept was to cut the nurbs surface in slices in the yz, xz and xy plane.

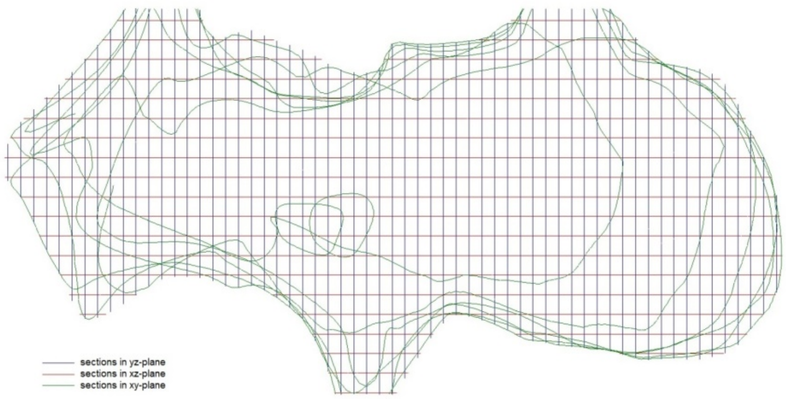

Figure 2: sections of the steel structure

In some areas this created reasonable slices which can easily be covered with membranes, but in many areas the geometry was not ideal and made the shape development of the membrane very difficult.

After a first try with another cladding supplier we have been involved in 2011 in the design of the membrane cladding. The interface to the steel had been defined with small studs made of rectangular hollow sections, where the initial contractor was supposed to attach his cladding.

The majority of the steel was already in place when we started our design, so that we had to find a detail that fits to the existing studs in the steel. The studs were oriented in the plane of the section, which led to geometry problems where one section joins the other. Different inclinations led to different levels which needed to be compensated with the attachment lines of the membrane.

2. ANALYSIS

Due to its location inside the building, the membrane is only loaded with internal overpressure. For the overall project a wind tunnel test has been performed by the University of Florence in their wind tunnel in Prato.

The static pressures on the inside and on the outside of the Nuvola membrane are equalizing one against the other, only due to fluctuation differential pressure it is acting on the membrane. The dynamic wind pressure used for the project is based on a 100 year return period. As the fabric cladding is not part of the primary structure and has a lower life expectancy, a return period of 20 years has been applied for the fabric.

With all these assumptions the wind load to be applied on the membrane has been determined with +/- 0.14 kN/m².

The material used is a silicone coated glass fabric with an acoustic punch pattern, to improve the sound absorption. The raw material has a tensile strength of 52 kN/m in warp and 40 kN/m in weft. Due to the punched holes and the stitched seams the strength is reduced.

Based on tensile tests performed, admissible stresses in the service limit state had been determined for permanent load (prestress) and for wind load. The admissible stress for permanent load was determined with 2.3 kN/m in warp and with 2 kN/m in weft. For wind load the admissible stress has been determined with 2.7 kN/m in warp and 2.4 kN/m in weft.

The membrane shape has been defined with an initial prestress state of 1.5 kN/m in warp and 0.5 kN/m in weft direction. In areas with sharp edges this ratio has been changed to 2.4 kN/m in warp and 0.4 kN/m in weft.

For the stress analysis a relevant numerical model in Zone 2 has been analysed. The shape was determined as a tension surface in-between the rigid support lines of the Nuvola. The saddle of the membrane was in the sharp edges of the Nuvola rather deep, and in flat areas almost negligible.

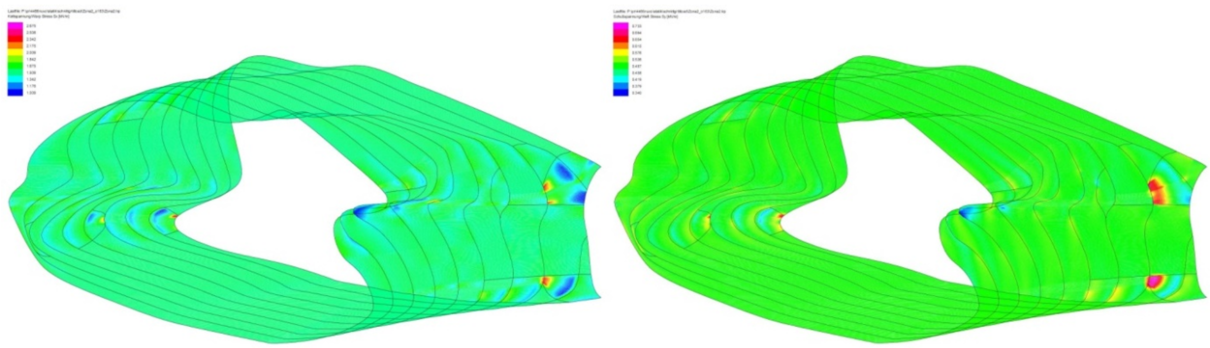

Figure 3: numerical model zone 2 - prestress state warp and weft stress

3. MOCK-UP

In order to test the details a mock-up of the most difficult area has been made. The seams should follow as much as possible the axes of the steel structure. Additional seams were necessary in areas with high curvature. In 2012 a third mock-up was introduced, which showed the minimized number of seams and represented the membrane shape with adopted stress ratio in heavy curved areas.

Figure 4 / Figure 5: First tensioned membrane mock-up / Second tensioned membrane mock-up

The conclusion of the mockup phase was that in no area of the project a distortion angle higher than 5° should be allowed, and that additional seams are needed to allow this. Furthermore a reasonable saddle should be kept even in sharp areas, so that the membrane is able to redistribute loads in both directions, and reduce stress peaks.

4. DETAILS

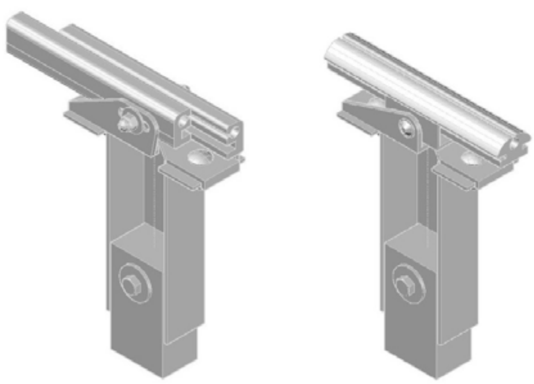

Figure 6 / Figure 7: stud detail of the steel structure / isometric view attachment and push up detail

As mentioned before, the steel structure has in a regular distance of typically 400 mm steel studs, where we had to fix the brackets for the secondary structure. We have developed a detail that consists of a channel section screwed laterally to the studs. A slotted hole allows the adjustment of the details. On the top, two extrusion profiles are attached to fix the membrane panels. The extrusions can be moved horizontally to compensate tolerances.

Where the membrane saddles come too close to the steel structure a push up profile has been inserted, this is a round extrusion profile which is redirecting the membrane around the steel structure. In some areas this push up profile is also used to pull the membrane, therefore the extrusion allows also to insert a keder.

The complex geometry of the project required to have these details with different heights and with different inclinations. All brackets are made with a reference line marking, and on the survey drawings for installation the level for all brackets differing form the standard are given. The brackets have been developed with a parametric design in the Inventor software, which allows an easy adaption to the different levels and inclinations.

For the detail development and the workshop process of the attachment lines an automatic process was developed. The input data were reference nodes on each stud in one section, which has been offset and splined. Along this spline, the bended extrusion profiles have been generated with machine ready dxf files to cut from the straight profiles and with all bending and drilling information. Where the brackets are inclined, the profiles needed to be bent in two axes.

In total approximately 6500 different pairs of clamping have been generated and approximately 180 different types of brackets.

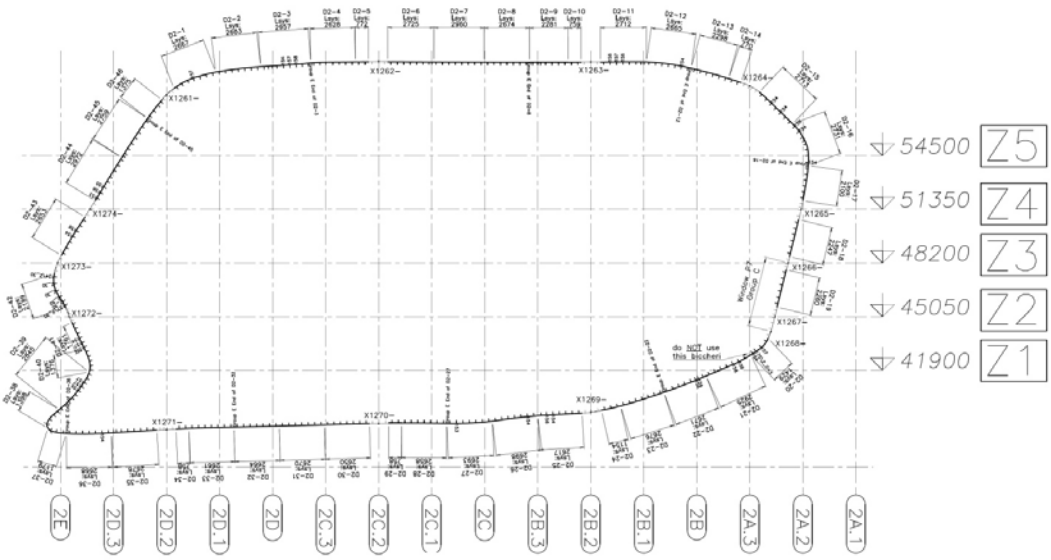

Figure 8: generated overview of clamping profiles in one section

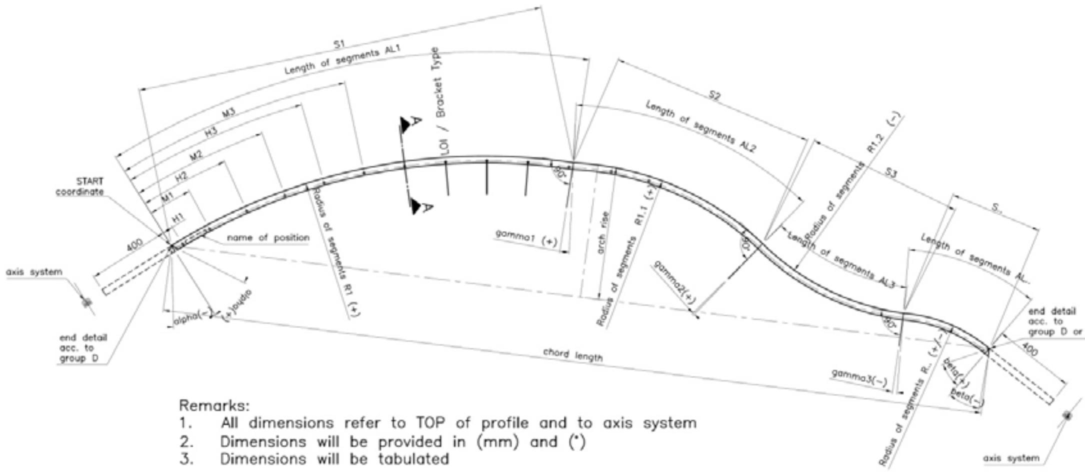

Figure 9: principle drawing for the generated clamping profiles

To avoid steps in the crossings, the attachment lines are joined with typically four sets of twisted twin profiles. The software generating the standard profiles left the space open and generated the input geometry and data for the software which generated the crossings. Also generated by this software generated are machine ready drawings for all profiles.

5. SEAM LAYOUT AND PATTERNING

Very important for the appearance of the Nuvola is the seam layout. The architects asked us to follow as much as possible the steel structure with the seam layout. As the curvature in many areas is rather high, it was necessary to add there additional seams in between the steel axes.

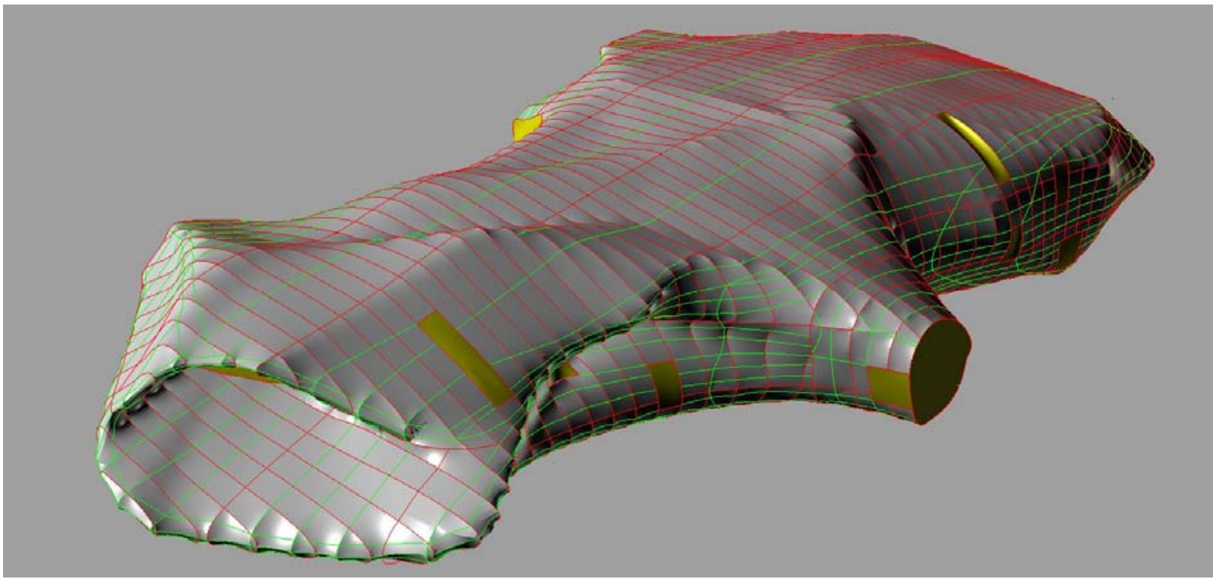

Figure 10: View on the "mouth" above the entrance

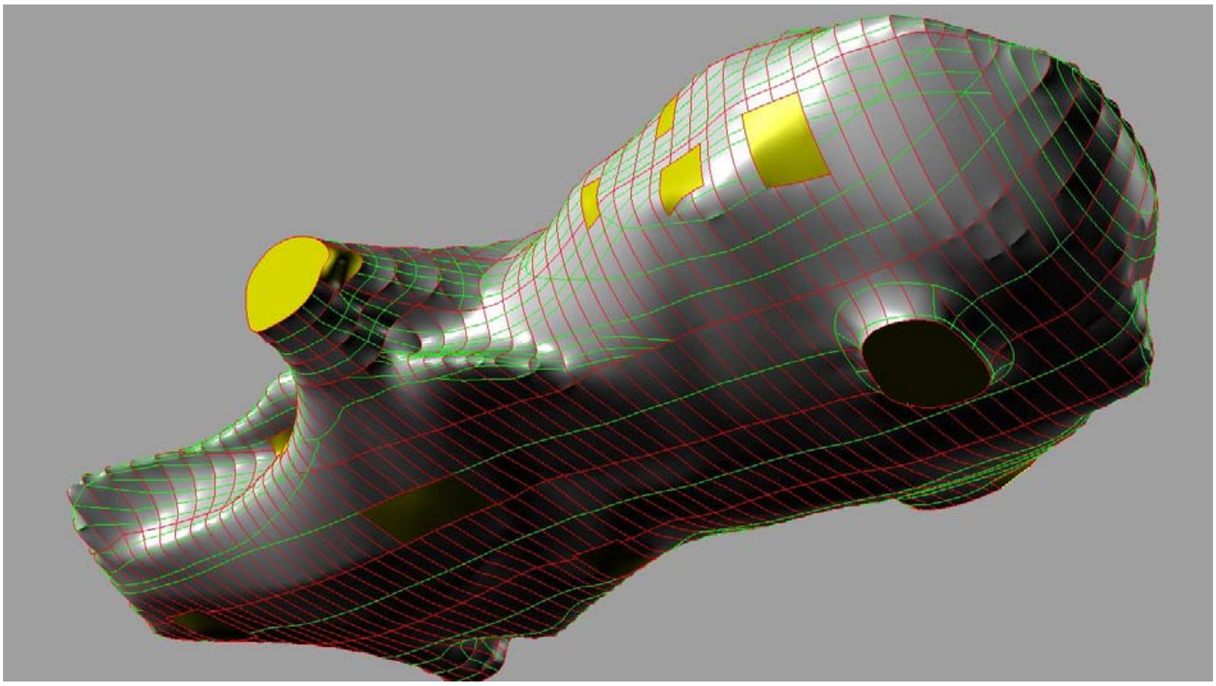

Figure 11: View form below

In a very long coordination process with the architect we determined the seam layout. In the following figure the version number 18 of this coordination process is shown, which was the finally agreed layout. The red lines show the panels borders, which are formed by the clamping lines, and the green lines show the stitched seams inside the panels.

This agreed seam layout was the basis of the patterning model. Many panels consist of only two patterns, some of only one, but all of the difficult ones consist of more patterns. The patterns are joined with stitched seams. The seam has been optimised with regard to the fabrication speed and to the resistance based on tests.

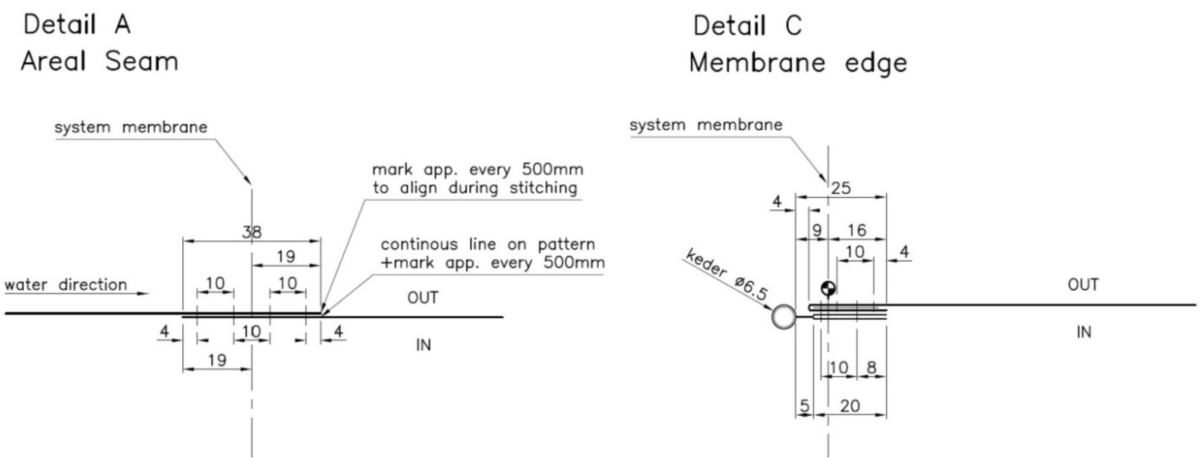

Figure 12: membrane details

6. REALISATION

The manufacturing of membrane clamping required highly specialized personal and methods to control the pre manufactured pieces.

Figure 13: work shop control template

The surface area of approximately 14000 m² has been realized with 607 panels which consist of 2763 individual cutting pattern. The panels have been have been joined with stitched seams.

Figure 14 / Figure 15: stitching process / packed panels

The logistic on site benefits from the workshop documentation, which provides information, which allows the site staff to organize their activity.

Prior to installation on site dimensions were taken to check, if as built dimensions of the primary steel match with the secondary structure.

The activity on site was divided in two lots. First all the clamping elements were installed. In this phase the accurate fit and functionality could be tested.

Figure 16: steel structure with installed secondary structure

The second step to install the membrane panels was launched at a later phase. The strategy was to install the visually highly relevant and most delicate membrane after a possible pollution from other trades is reduced. The membrane installation was executed with climbing personal, since traditional methods were not flexible enough. The membranes needed to be installed from the inside of the structure as façade parts, roof parts outside down and roof parts outside upwards.

Figure 17: installation from inside

The segmentation size of the membranes allowed to move the material in position and attach it to the secondary structure without heavy equipement. All the adjacent panels were installed to a reduced stress level. In this situation the joints between the membranes were slightly open. Finetuning like aligning the seams was possible at this time.

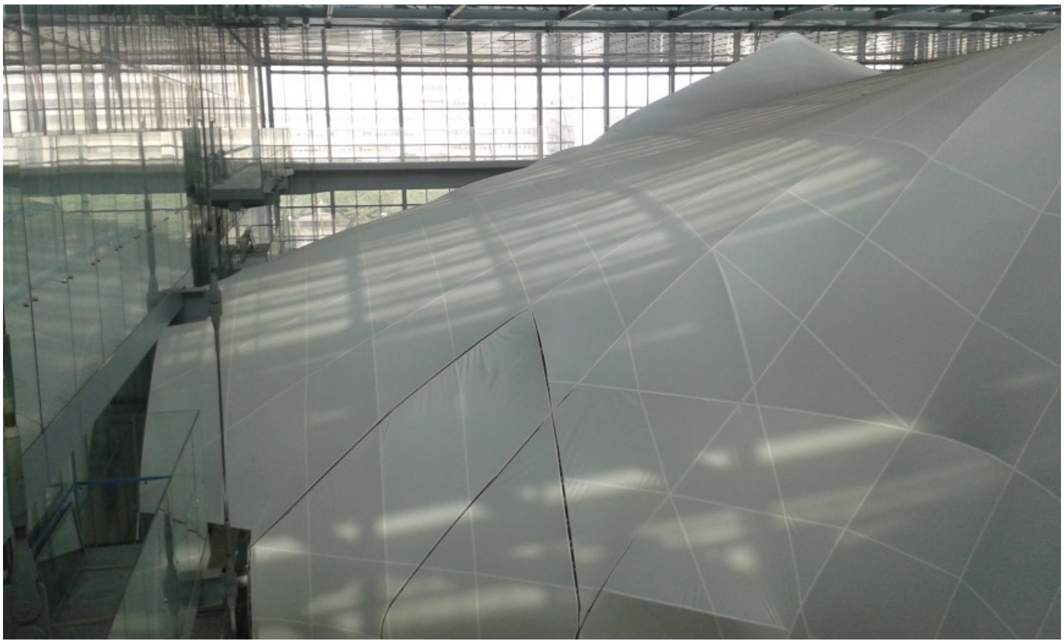

Figure 18: open joints during installation

In the final installation step the joints were closed by turning the bolts in the double clamping channel. No addiontal access from outside was neccessary.

Figure 19: outside view zone 5

7. CONCLUSION

The Nuvola is a complex project, different from all other tensile projects. The panels are very small and the amount of attachment details is very high. The shape is difficult, and the constraints of the project are higher than usual. The design tools had to be improved as much as possible, so that the big quantities of drawings and fabrication documents could be finalised on time.

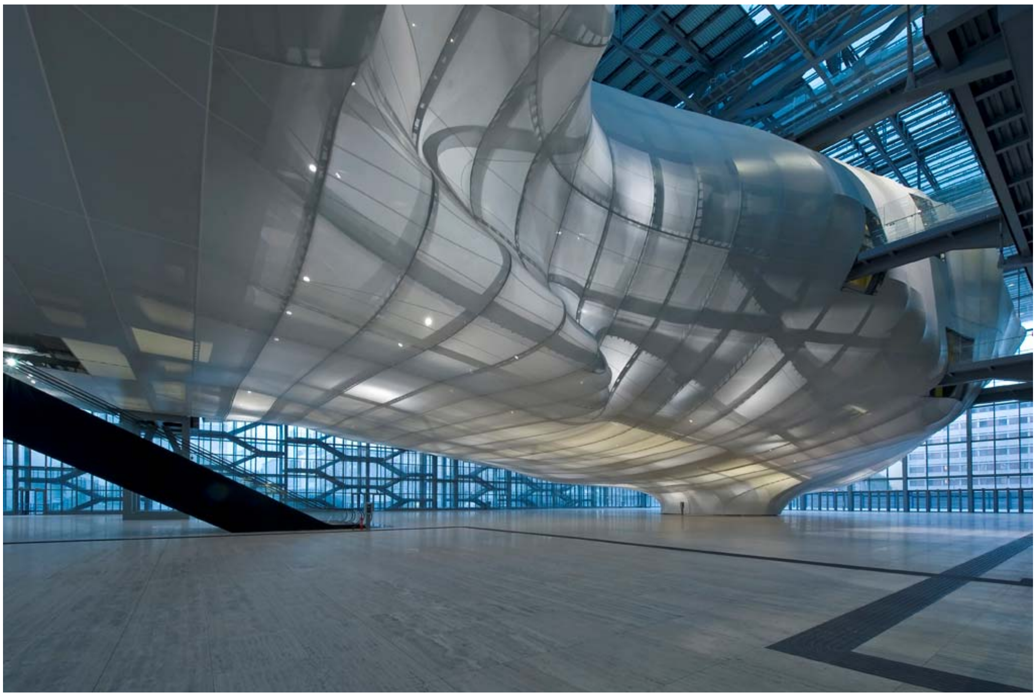

Figure 20: bottom view zone 3/4


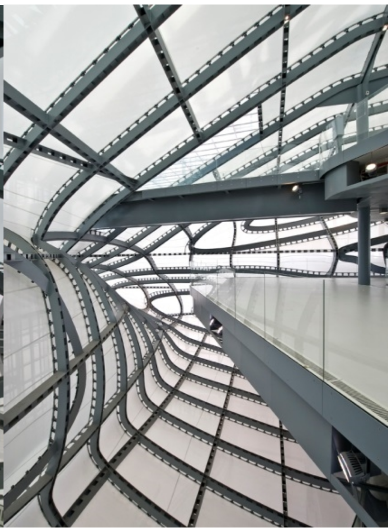

Figure 21 / Figure 22: View through the “mouth” / inside appearance


Figure 23 / Figure 24: general view form outside / Nuvola zone 1a

PROJECT DATA AND PARTICIPANTS

Name of the project: Nuvola del Nuovo Centro Congressi, Rome
Location address: Via Christoforo Colombo, Rome
Function of building: Convention centre
Type of application of the membrane: mechanically tensioned
Year of construction: finished in 2016
Material: Atex 2000 with punch pattern WS 14
Membrane surface area: 14400 m²
Client (investor): E.U.R. S.p.A., Rome
Architect: Massimiliano Fuksas, Rome
Consulting engineer for the membrane: formTL, Radolfzell
Main contractor: Condotte S.p.A., Rome
Contractor for the membrane (Tensile membrane contractor): Canobbio, Castelnuovo-Scrivia
Supplier of the membrane material: Valmiera Glass UK, Sherborne
Manufacture: Canobbio, Castelnuovo-Scrivia
Installation: Condotte S.p.A., Rome

PICTURE CREDITS

Figures 1 to 12 formTL and Canobbio, Figures 13 to 18 Studio Moreno Maggi

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