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Multi Purpose Membrane Structure in Abano Terme

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Key words: Membrane Cladding, Spaceframe, Patterning.

Summary. In Abano Terme, Italy, a new multi-purpose structure has been built in the urban park. The structure is a Mero spaceframe structure cladded with membrane on nodal supports. In close collaboration with the architects and the supplier of the space frame structure the top chord geometry has been optimised in order to achieve a homogeneous membrane geometry together with an evenly distributed membrane stress. This paper presents the project form the geometry development to the detail design, fabrication and installation.

1 INTRODUCTION

The new multi-purpose roof structure in the heart of the Urban Thermal Park of Abano Terme has been successfully completed, replacing the former Teatro Magnolia. Funded as part of the National Recovery and Resilience Plan (PNRR), the project stands as one of the most significant urban regeneration efforts in the region, with strong architectural, environmental, and social value.

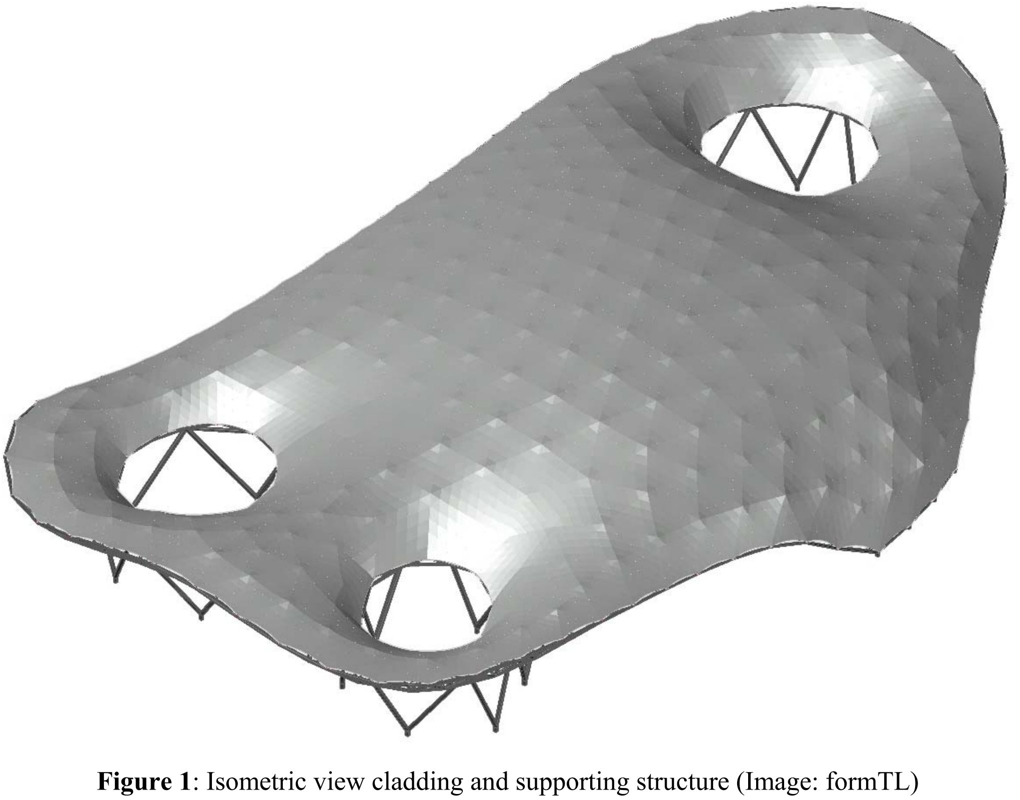

Figure 1: Isometric view cladding and supporting structure (Image: formTL)

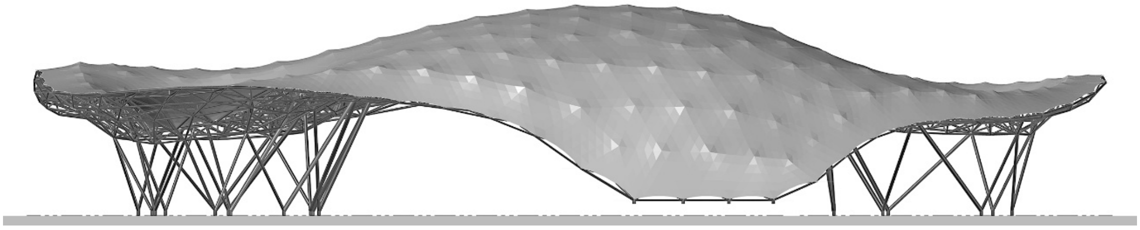

Figure 2: Side view cladding and supporting structure (Image: formTL)

2 DESIGN

The structure is light, elegant, and seamlessly integrated into the natural surroundings. It features a high-quality membrane roof supported by a spaceframe structure. The overall geometry has been carefully studied to ensure a high level of surface uniformity and optimal distribution of membrane tension, just with the use the use of nodal supports and prestressed circumferential cables.

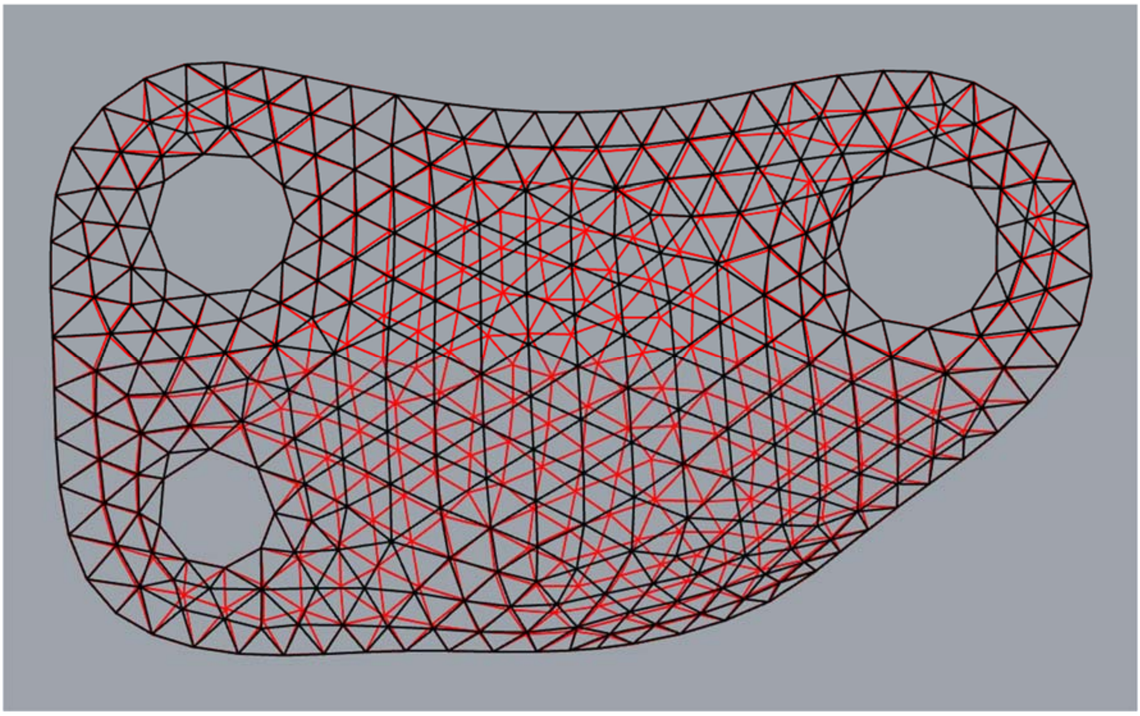

Figure 3: Original grid in red and optimized grid in black (Image: formTL)

One of the most innovative aspects is the rainwater management system. Three central openings have been designed to collect and channel rainwater to the buildings below. Soft upstands integrated into the membrane edge guide the water in these openings, where structural loop cables allow the absorption of local stress in the membrane transferring mainly vertical load to the main structure.

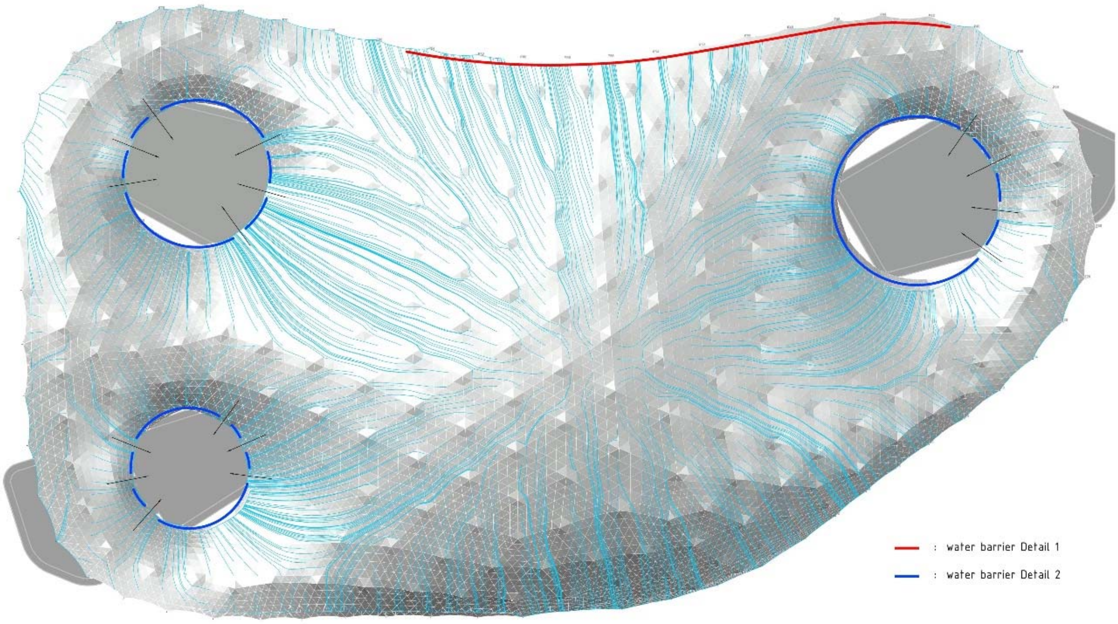

Figure 4: Drainage analysis (Image: formTL)

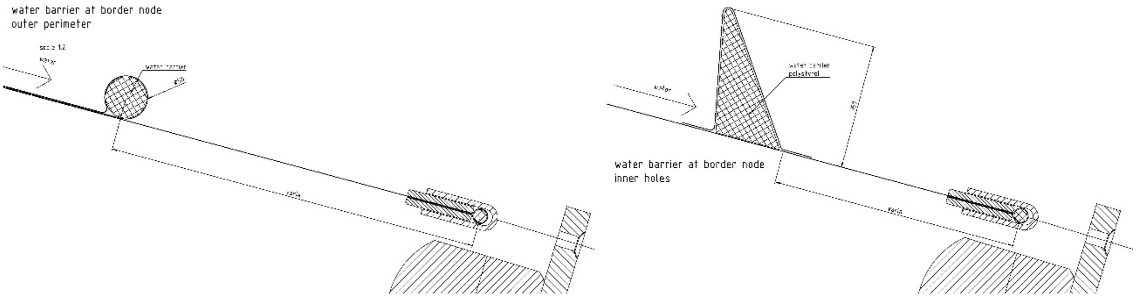

Figure 5: Drainage detail (Image: formTL)

Unlike the initial design, which called for the roof to be divided into four panels, the membrane was instead produced as a single continuous piece, completely eliminating site joints. This solution significantly enhanced the overall aesthetic, giving the structure a smooth, uninterrupted appearance.

3. ANALYSIS

Professor Mike Barnes' software was used for the analysis. TLform for formfinding and TLload for the load analysis. The software uses the method of dynamic relaxation and considers the behaviour of membrane, foil and rope structures. These are, to name some examples, formfinding, orthotropic material behaviour (longitudinal and transversal direction) and large deformations.

The numerical model is discretised by cable, strut and beam elements, as well as triangular membrane elements. It is analysed with geometric non-linearity, considering the change in length of the elements as well as the deformation of the entire structure. The equilibrium is determined in the deformed states.

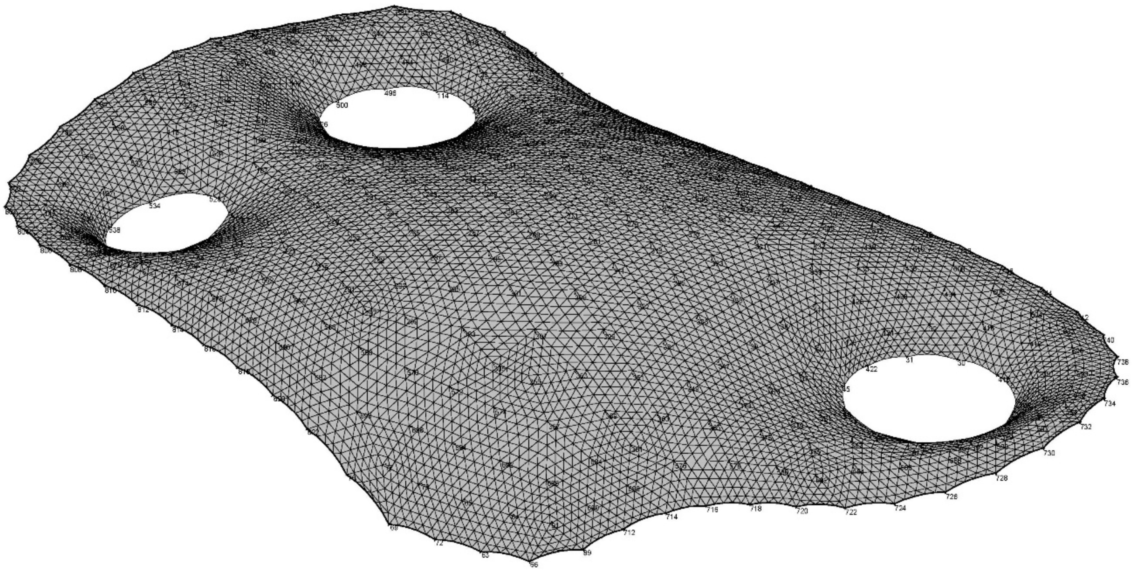

Figure 6: Numerical model (Image: formTL)

The analysis is performed based on the Italian code NTC 2018 with a characteristic snow load of s_k= 1 kN/m² and a reference wind speed of v_b= 25 m/s. For the snow load a uniform distribution has been applied, as well as different asymmetric configurations due to snow drift. For the wind load distribution, the pressure coefficients have been derived from the table for freestanding canopies.

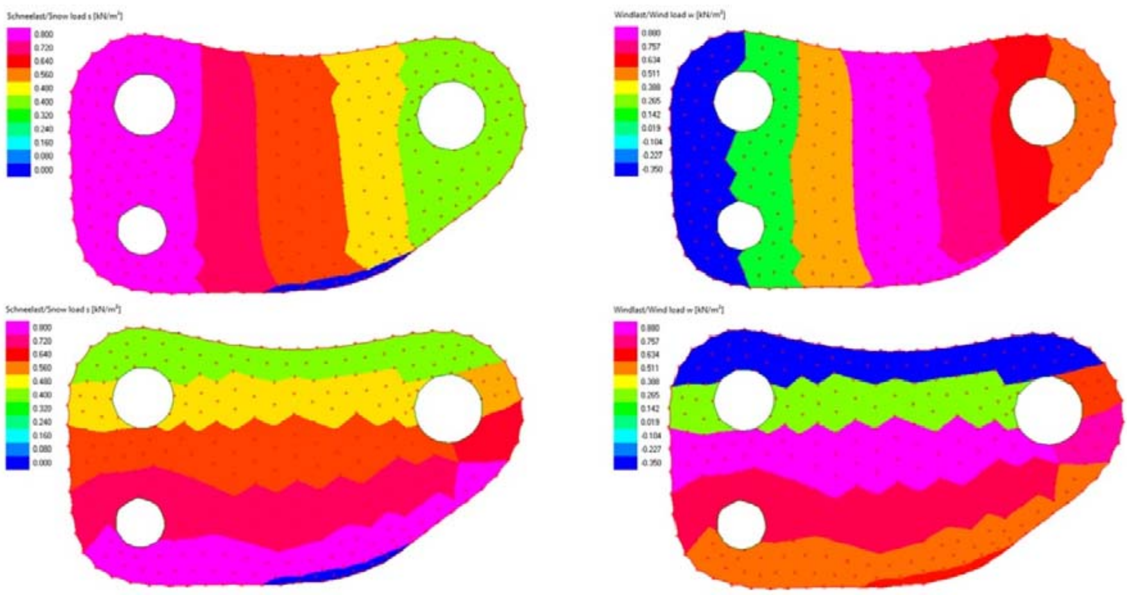

Figure 7: Asymmetric Loadcases Snow and Wind (Image: formTL)

The upstands allow only for a certain deformation. In order to achieve the same behaviour in the numerical model, all upstands are analysed as cantilevers, with an equivalent stiffness to allow for 2° rotation under the applied horizontal load.

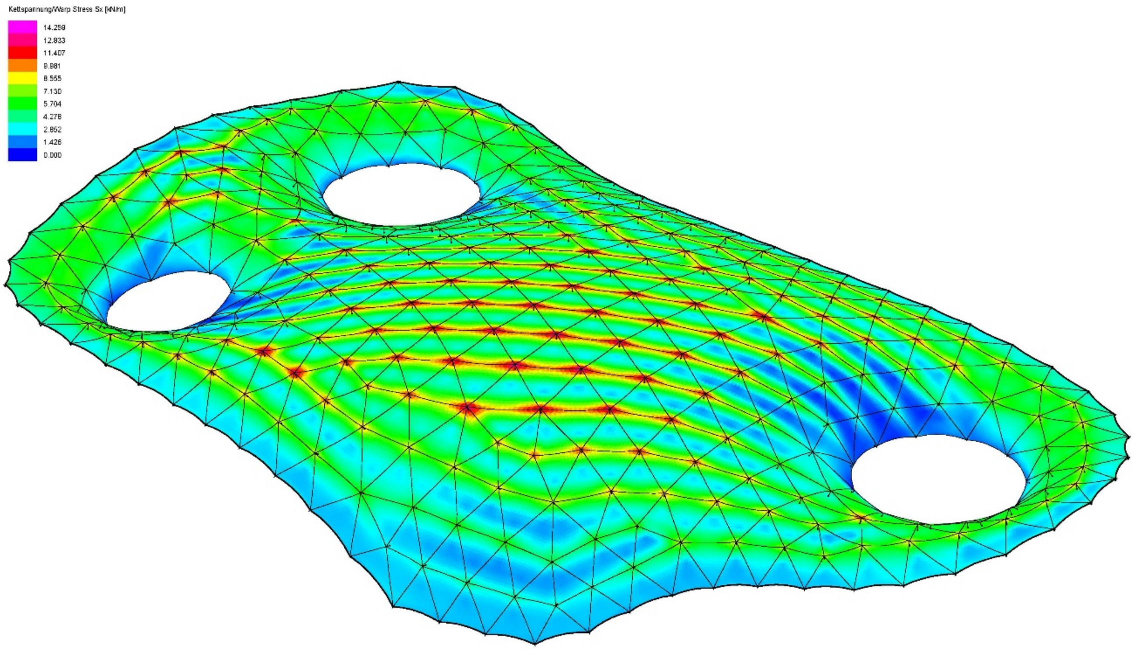

Figure 8: Stress concentration under snow load (Image: formTL)

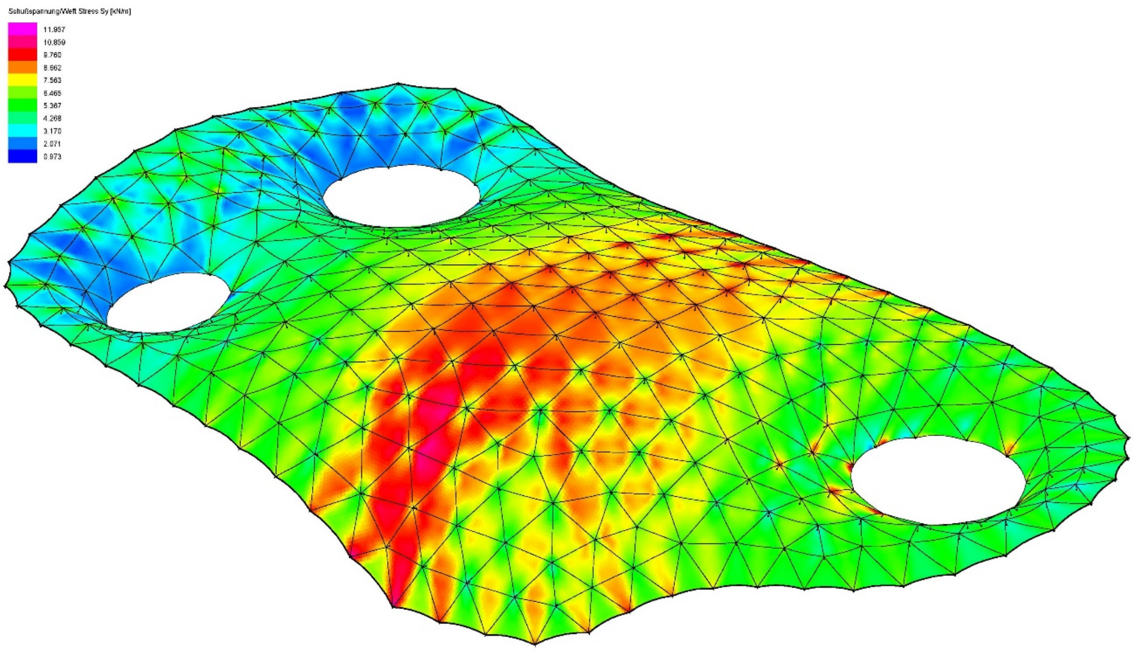

Figure 9: Stress distribution under wind load (Image: formTL)

4. DETAILING

The design and development of the membrane, tensioning systems, and cable layout was performed in close collaboration with the membrane contractor. Every technical detail related to the fixing systems, prestressing, and the interface between the membrane and the supporting steel structure had been studied intensively in order to find the best fitting solution. The entire process was supported by simulations and physical testing.

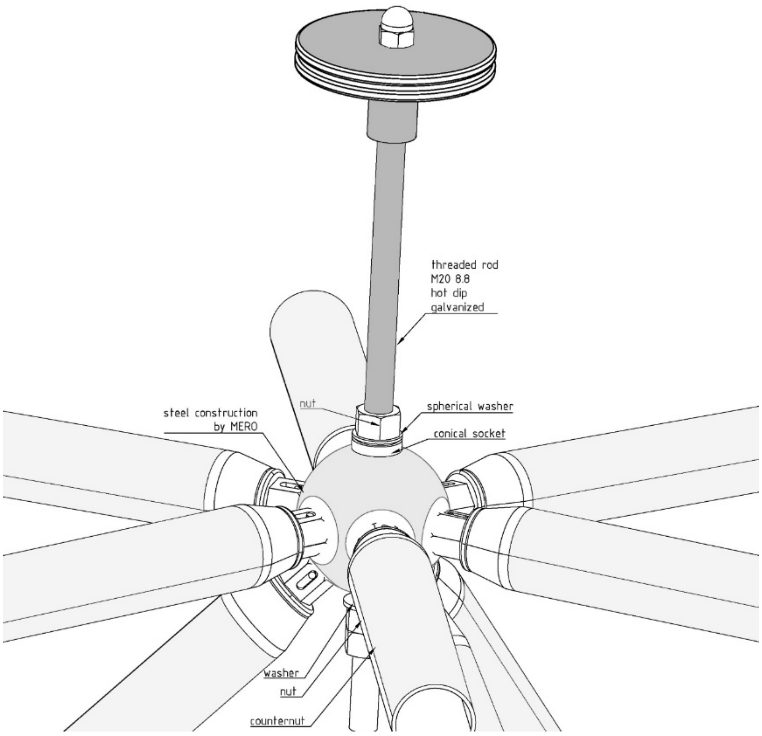

Figure 10: Nodal detail (Image: formTL)

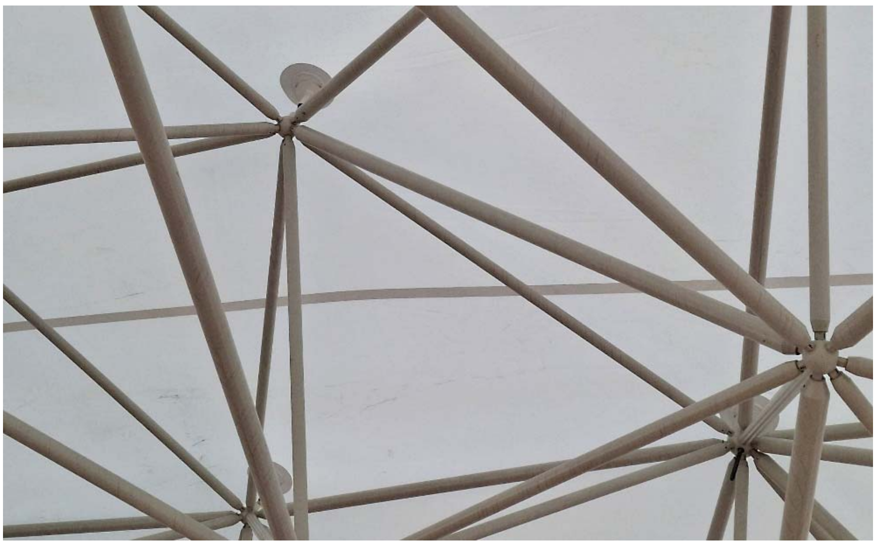

Figure 11: Nodal detail from inside (Photo: Canobbio Textile)

Figure 12: Nodal detail from outside (Photo: Canobbio Textile)

Along the funnels loop cables couple the membrane stress. They are fixed to brackets at the space frame nodes with moveable link elements, so that mainly vertical forces are anchored here. All nodal details at these inner edges have an individual geometry. A parametric process has been set up in Inventor in order to generate all these nodes and their workshop drawings just be few geometrical parameters.

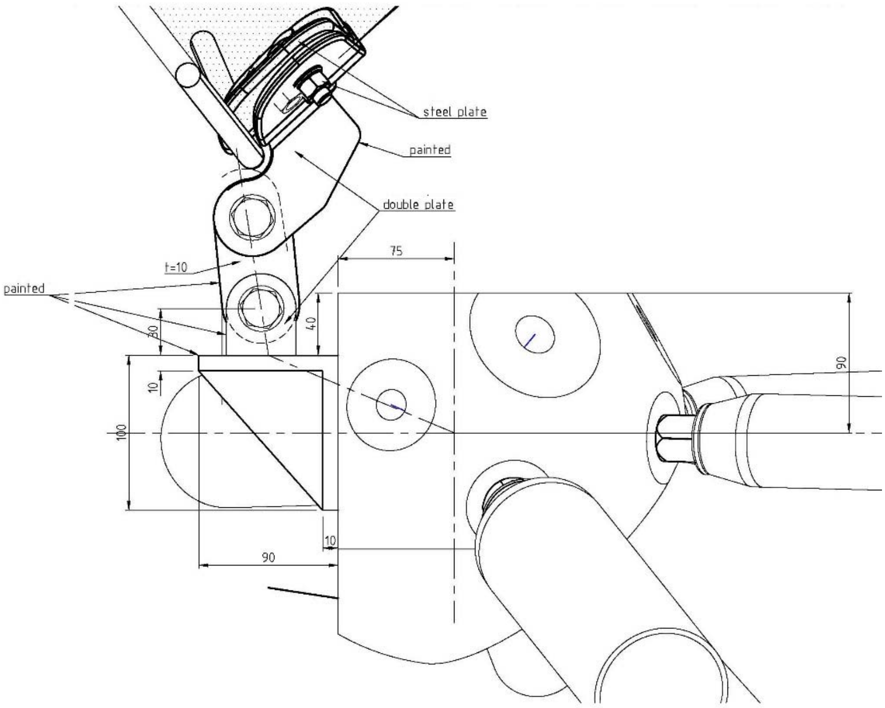

Figure 13: Funnel connection detail (Image: formTL

The membrane along the perimeter arrives with a more regular geometry, so that one single detail fits around the whole roof, consisting of a thick steel plate bolted to the nodes.

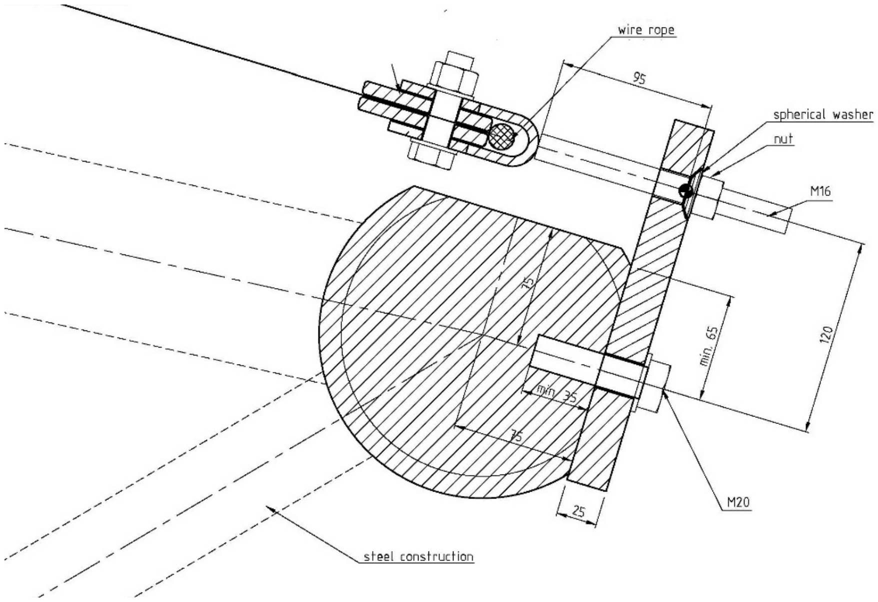

Figure 14: Perimeter connection detail (Image: formTL)

The interface with the space frame is either provided a threaded hole, or by a full drill passing through the bigger nodes. All this information was transferred as a set of vectors to the space frame supplier who could fit this information into the automatic fabrication process.

4. PATTERNING

The shape of the membrane is locally curved where the support nodes carry the membrane. For the fabrication this would be a lot of effort and require a higher amount of weld seams. To facilitate the fabrication, the cutting pattern geometry has been derived from a smoothened surface. The nodal supports create then the local geometry by elastic strain. A comparing analysis proved this concept prior to the final cutting pattern.

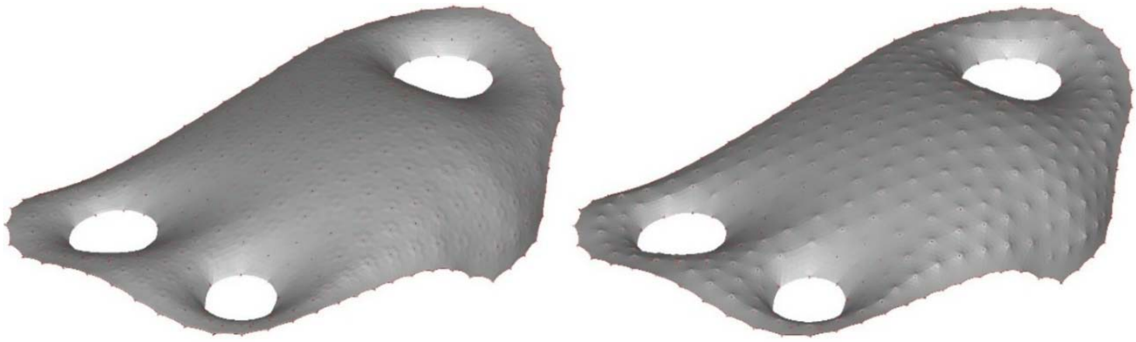

Figure 15: Smooth shape and result of comparing analysis (Image: formTL)

The overall geometry was divided in four subpanels, three with a radial seam layout around the funnels, and one with a parallel seam layout in the central part. In a parametric process the seam layout was applied and optimized.

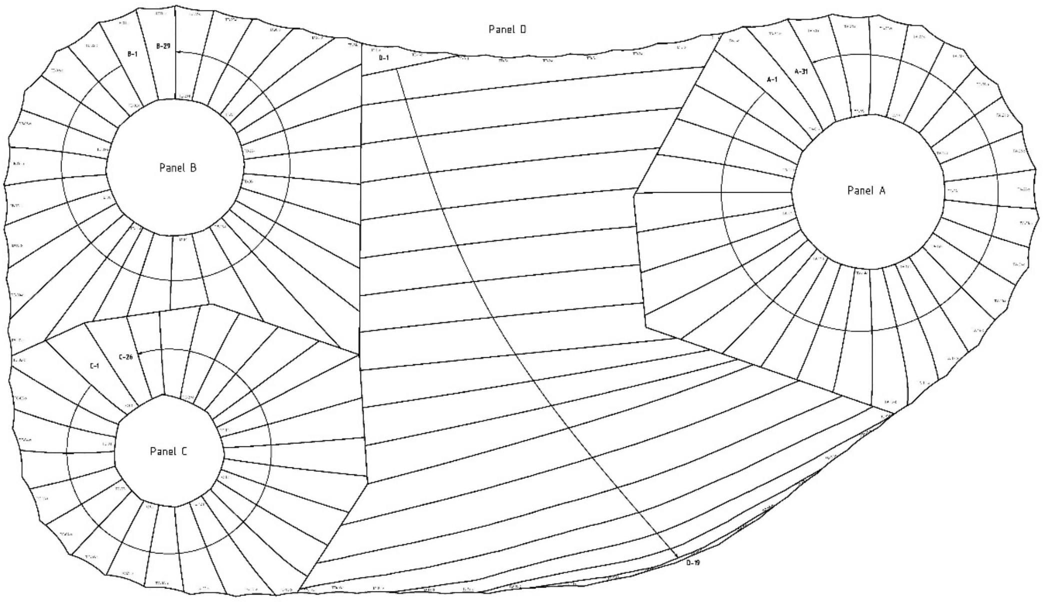

Figure 16: Patterning Layout (Image: formTL)

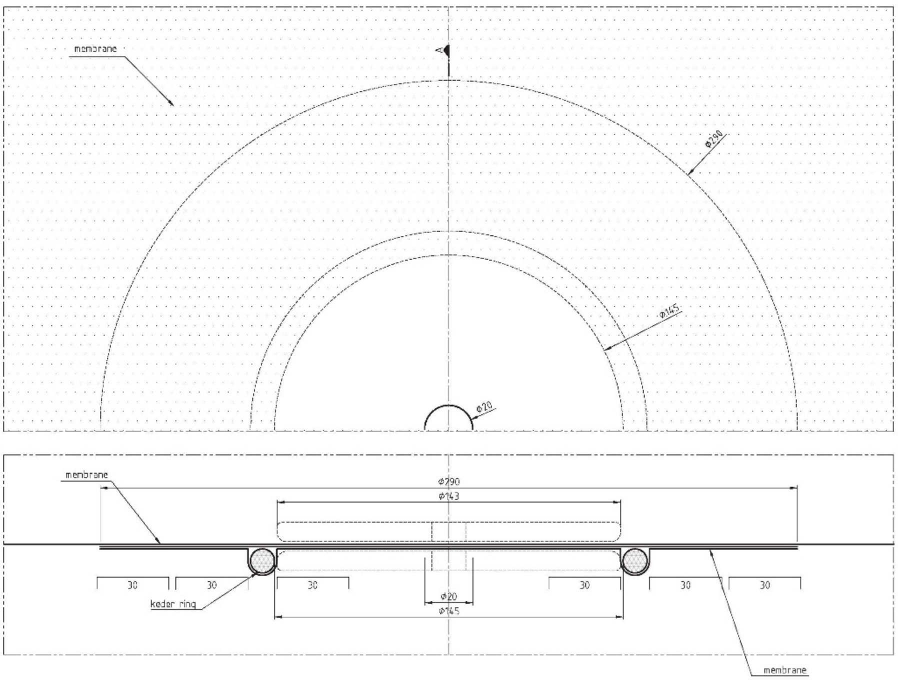

Figure 17: Membrane detail of the nodes (Image: formTL)

5. INSTALLATION

The installation was carried out by a specialist installation team who managed all challenges to install and adjust such a complex structure with the required precision. The membrane was carefully unfolded, stretched and tensioned section by section, ensuring perfect alignment of every connection point.

All nodal supports were set to the theoretical values, and then slightly adjusted where needed. Due to the overall geometry and the compensation of the membranes the nodes moved to the final position only in the final step of the installation when all was properly tensioned.

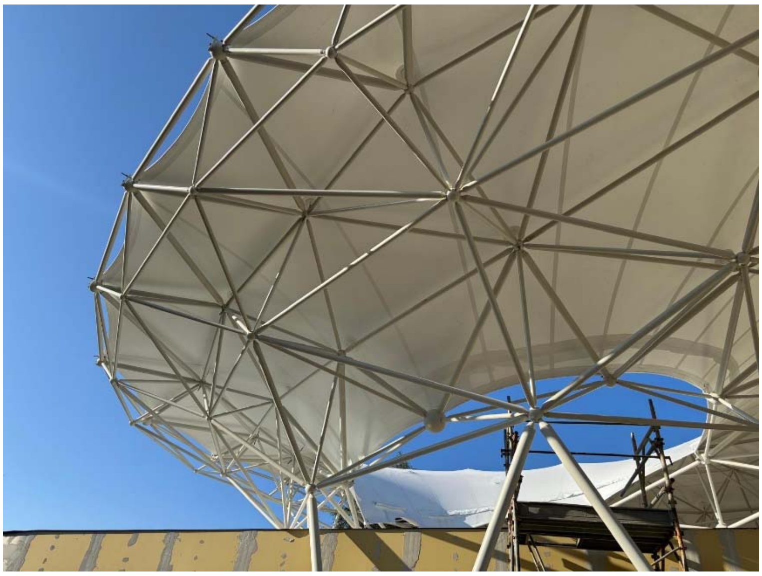

Figure 18: Inner view internal opening (Photo: Canobbio Textile)

Figure 19: Membrane Installation access to all nodes from below (Photo: Canobbio Textile)

CONCLUSION

With the completion of the works, Abano Terme gains a new iconic space -vibrant, inclusive, and open to the public - ready to host cultural events, performances, public initiatives, and moments of community gathering, all in harmony with the city's thermal and landscape identity.

For the whole project team this project represents yet another symbolic and iconic achievement, now part of the architectural heritage of Italian cities. A work that unites engineering and beauty, innovation and sustainability - one we are proud to have contributed to.

Figure 20: Funnel and building (Photo: private)

Figure 21: Finalised structure seen from outside (Photo: private)

Figure 22: Finalised structure seen from below (Photo: private)

Figure 23: Point supported membrane cladding (Photo: Canobbio Textile)

PROJECT DATA

Project: Multipurpose facility Parco Urbano Termale - Abano Terme, Italy
Client: Comune di Abano Terme
Architect/general planner: Incide Engineering S.r.l.
Space frame: Mero Italiana SpA
Membrane Contractor: Canobbio Textile Engineering Srl
Membrane installation; MB Montaggi Srl
Membrane Material: SergeFerrari SergeFerrari 1002 S2
Cables: FAS SpA
Surface Area: 2040 m²
Dimensions: 65 m length, 37 m width, 11.8 m height