SOFTENING THE HABITATS
SUSTAINABLE INNOVATION IN MINIMAL MASS STRUCTURES AND LIGHTWEIGHT ARCHITECTURES

Proceedings of the TensiNet Symposium 2019
Softening the habitats | 3-5 June 2019, Politecnico di Milano, Milan, Italy
Alessandra Zanelli, Carol Monticelli, Marijke Mollaert, Bernd Stimpfle (Eds.)

Atrium Roof in the New Lilienthalhaus in Brunswick, Job Report

Bernd STIMPFLE*, Michael SCHÄFFER*

*form TL Ingenieure für Tragwerk und Leichtbau Gmbh, Güttinger Straße 37,78315 Radolfzell, Germany, bernd.stimpfle@form-tl.de

Abstract

Vis-à-vis to the Brunswick research airport the new Lilienthalhaus, a four storied service and office building has been opened as the first part of the new developed Lilienthalquarter. Not only the location is vis-à-vis to the airport building, also the architecture is in contrast to the 1940th airport design. The architect Hartmut Rüdiger from Architekten Rüdiger Brunswick wants to represent the new break up at this area with new technologies and services. Nearby the German Luftfahrt Bundesamt and several aviation research plants are located. The Volksbank Brunswick as building owner together with the city of Brunswick want to develop a new progressive business park. The triangular plan view with its rounded sides was developed based on the site plot and other boundary conditions. The building is a monolith without extensions exceeding from its primary shape. Also the transparent roof structure and the entrance is placed behind the primary border lines.

Keywords: ETFE, cushion, pneumatic, cable surrounded, inflation system, integrated drainage, structural design, analysis, installation

DOI: 10.30448/ts2019.3245.09

Peer-review under responsibility of the TensiNet Association

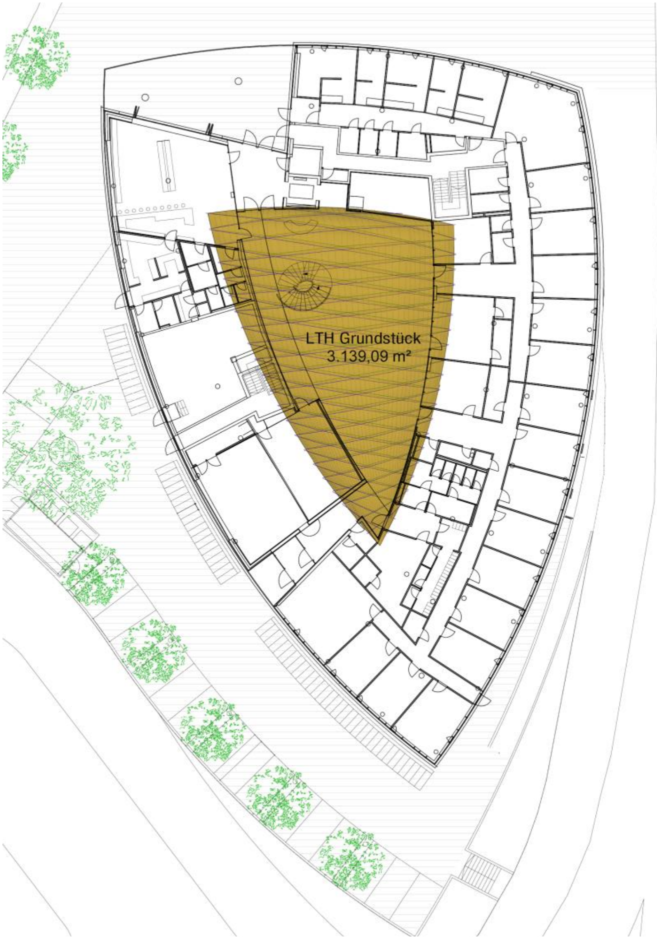

Figure 1: plan view Lilienthalhaus with highlighted ETFE-cushion roof (Rüdiger Architekten/formTL)

Figure 2: façade with ETFE-cushion-roof (formTL)

The entrance leads into the bright atrium with a sculptural spiral stair. The roofing of this area is almost invisible. The transparent roof is not located directly on the concrete structure. The roof is lifted up, so that the skylounge which is placed on top of the fourth floor is integrated to the atrium area. So the roof surface is inclined from top of fourth floor to the top of third floor at the tip of the triangle. To get a complete open image the border frame of the roof is placed behind the concrete parapet. Hence the roof-facade is inclined and has also transparent cladding.

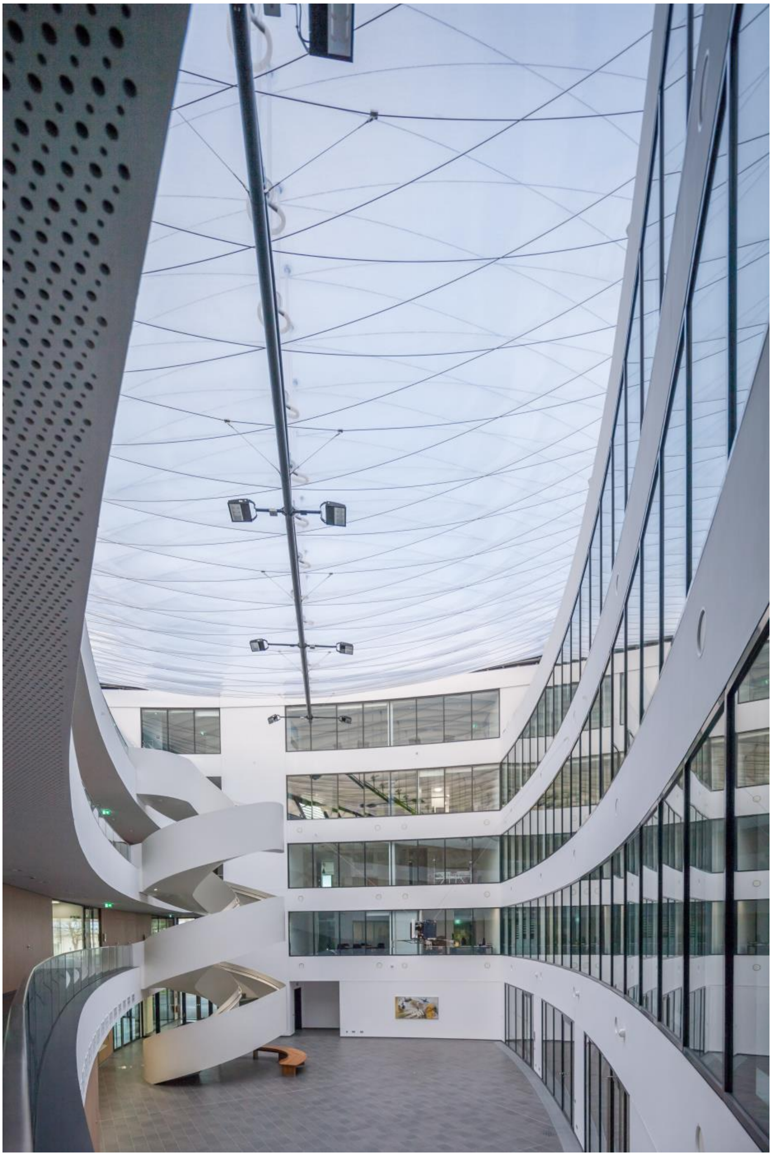

Figure 3: Atrium (Hanno Keppel)

In the initial design step a glass roof was intended. The heavy primary steel structure for the glass roof required a sprinkler system. To avoid additional cost the client searched for alternative solutions. With the big ETFE-cushion this was solved. The primary steel structure is a perimetral steel frame, placed on the concrete structure. The load carrying cables forming the cushion reinforcement are the only primary steel parts placed upon the atrium.

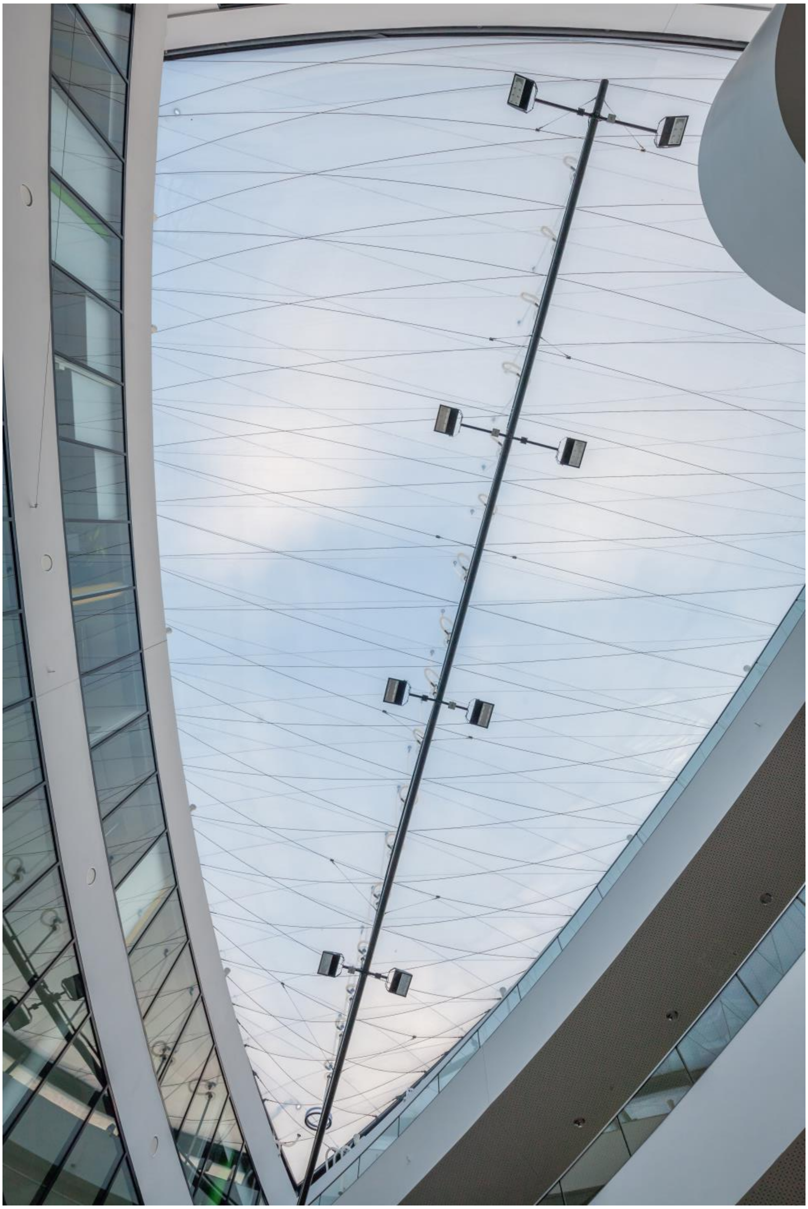

Figure 4: view from below to the atrium roof (Hanno Keppel)

The stainless steel cables with a diameter of 10 mm have an overall weight of 711 kg on a covered ground area of 430 m^2 which gives a unit weight of just 1.7kg/m^2. In case of fire the ETFE foil with its melting temperature of approx. 270°C will open the roof before reaching melting point of the stainless steel cables, so that the primary atrium structure cannot fall down due to fire. The ETFE-foil with its B1 certificate according to DIN 4102 and being not dripping burning was approved by the authorities.

Figure 5: ETFE-cushion with stainless steel cable reinforcement (Hanno Keppel)

The structural principle of the large cushion structure is a perimetral steel frame according to the shape of the atrium area raised on the upper concrete slab. With this raise the frame moves back and opens a larger space than the ground floor itself, so the roof gets even more light. The inclined sidewalls are also covered with ETFE-cushions and allow more light coming in.

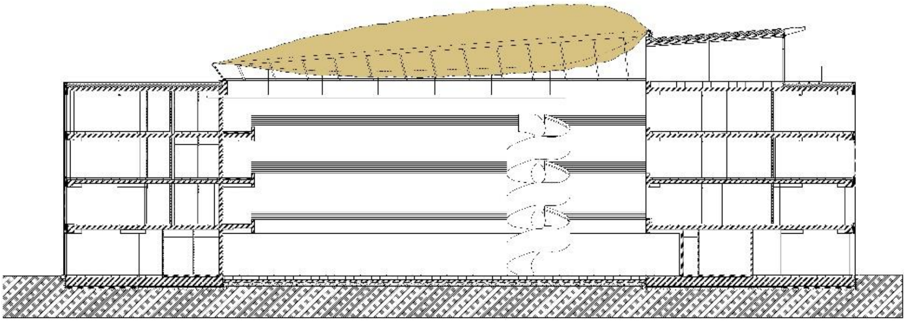

Figure 6: longitudinal section (formTL)

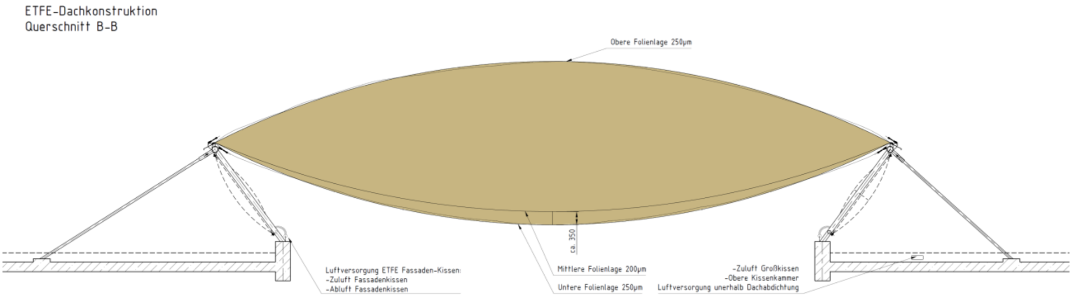

Figure 7: cross section (formTL)

The main space upon the atrium is covered by a single cushion consisting of three layers. The cushion with its covered area of 430m^2 was fabricated in one piece. The upper and lower layer are supported by steel cables so that the maximum foil stress can be safely carried.

Brunswick is located in the area called North German Plain where high snow loads have to be applied. 1.5 kN/m^2 as accidental snow load case has to be carried by the increased inner pressure in the cushion. So the maximum pressure is defined with 1600 Pa. To reduce the forces in the cables and also to the steel structure the sag of the ETFE-cushion was increased. The result was the reduction of the forces in the cables. Stainless steel cables 1x19 with a diameter of 10 mm are sufficient The ETFE-foil is not connected to the cables, so the cables can slide on the foil and local stress peaks between cables and foil are avoided. The horizontal loads of the cables are guided to the border frame and then into the concrete slab. The concrete structure is has no expansion joint so the inner forces of the cushion are coupled in the slab level.

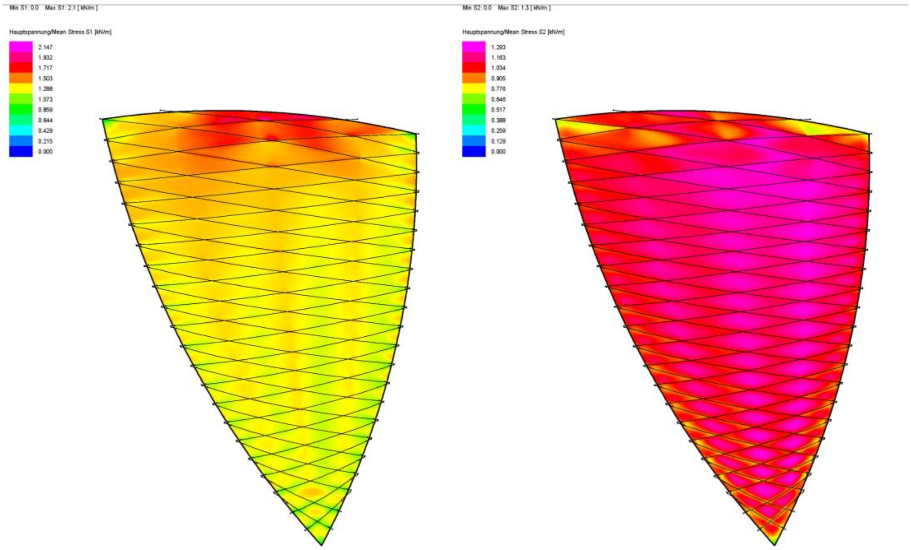

Figure 8: foil tension in longitudinal and cross direction at 800 Pa inner pressure (formTL)

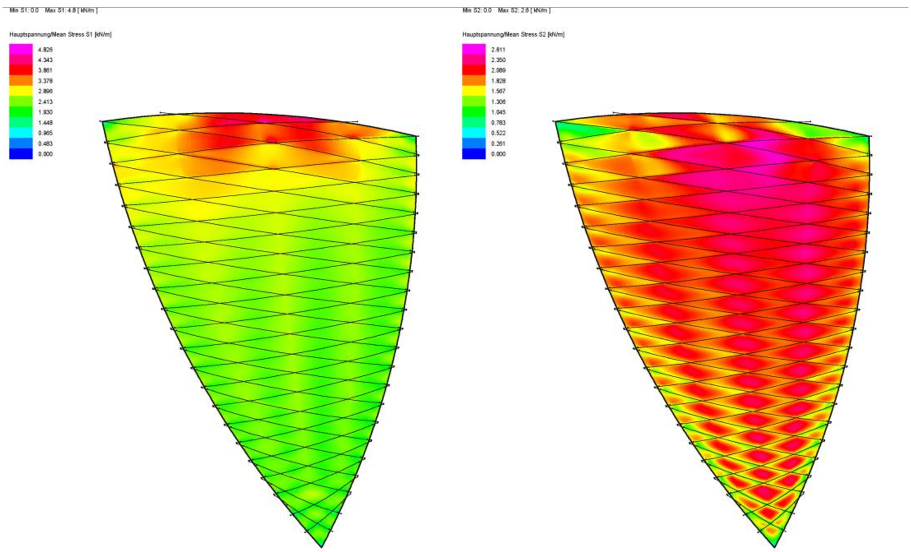

Figure 9: foil tension in longitudinal and cross direction at 1600 Pa inner pressure (formTL)

The cushion volume is about 1100 m^3 split in two chambers. The middle foil layer is located near to the lower layer so the chambers have different volumes. The lower volume has also less convection and so a better thermal insulation. The U-value for a three layer cushion is about 2.0 W/(m^2K). The inner layer is not reinforced. To avoid wrinkles in the foil the pressure between the upper and the lower chamber is 50 Pa. With this little difference in pressure the foil has a significant prestress. The usual inner pressure is 350/300 Pa. In case of snow load the pressure is increased according to the snow height up to 1600/1550 Pa controlled by a snow sensor. The differential pressure in the chambers is controlled by the blower system which is executed as circuit. Only air loss, due to leakage and diffusion must be replaced with air from the outside. With this closed system the required energy for drying can be reduced significantly.

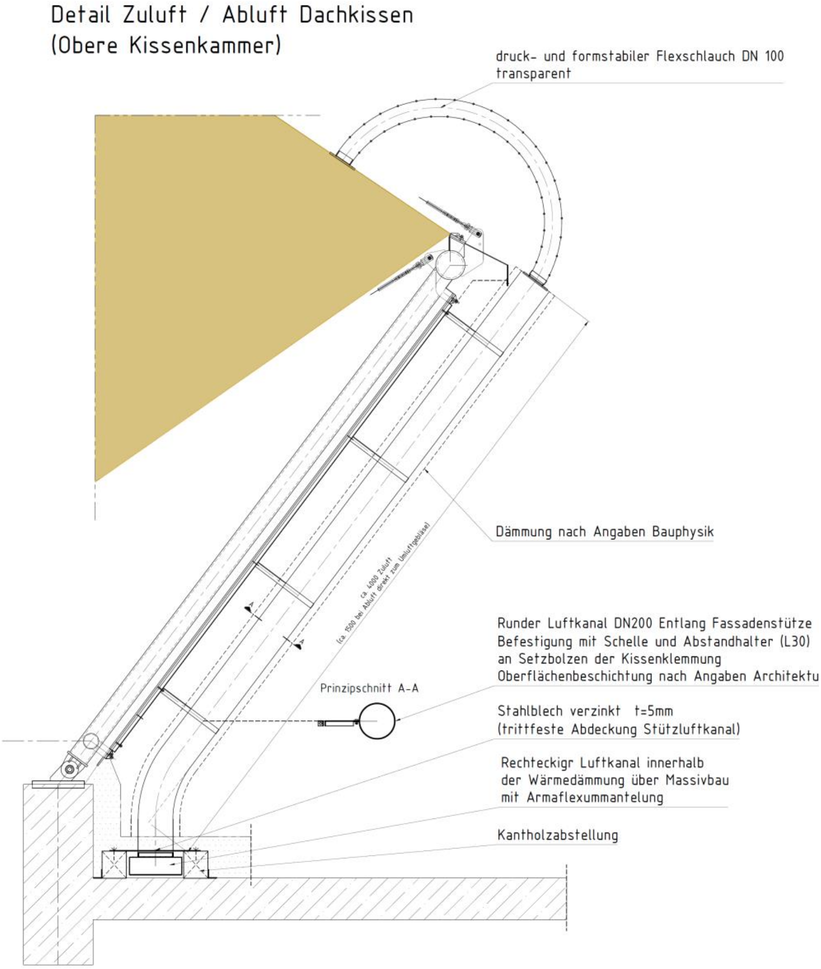

Figure 10: detail air supply for ETFE-cushion (formTL)

In case of pressure loss in the cushion over longer period, the cushion deflates and the three layer of foil lay on each other. The middle foil layer is stretched to the inner layer. This strain is not big because of the close location of the two foils. The strain is in the elastic range of the foil. So once the cushion is up again the inner foil will return to its initial state. When the three foils lay on each other rain water cannot drain over the border frame. To avoid water accumulation several flexible drainage pipes connect the outer and the inner foil so that water can flow through the cushion. In botanical garden coverings or in roofs above swimming pools this water can drain freely to the floor. In the Lilienthalhaus there is no drainage on the atrium floor. The water must be guided directly to the waste water, so under the cushion a pipe is located which also serves as fixation for the atrium lighting.

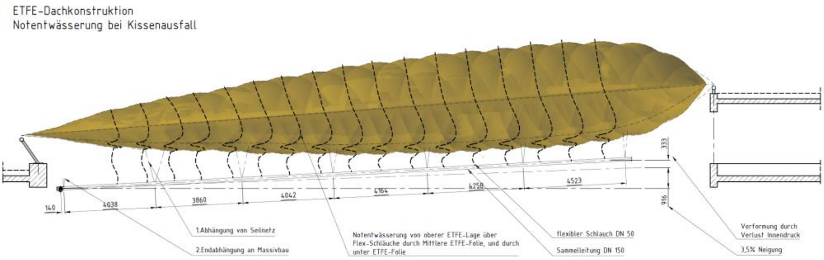

Figure 11: longitudinal section with collapse dewatering pipes (formTL)

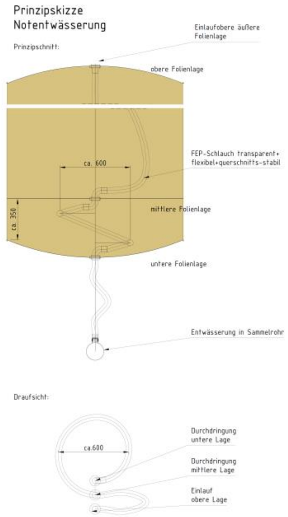

Figure 12: details dewatering pipe (formTL)

In some projects the transmission of UV-A and UV-B radiation of the ETFE-foil is an advantage in comparison to glass, which absorbs most of this radiation which is important for plants. In the Lilienthalhaus project this was not important, but also no problem. But the solar gain must be considered. On the one hand the transparency of the light foil covering was desired, on the other hand a reduction of the solar radiation was necessary. A conventional additional blind layer on top of the roof was not compatible with the architectural design of the façade and the roof covering. So the outer foil was silver printed. The requirement for the transparent roof covering was a g-value of 0.26. This was possible with a printing of 89% of the surface with a reflecting silver colour. The 89% seem to be a high ratio, also when you take a look at a small sample of foil. In the overall appearance of the roof a silver shadow is realized, but it remains transparent and light. Only in direct comparison with the printing is realized.

Figure 13: cable connection detail with printed upper cushion layer (formTL)

In comparison to a glass covered roof structure the installation is easier and also faster on site. The primary steel structure is placed on the upper concrete slab. So the installation of the elevated surrounding steel frame can be done directly from the main building roof without scaffolding.

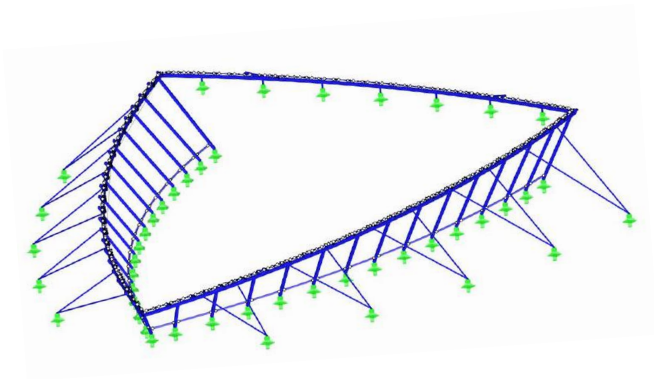

Figure 14: primary steel frame (formTL)

The lower cable layer was installed from the border of the atrium. Afterwards the pipe for the emergency drainage and the atrium lighting was lifted up and installed by using the crane before closing the roof. For the following installation of the cushion an installation net was fixed to the steel-frame. The three layer ETFE-cushion was completely prefabricated. All three layer were welded tight and have only one surrounding keder. This is the only fixation of the cushion to the primary structure. The whole foil-package has an overall weight of 450 kg and was lifted up in a timber box with a mobile crane to the middle of the installation net.

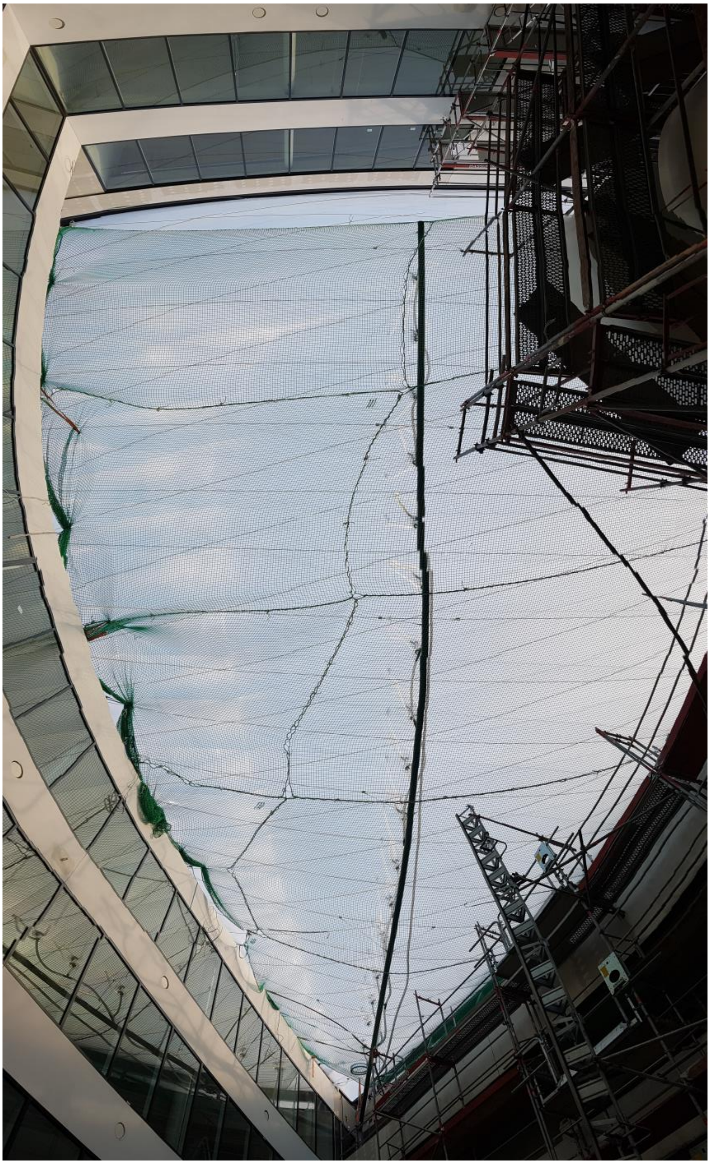

Figure 15: installation web, view from below (formTL)

To avoid elongation in the foil, horizontal belts were spanned in plane of the frame. The foil was spread out on this support and the border was clamped to the pre installed border clamps. On the horizontal installation plane the ETFE-cushion was clamped without any stress. Afterwards the upper cables were installed, the belts removed and the cushion was inflated.

Acknowledgements

Client: Volksbank BraWo Projekt GmbH, Braunschweig
Architect: Hartmut Rüdiger, Braunschweig/DE
Structural design of the atrium roof formTL ingenieure für tragwerk und leichtbau gmbh
Contractor: Temme // Obermeier GmbH, Rosenheim
Picture credits: Hanno Keppel, Braunschweig and formTL, Radolfzell

References

Schäffer, M., Stimpfle, B.: ETFE Großkissendach über dem Lilienthalhaus in Braunschweig, *Stahlbau 87 (2018)*, Heft 7

Schäffer, M., Stimpfle, B.: Luftfahrtpionier als Namensgeber, Membranüberdachung für ein Atrium, *DIB*, 7-8-2018

Sauerbrei, C.: Fast so leicht wie Luft, Lilienthalhaus, Braunschweig, *DBZ*, 7-8-2018