From the Hangar to the Tropical Island

form TL

ingenieure für
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Modification

Description

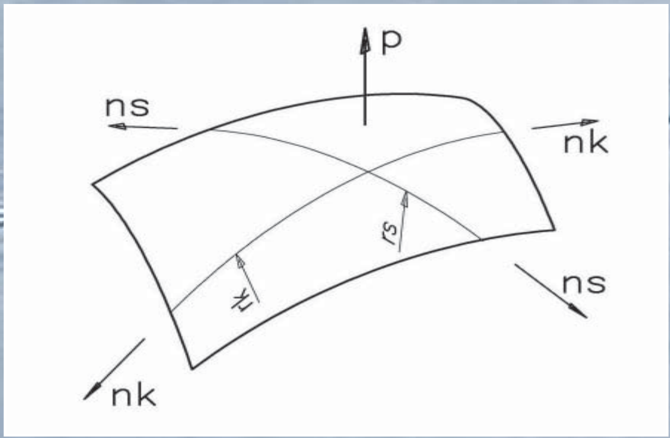
At present the former CargoLifter hangar in Brand, south of Berlin, is transformed into a leisure park.

The membrane covering is replaced by a transparent covering to get more light into the hangar. Glass is not transmissible enough for the ultraviolet light which is necessary for the growth of the plants, therefore owner and planner have decided to use tree-layer ETFE

Cushion structures

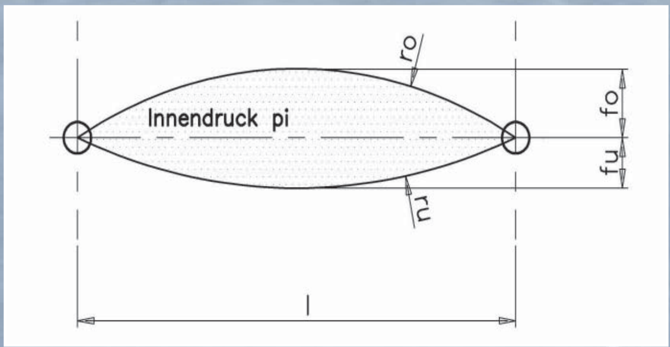
Pneumatic structures follow strict rules, which influence their formfinding and their design process.

The form of a pneumatic structures always follows the formula (allgemeine Kesselformel)
$p = nk / rk + nS / rS$ with internal pressure p, membrane stress nk and nS and the radius of the curve rk and rS.



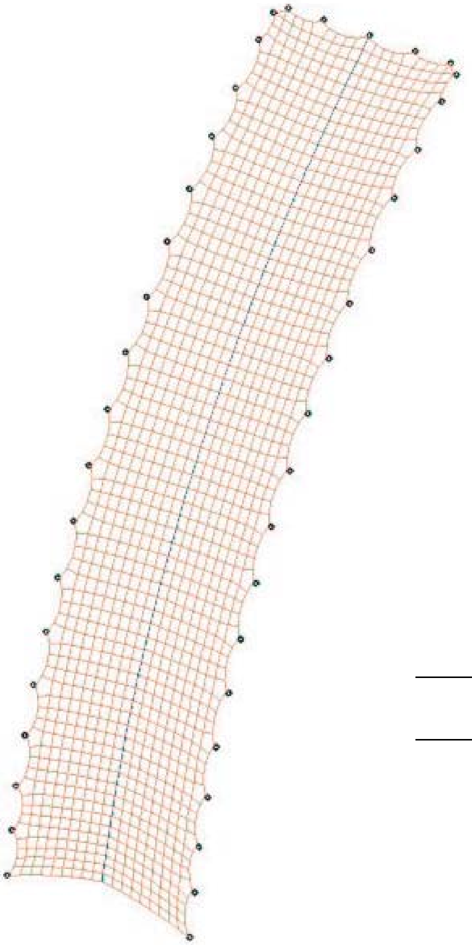
Cushion structures are two layer, pneumatic structures. They are attached to an internal structure which is able to couple the high lateral forces of the border in the cushion. Or they are set as a cover on a primary structure and guide the resulting horizontal forces into the main structure.

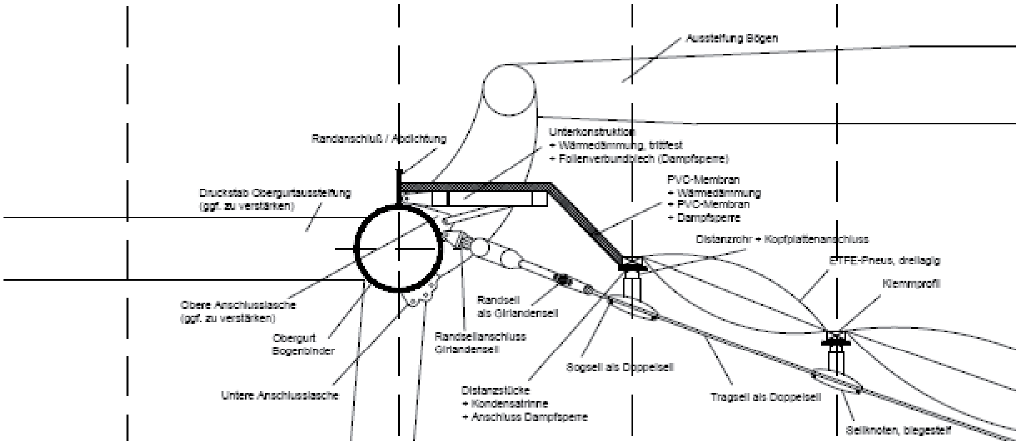
The compression load on the cushion is carried by a pressure increasing on the other side of the cushion. The suction load increases the membrane stress on the upper side. Suctions loads result from the wind exclusively, therefore they are only short-term loads. The pneumatic system is not able to react to the change of volume resulting from an elongation of the upper layer, therefore the upper side has to take only the wind load, without interaction of the internal pressure.



Cable net version of the tender

In the solution of the tender the outer membrane should be replaced by a single layer cable net and the ETFE foil cushions should be set on them. This cable net is much stiffer than the membrane, therefore this design attempt would have led to higher anchorage forces and to a more complex reinforcement of the primary steel.

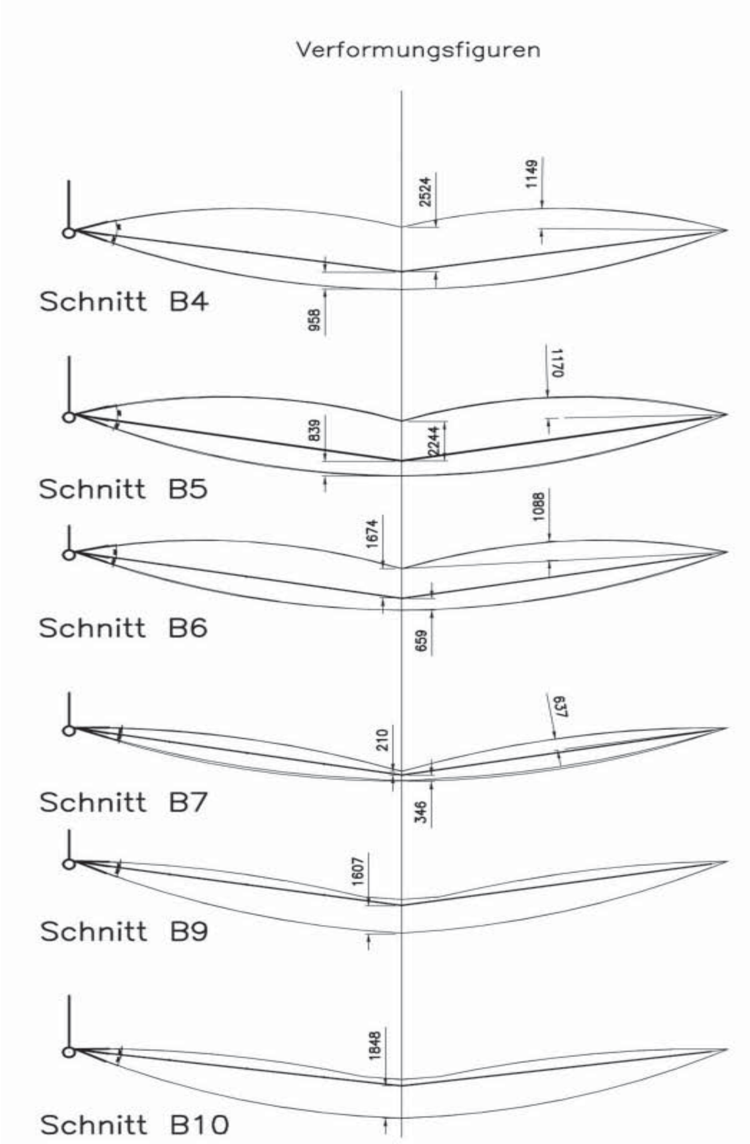




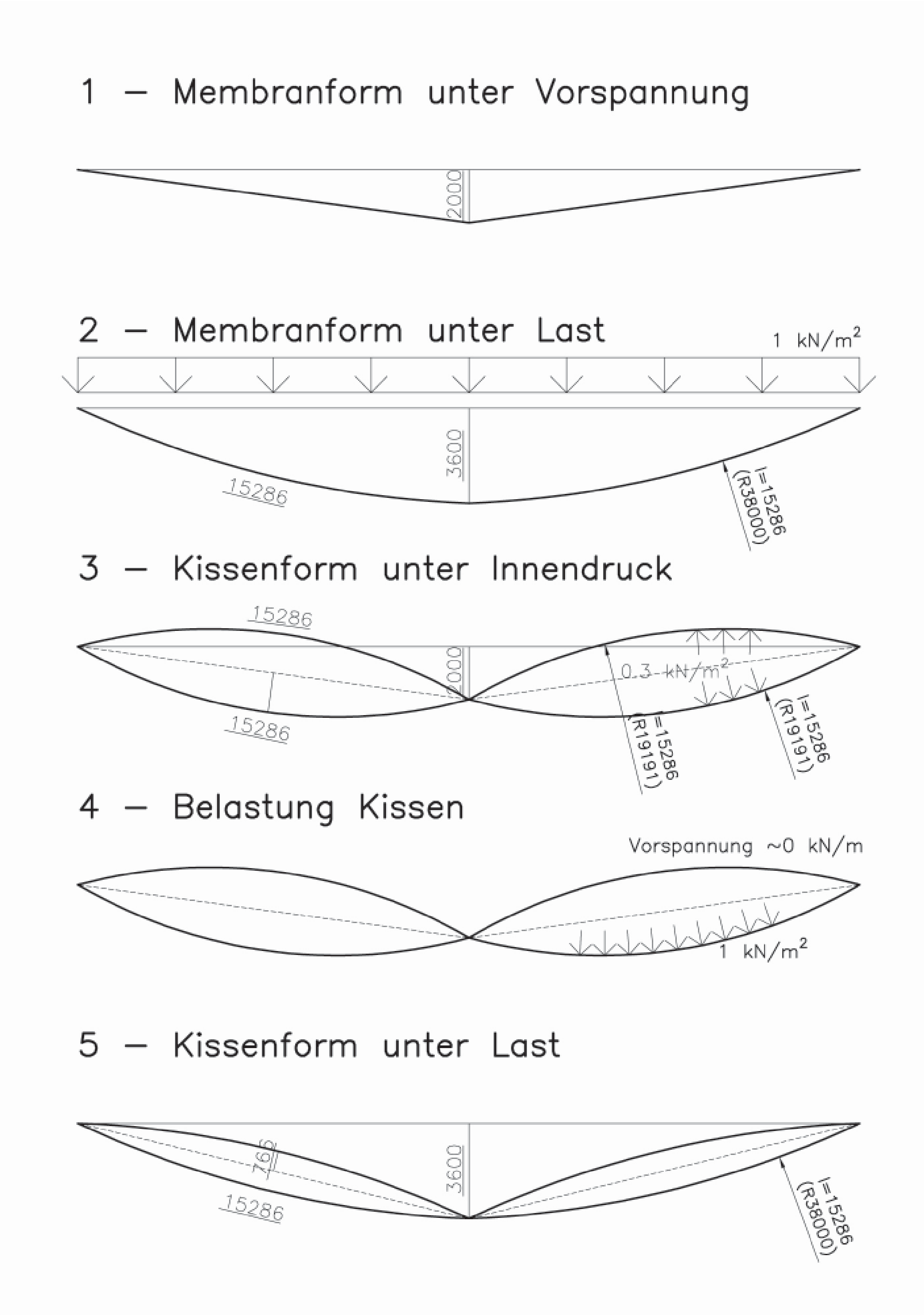
single cushions fixed on the cable net (CL-MAP)

Specific proposal

Based on the deflection of the original membrane solution we have chosen a large pneumatic cushion. The cushion sags correspond exactly the deformations of the present membrane.



Determining the cushion-shape under wind pressure

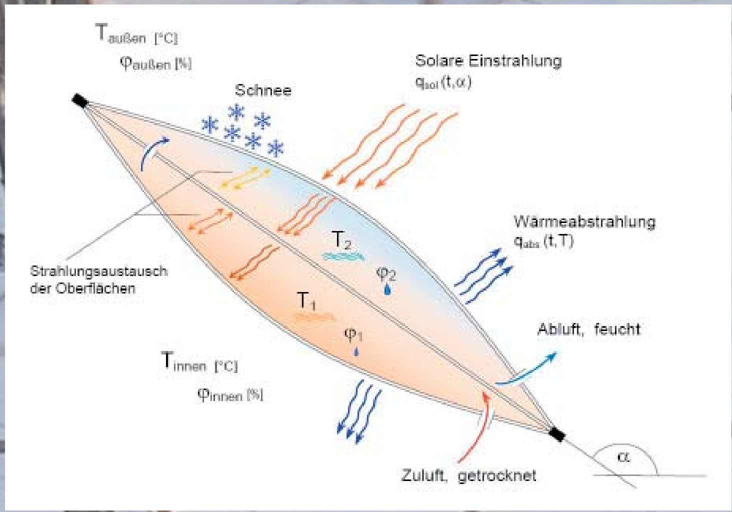


Requirements of the building physics
To realize a comfortable tropical climate inside the hangar, the heat loss caused by the lucent ETFE cushions had to be minimized and condensate should not accumulate on the inside of the cushion.

The tender specified a three-layer ETFE cushion with a U-value that should not exceed 2.0. On the basis of the corresponding standards a heat transmission resistance for air spaces of 0.17 m²K/W each can be determined, but limited to air spaces < 0.5m according DIN 4108, or < 0.3 m according the new EN ISO 6946.

With larger air spaces there is a air flow within the cushion, so a simulation has to be carried out.

The simulation of the cushions was executed by Dr. Mahler in cooperation with
Dipl.-Ing. Buchner to determine the U-value, the rate of air exchange within the cushion and the amount of condensate.

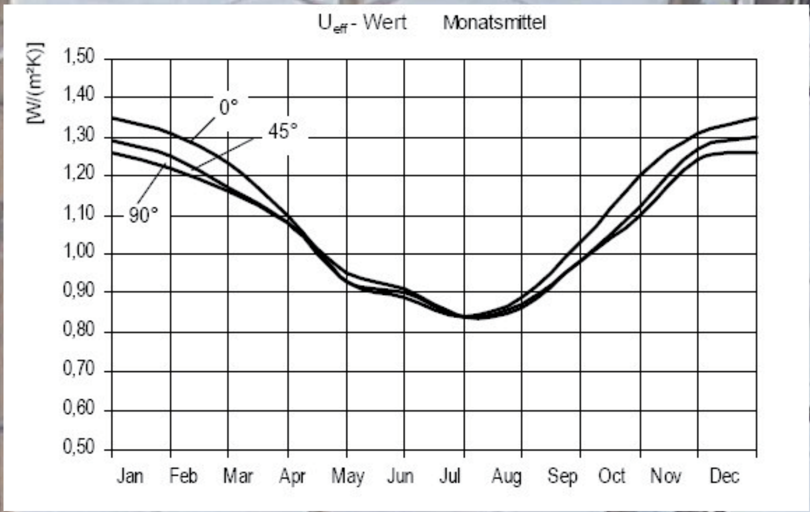


thermodynamic processes

The cushion sag is kept small to keep the air flow inside the cushion as low as possible. This leads to higher loads in the cushion anchorage.
The size of the sag was chosen in an iterative process so that a load transmission into the primary steel was possible without problems.

The final cushion sag is with 1.3 m to the outside and 1.8 m to the inside well over the wished sag by the building physicians which was 1 m to each side maximum. The simulation nevertheless showed much better values than demanded.

The U-value of the cushion is below 1.4 W/m² K maximum, and there will be only small amounts of condensate at the inner side of the cushion under extreme climatic conditions. This condensate will be removed by the air movement in the hall.



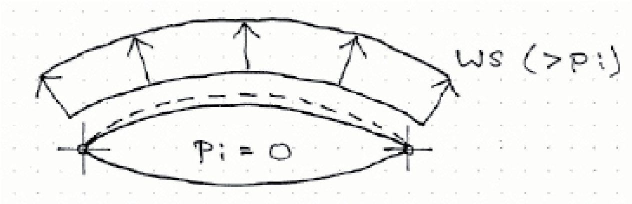
Effective U-value over the year

Loadbearing behaviour
The structural system of the cushion roof works as a large cushion. On the upper side a rhombic cable net and on the lower side parallel cables are spread between the lateral arch trusses and the valley cable.

Between these two layers there are altogether 14 single cushions, which spread the two cable layers and by this form the cushion.

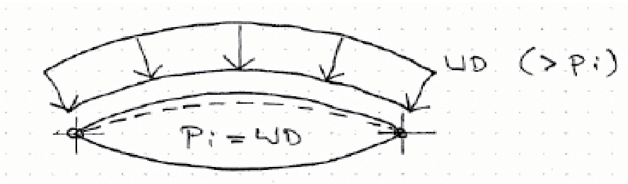
The two cushions have a regular internal pressure of 300 Pa. With snowfall the internal pressure of the upper cushions is increased to 800 Pa, to carry the snow load of 0.75kN/m².

Wind suction pulls the upper side of the cushion to the outside and tries to increase the volume. Because the air cannot follow and already a small change of volume leads to a loss of pressure in the cushion, the maximum wind suction is working on the upper side of the cushion and the internal pressure is becoming 0.
- The upper layer carries the wind suction loads.
- The lower layer is discharged.



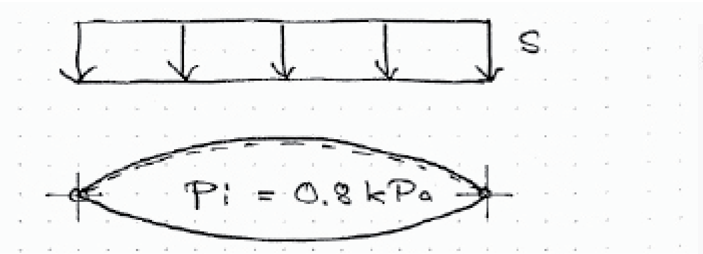
Load transmission with wind suction

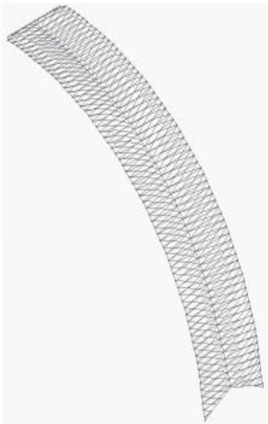
Wind pressures pushes the upper side of the cushion inside and in the cushion, a balance with the wind load is set up. Is the wind pressure higher than the internal pressure, inside the cushion a internal pressure equal to the wind pressure is resulting.
- The upper layer is discharged.
- The lower layer carries the wind pressure loads.

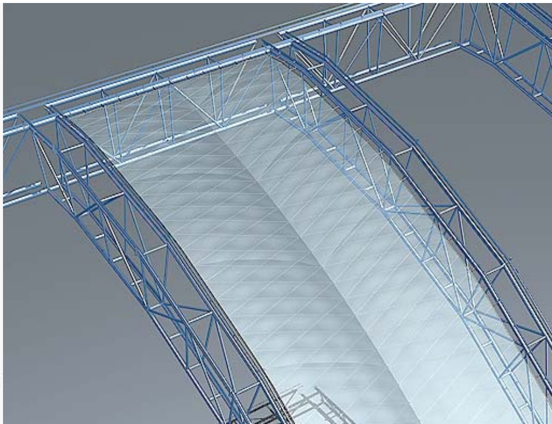


Load transmission with wind pressure

In case of snow the internal pressure is increased to 800 Pa controlled by electric snow sensors. The internal pressure carries the snow load.

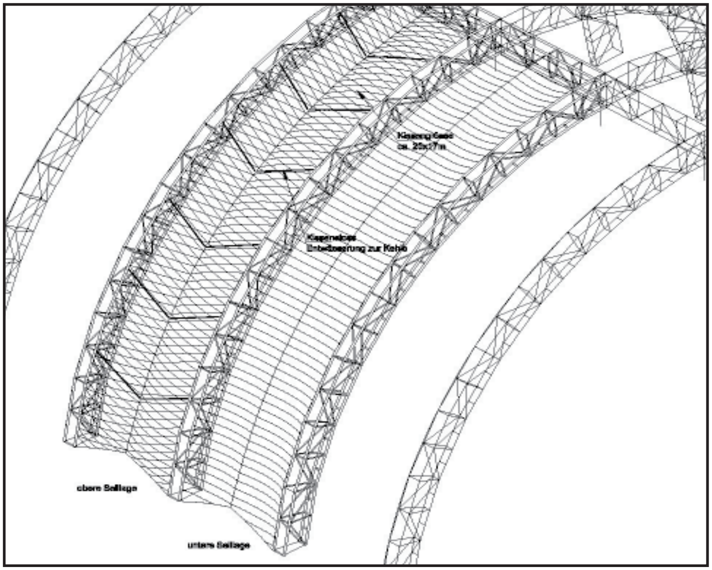


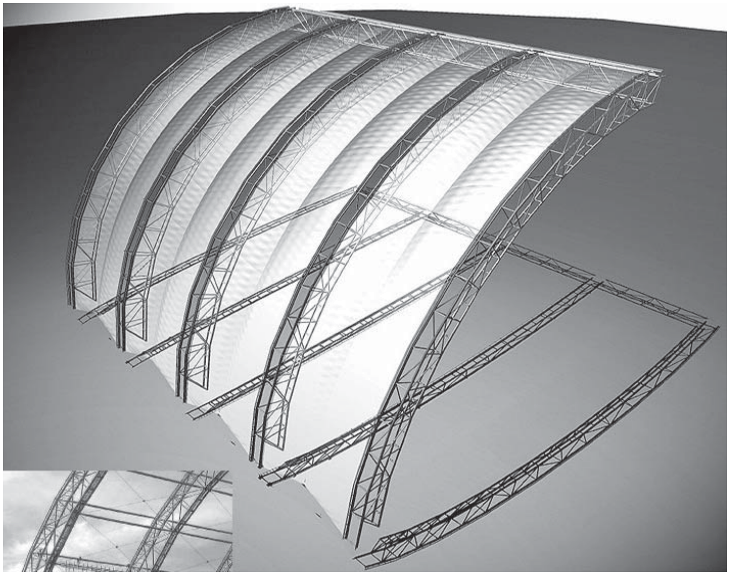




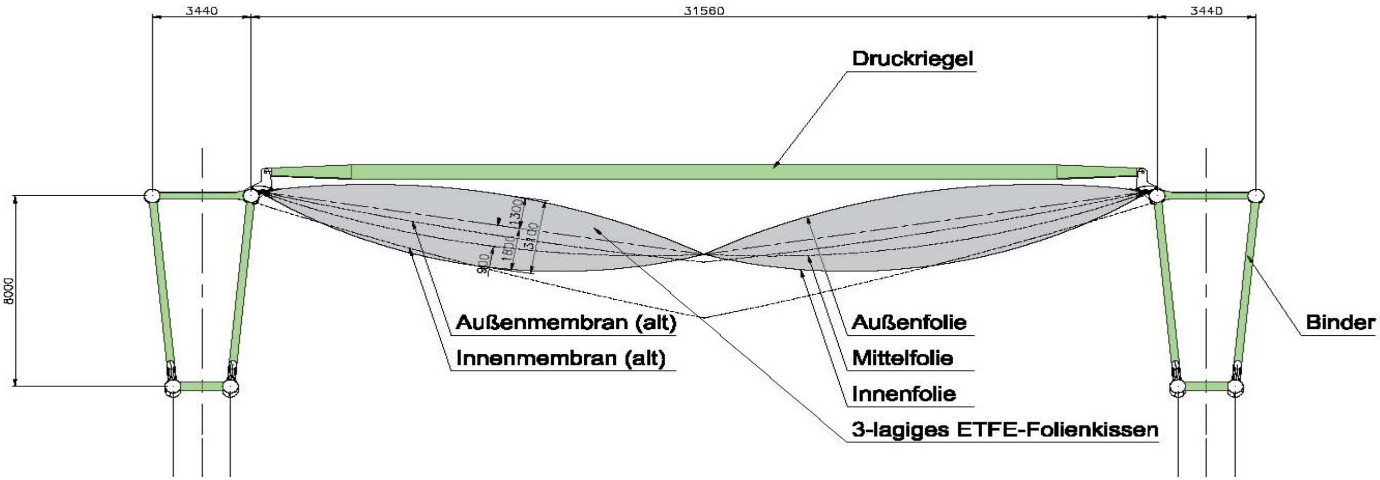
A rhombic shaped cable net of spiral stands with a diameter of 14mm forms the upper side of the cushion. In the area near the cushion joint the ascending cables are connected with a socket joint. A parallel array of spiral stands with 16 mm diameter forms the underside of the cushion. For corrosion protection reasons aluminium coated steel cables were used.

The reused valley cable is a full locked cable with a diameter of 50 mm. The border cables, which are reused as well, are full locked cables with a diameter of 59 mm.





Survey upper and lower cable position

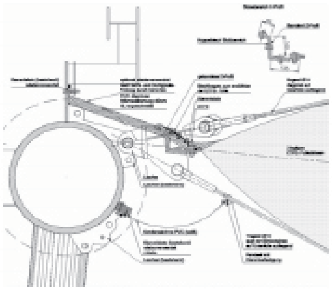


Section through the large cushion

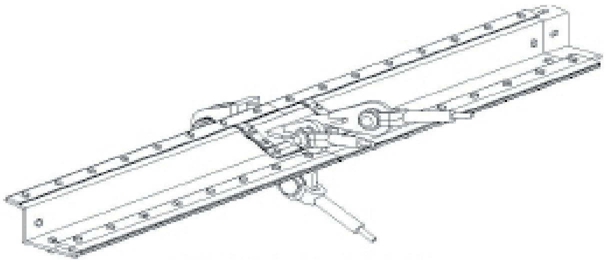
The selected structural system has allowed to stay with the anchoring forces within the loads of the original roof and to keep the maximum forces of valley cable and border cable.

Details

The cushion roof is attached to the existing brackets of the arch truss. The brackets have a distance of 2.36 m. Between those connections the foil cushion is clamped with a continuous Z-profile.

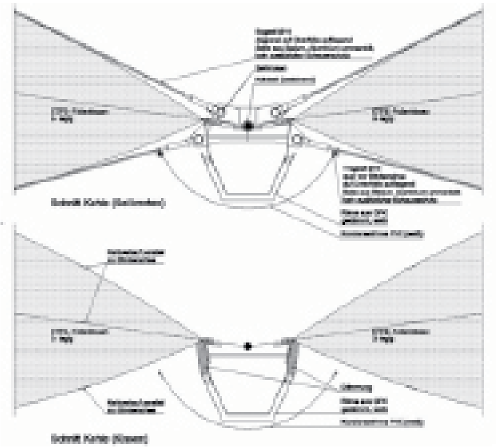


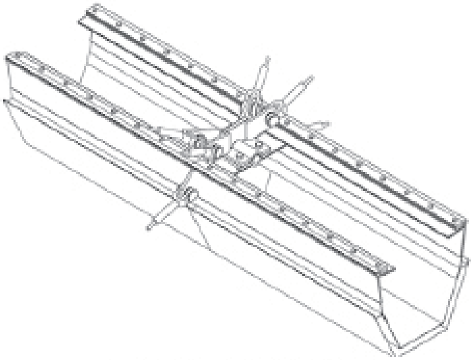
Anschlussdetail am Bogenbinder



Z-profile single element

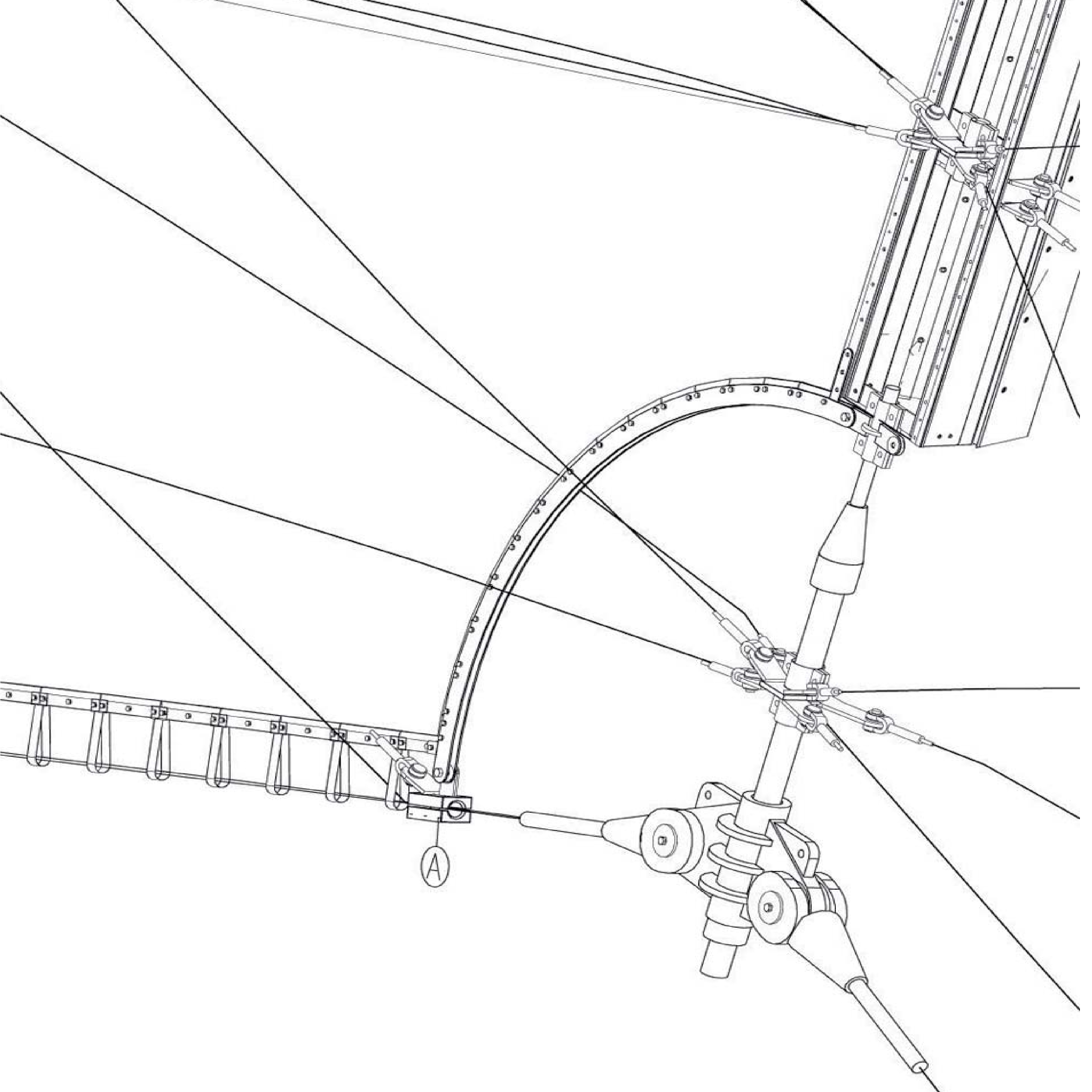
The upper and lower cables are directly connected to the border profile in the area of the plate links.





Gutter profile single element

In the valley zone the two layers of cables are attached to the valley cable with cable clamps. The insulated gutter which drains the roof water is attached to the cable clamps. The connection of the foil cushions is linear analogue to the border detail.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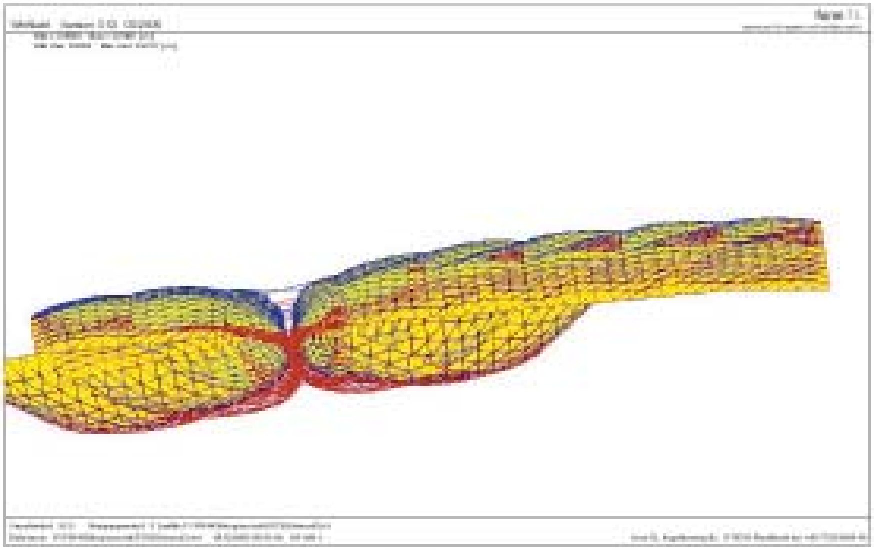
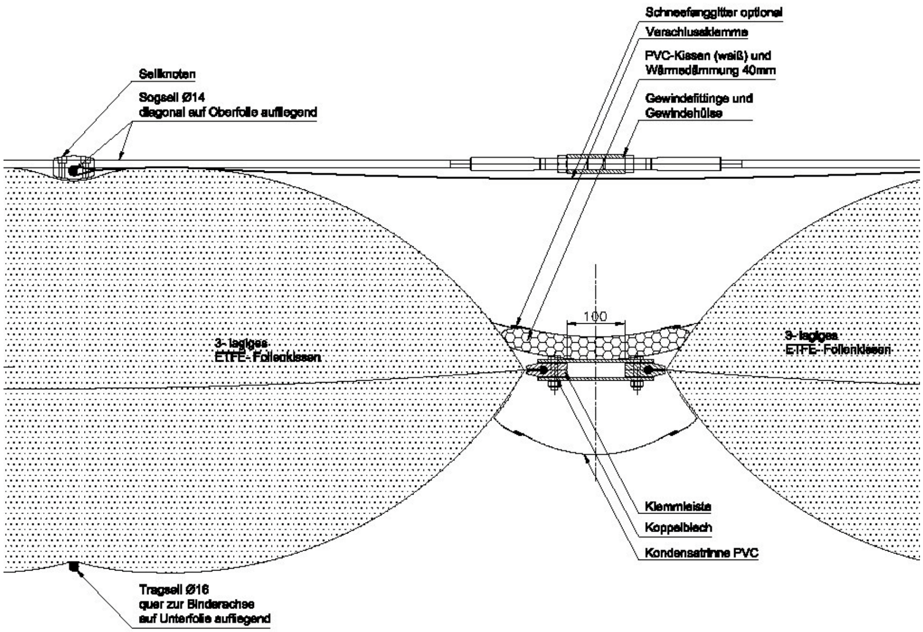
Kehldetail

The large cushion is divided into 14 single cushions. At the joints the cushions are fixed with clamping plates. The clamping plates of the two cushions are connected with flats in the joint area. A heat insulated closure flap is put over the clamping.



Analysis model of the connection joint



Joint detail

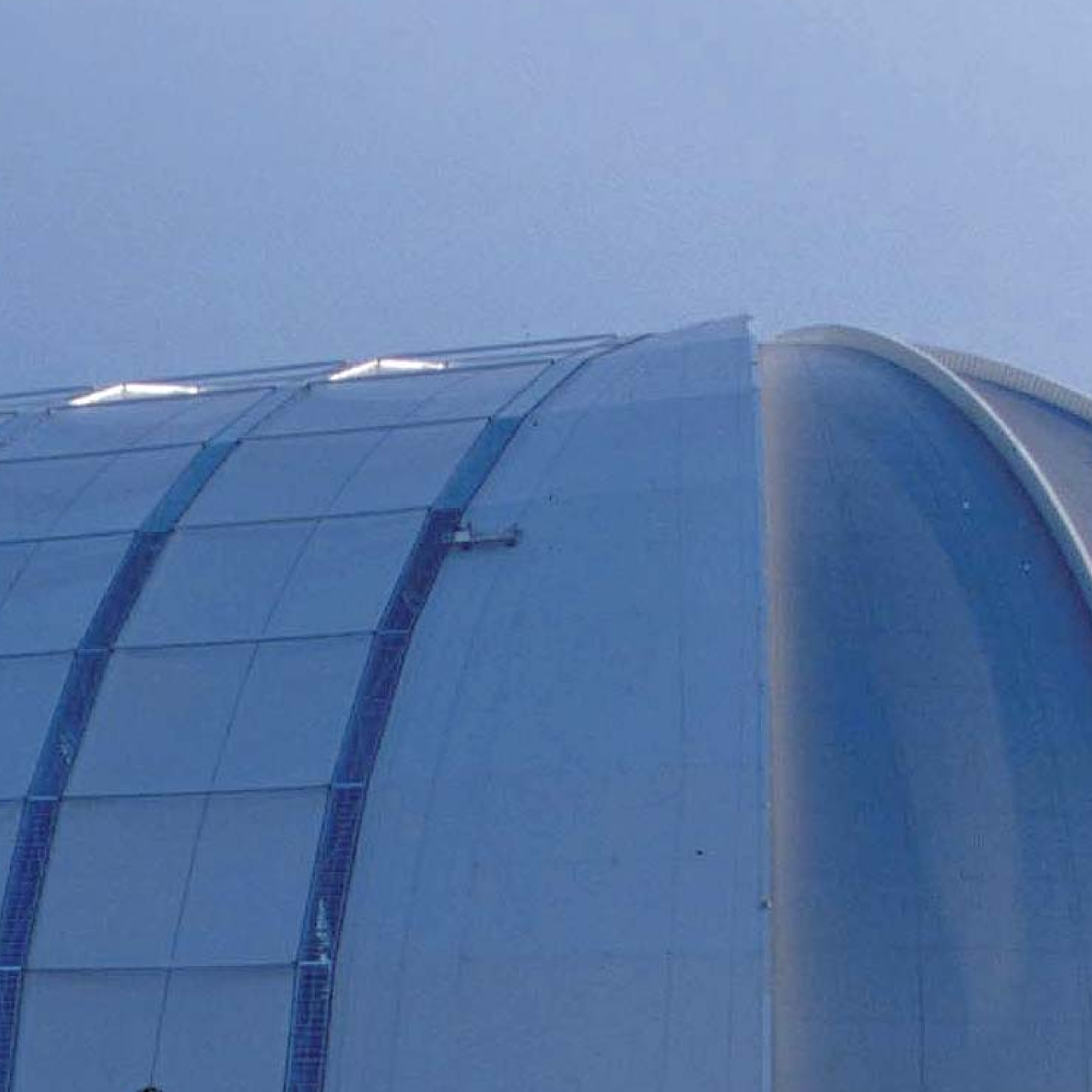
Realisation

The assembly of the foil cushions is carried out from the outside on the present inner membrane.

After dismantling the outer membrane, continuous connection profiles are fixed. With temporary cables the valley cable is brought to the final height and the gutter parts are fixed.

Beginning at the ridge the single cushions are spread out on the lower parallel cables and are fixed to the boundary.

Afterwards the upper cable net is applied and the cushion is blown up with a reduced pressure.
After the bay is fully assembled the inner membrane is dismantled slowly. The temporary cables are removed step by step. With the final inner pressure in the cushion the final structural system is made up.



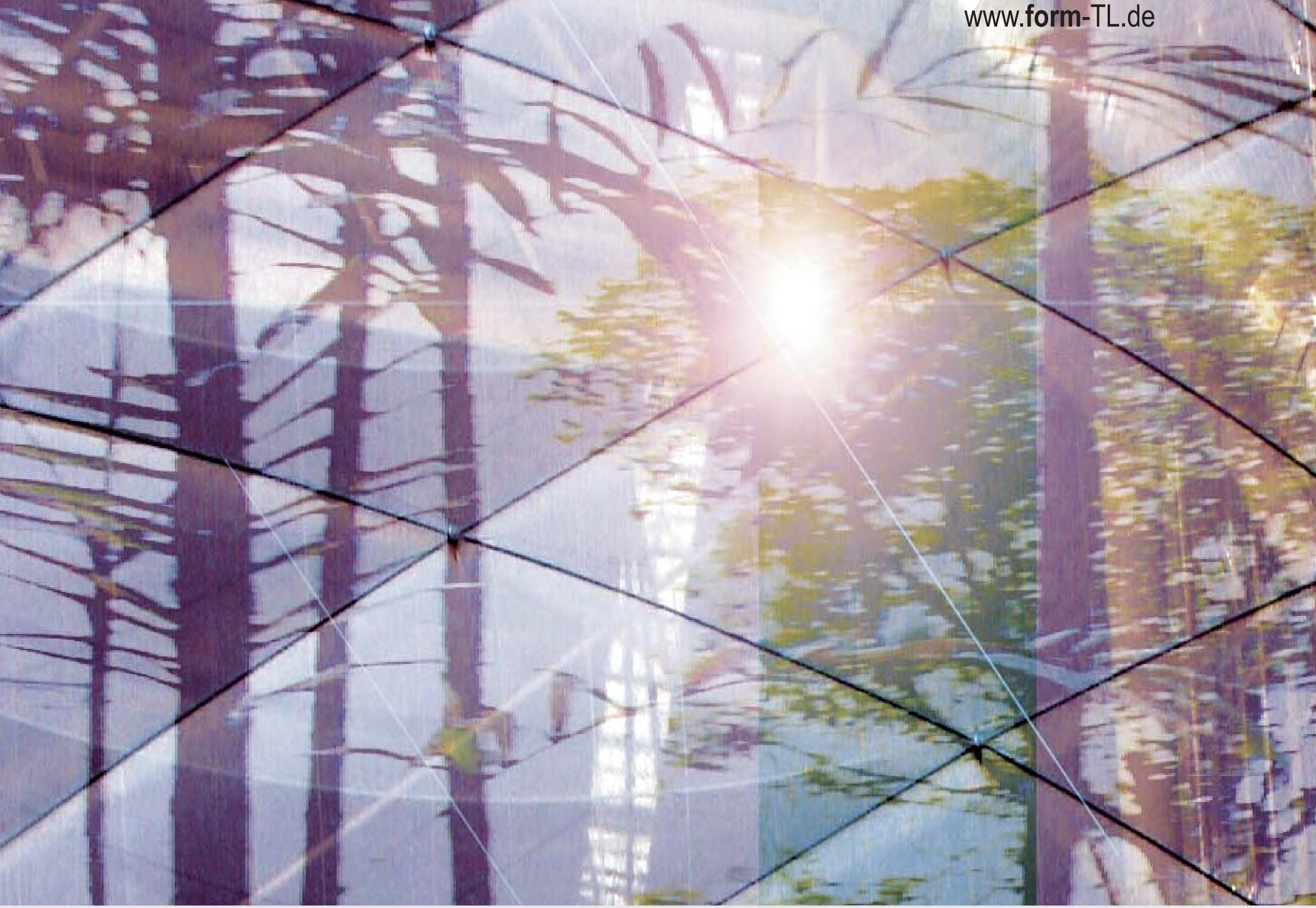
From Cargolifter Airship Hangar to Tropical Islands - Design

For the modification of the CargoLifter-Hangar into a leisure park with a tropical rain forest and bathing areas, four of the southwards directed bays should have, beneath a high general transparency, a high portion of ultraviolet transparency.

The tendered solution assumed a cable truss or a single-layer cable net, which instead of the present outer membrane carries the loads of the roof to the arches. On this cable net the ETFE foil cushions should be elevated by a secondary structure.

Based on the deflections of the original membrane solution a specific proposal in form of an huge pneumatic cushion was developed.

Under applied loads the sag of this cushion correspond to the deflections of the original membrane and therefore has the same load carrying behaviour, that is the same reaction forces.



Impressum

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