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A new ETFE façade creates a landmark for Puebla F.C.

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Cuauhtémoc Stadium, a first division football stadium in Puebla, México, with more than 51 000 seats, has recently been completely renovated. The brand-new façade has become an icon for the club and for the city. The façade is designed as a skin of single-layer ETFE foil in a combination of three different shades of blue and translucent white. The design and construction of the façade is the result of an international collaboration between local contractor DÜNN Lightweight Architecture, from Zapopan, Mexico, and LEICHT Structural engineering and specialists consulting GmbH, based in Munich, Germany. This paper will elaborate on the boundary conditions of the project and the technical decisions made for the construction of the façade.

1 Introduction

The all-new façade to Cuauhtémoc Stadium is part of a project for the full refurbishment of the stadium originally built in 1968 and designed by Pedro Ramirez Vázquez. The commission for the refurbishment was granted via a public competition in 2014 and the new stadium was inaugurated in November 2015.

The tight deadline, together with the considerable dimensions of the façade, made the project a real challenge for DÜNN Lightweight Architecture, the local contractor appointed to build the lightweight façade.

ETFE has become established as a construction material for lightweight facades and is already used at many football stadiums all over the world. Examples include the Allianz Arena in Munich, where ETFE is used in the form of pneumatic cushions, or Stadium Océane in Le Havre, which is covered by a single-layer ETFE façade. However, ETFE still has to be considered as a new construction material, as experience with the material stretches back no more than 20 years.

All those boundary conditions convinced the contractor that it would be prudent to build an international team with experts from LEICHT Structural engineering based in Munich, Germany, in order to collaborate on the engineering of the ETFE foil and clamping details as well as the planning of the fabrication.

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1.1 ETFE façade – high performance from a lightweight envelope

The envelope to Cuauhtémoc Stadium has one main function: to function as an icon for a modern, vibrant young city, standing for cosmopolitanism and radiant vitality. The new façade is supposed to convert the old stadium into a new, fresh symbol for the football club. The construction material had to allow the stadium to shine not only during the day, but also at night. As in many other stadiums, the

Fig. 1. ETFE envelope during lighting tests; source: DÜNN Lightweight Architecture

envelope was planned to be translucent in order to let the stadium “glow” during evening matches.

The material of choice was ETFE, a perfectly stable outdoor material that provides the translucency and colourful appearance required while having all the advantages of a membrane construction.

2 A total of 120 independent panels with a close relationship

The façade covers approx. 26 000 m² and is divided into 120 ETFE panels. The substructure is composed of steel trusses, which are equidistant and radially distributed. Fig. 2 and Fig. 3 show the distribution of the panels. The double symmetry of the stadium allowed the 120 panels to be grouped into just eight types, thus optimizing the fabrication planning of the ETFE foil and the aluminium and steel clamping elements.

The façade panels span between the steel trusses, which are installed with a centre-to-centre spacing of approx. 6 m. The total height of the panels is approx. 36 m.

An aluminium keder profile clamps each panel along the edges. However, a single layer of ETFE foil is not able to span the 6 m of the entire panel, and therefore an 8 mm stainless steel cable reinforces it every approx. 800 mm. The result is that the span of the ETFE material is reduced from 6 m to about 0.8 m. This span is easily possible with 200 µm thick ETFE foil.

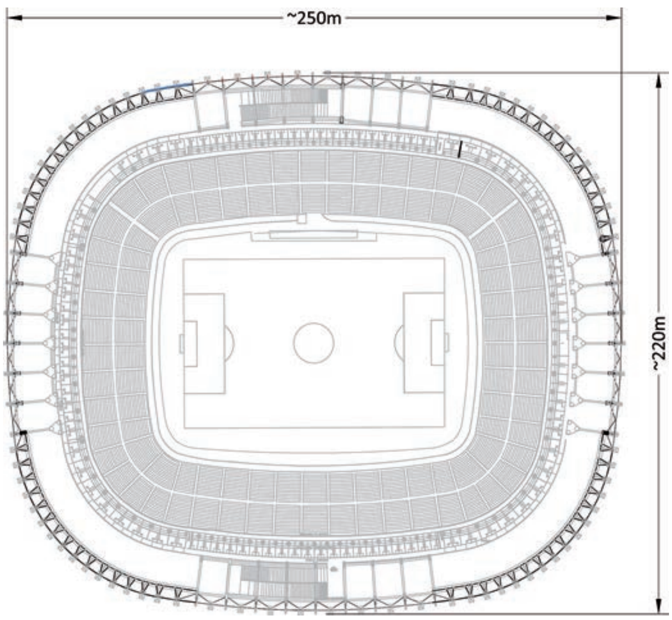

Fig. 2. Plan of Cuauhtémoc Stadium; source: DÜNN Lightweight Architecture

Fig. 4. ETFE façade panel; source: DÜNN Lightweight Architecture

Fig. 4 shows the first panel that was built. It was intended to be built as a mock-up, but given the successful results, the panel was kept in place and the cutting patterns were used to produce the other panels.

The reduced diameter of the cables makes them imperceptible. Additionally, the location of the cable pockets in the membrane matches with the overlap between the different strips, in most situations also coinciding with a colour change.

According to the system described, most of the loads on the foil will be transmitted to the substructure through the cables. Details of the cable clamping can be seen in Fig. 5.

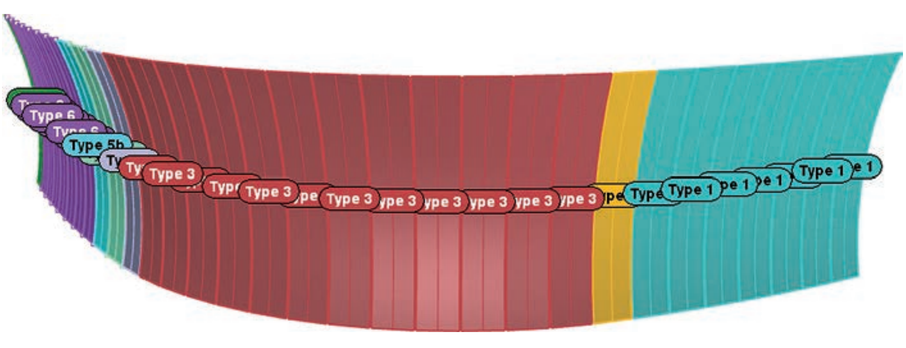

Fig. 3. Façade panels for one-quarter of the stadium – visualization; source: LEICHT

Fig. 5. Façade mock-up – cable clamping; source: DÜNN Lightweight Architecture. The cable clamping detail can adjust the length of the cable according to the measurements on site, avoiding any deviations due to imperfections in the steel structure.

2.1 Clamping system

It was important to offset the complete clamping system from the steel structure in order to avoid possible collisions between the deflected ETFE and the steel trusses. The standoffs were dimensioned accordingly in order to fulfil these requirements. Fig. 6 displays the determination of the offsetting distance.

Fig. 7 and Fig. 8 show the details of the clamping system. The aluminium keder profile that needs to span between the standoffs is reinforced by a steel profile, which is then clamped to the standoffs. The locations of the standoffs are directly related to the positions of the cables, as the cable clamping is connected directly to the standoff plates. Fig. 9 shows a close-up image of the clamping system.

The linear reaction forces at the edges of the panels are counteracted by the neighbouring panels, which means that the complete envelope neutralizes the horizontal linear reaction forces resulting from the membrane prestress. This is achieved through the horizontal bolted connections between panels. As soon as the panels are fully installed, the connections between steel beam and standoffs no longer carry any shear forces. This allowed the use of slotted holes, which were needed to fulfil the tolerance requirements.

2.2 Tight tolerances for precise construction

Owing to the requirements of the steel contractor, all connections had to allow a considerable degree of tolerances. The ETFE membrane was planned to be prestressed with 0.6 kN/m in both the x and the y directions. This value was only allowed to vary by ± 0.2 %, which meant that the membrane needed precise clamping conditions to achieve a positional accuracy of ± 0.2 %.

In general, the ETFE panel will exhibit a better material behaviour in addition to a better visual appearance when installed according to the planned prestressed levels. If this prestress level is lower, the appearance will be directly affected and there will be a risk of wrinkles developing. If, on the contrary, the prestress level is higher than planned, the mechanical behaviour of the membrane and its safety factor will be adversely affected; however, the risk of wrinkle development will be significantly lower. Other secondary effects such as creep can be caused by wrong levels of prestress in the membrane.

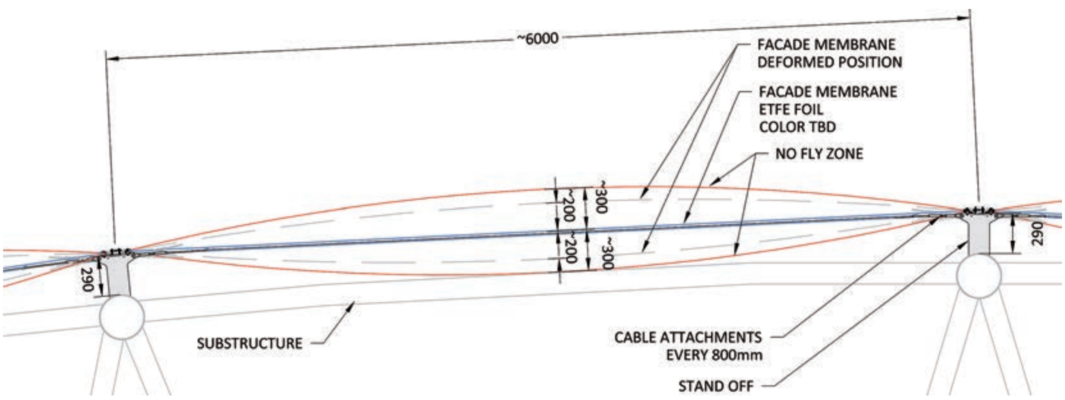

Fig. 6. Deflection of ETFE façade panel – horizontal section; source: LEICHT

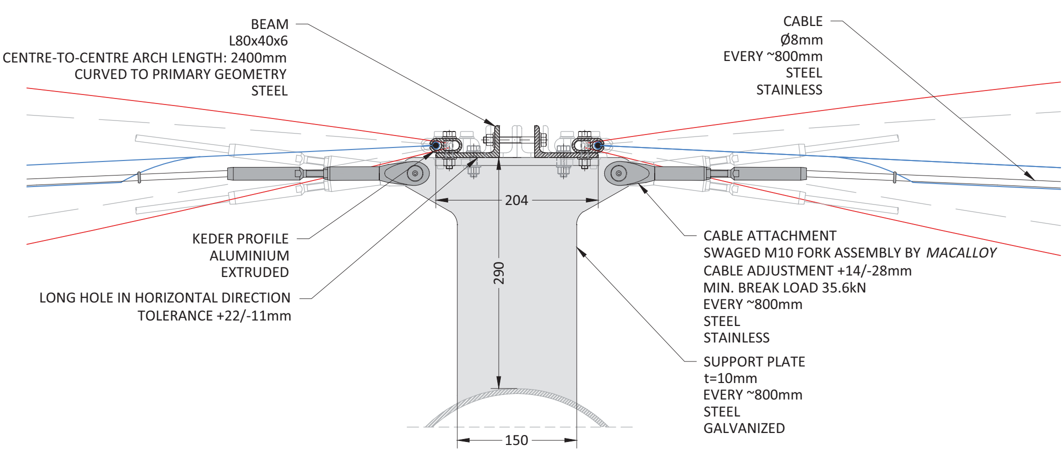

Fig. 7. ETFE façade panel clamping detail – horizontal section; source: LEICHT

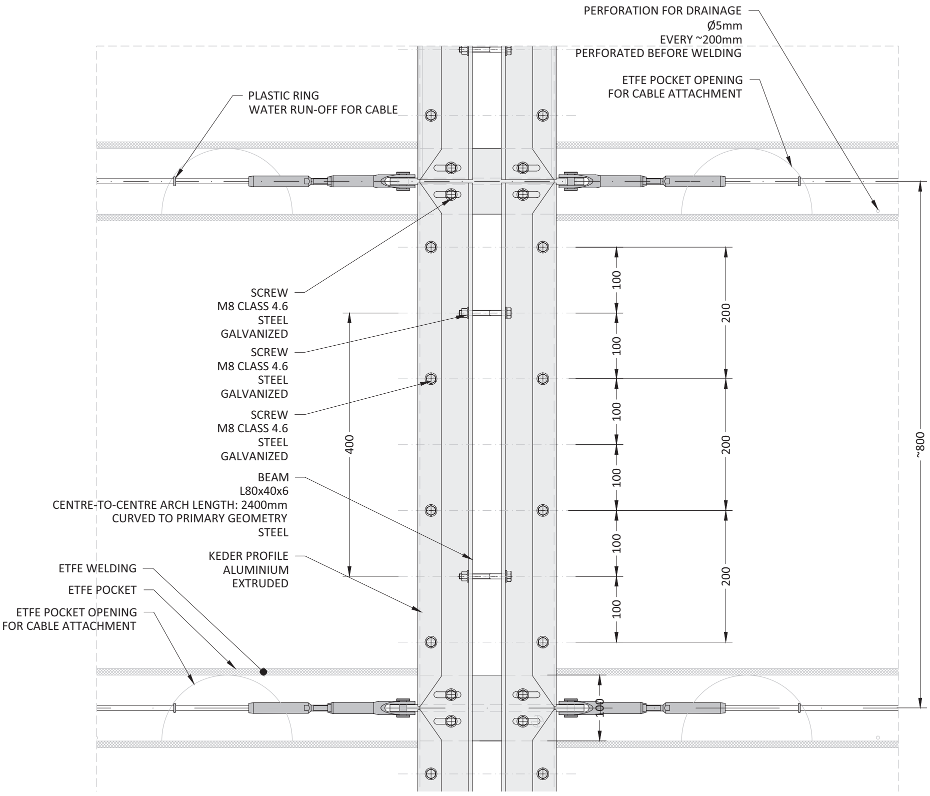

Fig. 8. ETFE façade panel clamping detail – elevation; source: LEICHT

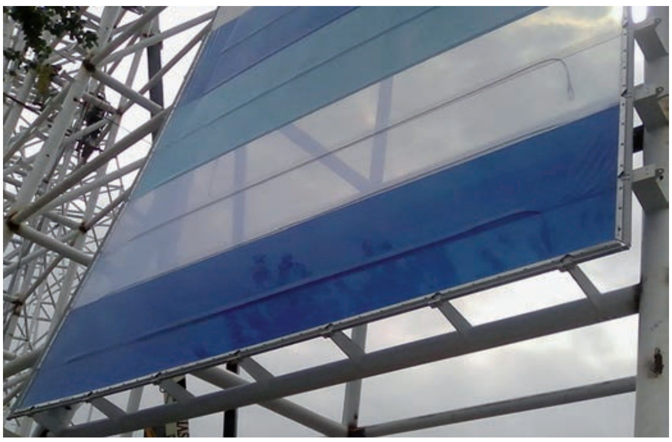

Fig. 9. Close-up of ETFE façade panel; source: DÜNN Lightweight Architecture

For this purpose, all the connections between the angle sections and the standoffs employ slotted holes. This way, the exact location of the edge system lines of the panels could be adjusted according to the actual conditions on site. As shown in Fig. 10, the tolerances in the positive direction are double those in the negative direction in order to allow for potential post-stressing events on site over the design life of the façade.

2.3 Membrane details

The panels have a quasi-rectangular geometry and they are composed of a superposition of ETFE strips in a range of three shades of blue and a translucent white foil. All the

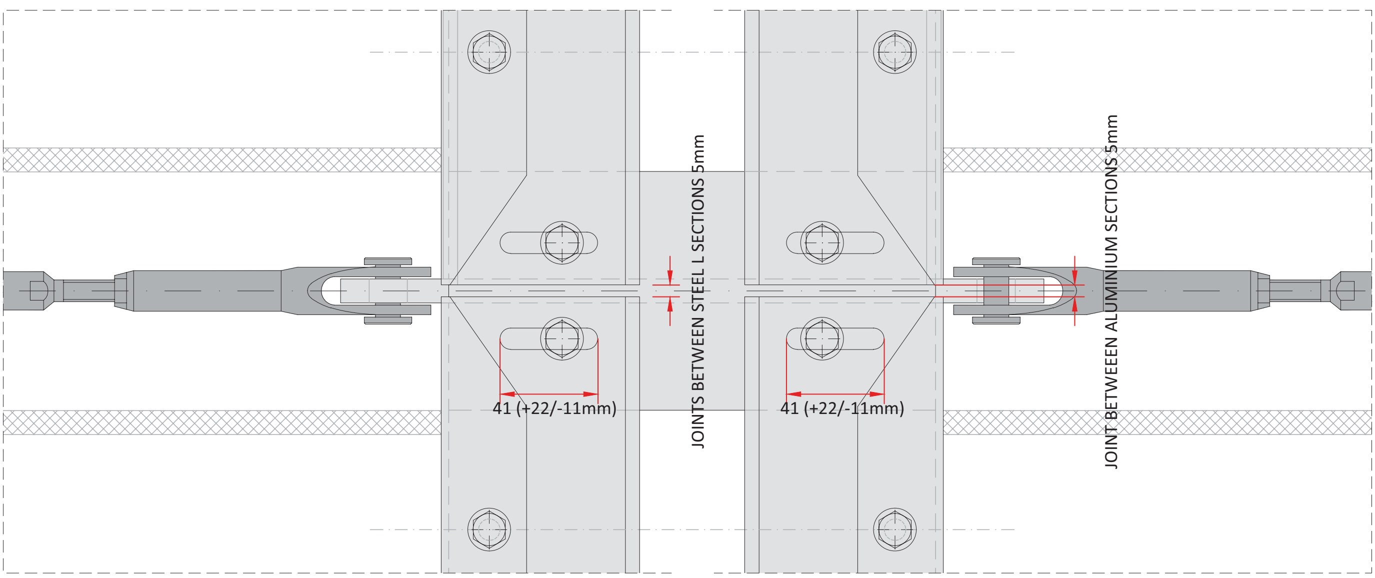

Fig. 10. Tolerances for clamping detail – elevation; source: LEICHT

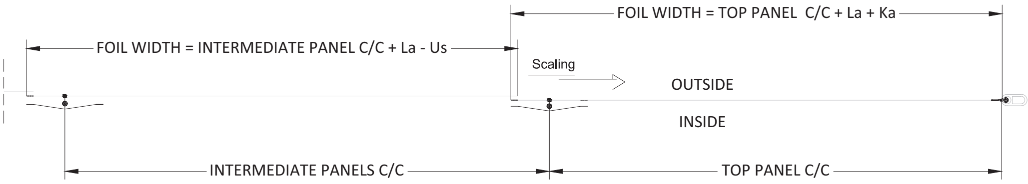

Fig. 11. Membrane detail – vertical section; source: LEICHT

panels were made from ETFE with the same thickness – 200 µm.

The cutting patterns were optimized to produce as little waste as possible. The foil, provided by German producer NOWOFOL®, is produced in rolls 160 cm wide and the panels were divided into 800 mm strips. As previously described, the positions of the cable pockets match the positions of the overlapping joints. This meant that the size of the cutting patterns had to be taken into account from the early stages of the project, as they are directly related to the positions of the cables and, consequently, they affect the structural calculations for the foil.

Fig. 11 shows an overview of the foil details. Please note that the foil overlap matches the position of the cable pockets.

3 Conclusions

The ETFE envelope for Puebla F.C. and the City of Puebla was well received by the citizens. According to the specialized website stadiumdb.com [1], Cuauhtémoc Stadium was voted one of the top 10 new stadiums of 2015.

Cuauhtémoc Stadium is one of the few structures recently inaugurated in North and Central America which use ETFE for its envelope. Other structures, such as “American Dream”, the new shopping mall in New Jersey, which is scheduled for completion in 2016, or the new Mercedes Benz Stadium for the Atlanta Falcons, which is currently under construction, also took a step forward and bet for the advantages of a lightweight ETFE envelope. Although it is a widely accepted construction material all over the world, its application is still rare in North and Latin America. However, based on the recent construction trend, it appears that ETFE history is set to begin on the American continent.

References

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Fig. 12. Cuauhtémoc Stadium on the day of its inauguration; source: DÜNN Lightweight Architecture

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