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Cable-stayed glass façades - 15 years of innovation at the cutting edge

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Today's demand for highly transparent building envelopes calls for innovative solutions. Cable-stayed glass façades make it possible to dematerialize the building envelope so as to make it almost imperceptible. Werner Sobek has designed a great number and variety of cable-stayed façades. The primary structural system carrying most of these façades consists of straight tension members (e.g. tension rods, cables), typically in a parallel arrangement. The tension members transfer the dead load of the glazing very efficiently to the supports. Under wind load the members undergo large deflections thus activating their lateral stiffness. As a result, the detailing of these façades requires innovative design approaches and special care to allow for such large deflections. Besides this, each project has its individual challenges such as a complex geometry, large openings, difficult edge conditions, warping of IG units, bomb blast requirements, etc. The present article gives an overview of the development of cable-stayed façades as designed by Werner Sobek over the last 15 years. The overview includes completed projects as well as façades currently under construction or in the design phase.

Keywords: Glass, Cable-stayed glass façades, Case studies

1. Introduction

The demand for dematerialized façades and highly transparent building envelopes has increasingly pushed architects and engineers to the limits of technical feasibility. The façade of the Bioclimatique Greenhouse in Paris (RFR and Adrien Fainsilber, 1986) and the atrium façade of the Hotel Kempinski (Murphy/Jahn and Schlaich Bergermann, 1993) are milestones on the development of cable-stayed glass façades. The former is a cable truss holding a glazed façade, while the latter is a cable net façade that is prestressed both horizontally and vertically. Both projects were an important step towards transparent building envelopes. Werner Sobek and his team have pushed the boundaries of transparency even further. This development started in 1995 with the design of the 40 m high façade of the New Bangkok International Airport.

The façade of the Bangkok Airport is one of the largest cable truss supported glass façades in the world. The reduction of the primary structure to its bare essentials led to the development of cable-stayed façades characterized by only straight prestressed tension members oriented in just one direction. Compared to conventional cable net structures (i.e. structures oriented in two directions) and cable trusses, this typology allows not only for an increased transparency, especially at the corners, but also leads to better solutions for openings, non-planar surfaces, support conditions, etc.

The tension members (e.g. tension rods, cables) transfer the dead load of the glazing very efficiently to the supports. Under wind load these members show large deflections activating their lateral stiffness. Over the years special solutions were developed to keep the deflections as small as possible and to obtain a homogeneous curvature in the deflected state to improve the warping condition of the individual glazing units. Special attention was paid to functional and aesthetical detailing (i.e. glass fixing) and on the design of sensitive fields such façade openings and corners.

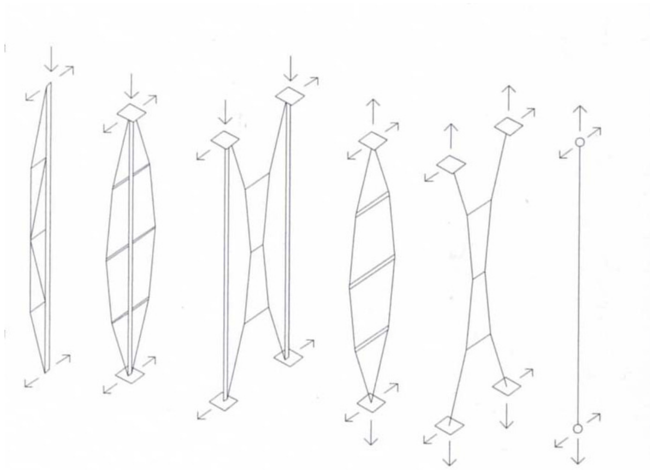

Figure 1: Principle primary structural systems of cable-stayed façades [1]

2. Realized Projects

2.1. Sony Center – Hotel Esplanade, Berlin

At the Sony Center in Berlin, completed in 2000, only vertical tension rods were used for the primary structural system. A highly transparent glass façade was to shelter the protected remnants of the former Hotel Esplanade. Together with the architect Helmut Jahn from Chicago, Werner Sobek developed a façade that is 60 m wide and 20 m high. The primary structure consists of pairs of tension rods with spring supports. The glass panels are placed between pairs of tension rods, thus avoiding eccentric loading that may result out of the self-weight of the glazing. Four drilled point fixings have been used for each glass panel (2 m x 2 m, FT).

Spring base supports keep the pretension force in the rods almost constant, independently of temperature changes. The Esplanade facade allows for horizontal deflections of up to 60 cm under wind loads. A similar design approach was used by Dewhurst Macfarlane and Partners for the façade of the Kimmel Center in Philadelphia, completed in 2001. In this case, however, the pretension force in the cables is kept constant by cast iron weights at the cable supports rather than by spring supports [2].

Figure 2: Sony Center – Hotel Esplanade, Berlin

2.2. ZBUB, Bremen

This facade of a new foyer building of the University of Bremen was designed by Werner Sobek and the architect Jan Störmer. The building was completed in 2000. The façade's main structure consists of fully locked cables (∅26mm) that are set 1.8 m apart from each other. The cables have spring supports to keep the pretension force almost constant under temperature variation and snow loading on the roof. The 15 m high façade can deflect up to 35 cm under wind loading. The glass units (1.8 m x 0.9 m, FT) have four clamped point fixings in the horizontal joints. Clamped point fixings instead of drilled point fixings have been used to minimize the local stress concentration in the glass. These point fixings are connected eccentrically with the fully locked cables, thus inducing bending in the cables.

In order to allow for a fully glazed corner Werner Sobek introduced a joint between the cable-stayed façade itself and the rigid façade structure in the corner. The joint is formed by two vertical glass fins. Brushes between the fins ensure a high level of insulation even when the cable-stayed facade deflects under strong wind loading.

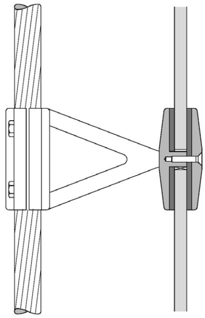

Figure 3: ZBUB, Bremen

2.3. Bayer Headquarter, Leverkusen

At the Bayer headquarter in Leverkusen (architect: Murphy/Jahn, Chicago, completion: 2002) Werner Sobek used open spiral cables with spring supports spaced at 1.5 m to each other [3]. Contrary to the ZBUB project, however, the glazed corner is not separated by joints from the rest of the façade to achieve an even more transparent glass corner. The deflection of the façade at the building corner area is homogenized by flat springs behind the horizontal joints (as shown in figure 4), thus minimizing the warping of the glass panels. The laminated glass panels (1.5 m x 1.8 m, FT) are held by clamped point fixings at the corners of the panels. The self-weight of the glass units is connected eccentrically to the cable.

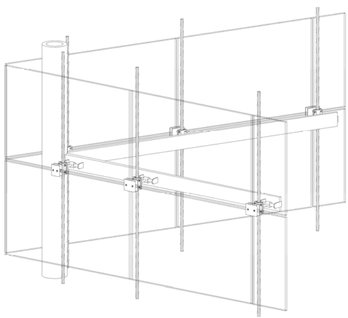

Figure 4: Bayer Headquarter, Leverkusen

2.4. O'Hare, Chicago

The new glass façade of Terminals 2 and 3 of the International O'Hare Airport in Chicago was designed by Werner Sobek together with Murphy/Jahn. This was the first time that insulating glass units were used for such a cable-stayed facade. The primary cables are open spiral cables (∅32mm and ∅20mm) spaced 3 m apart. These cables were strongly prestressed to minimize the overall deflections of the façade, thus also reducing the warping of the IG units (3.0 m x 1.4m, FT and HS). Each IG unit is supported by four clamped point fixings. Beside the wind loading scenarios the IG units were also designed to fulfil blast mitigation requirements.

The IG units are suspended via secondary tension members within the vertical glass joints. This helps to avoid eccentric loading of the primary cable which may otherwise result from the heavy self-weight of the IG units. Since there are various entrances into the terminal building, a solution had to be found for the many joints resulting from these openings. Werner Sobek developed profiles similar to convoluted rubber gaiters to deal with particular situation thus limiting the warping of the IG units.

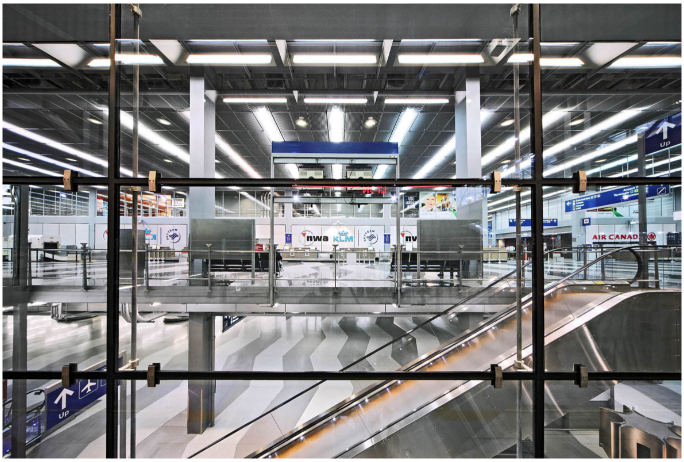

Figure 5: O'Hare, Chicago

2.5. Lufthansa Aviation Center, Frankfurt

The Lufthansa Aviation Center in Frankfurt was completed in 2005 following a design by Ingenhoven Architects. The comb-shaped structure has ten 'fingers' linked by fully glazed atriums. In order to achieve maximum transparency, the external façades of these atriums are designed as a cable-stayed façade, the only load-bearing elements are vertically tensioned cables. The IG units (1.45 m x 3.45 m, FT) are supported by pairs of vertical open spiral cables (∅28 mm) spaced 1.45 m apart. Each IG unit transmits wind loads to the cables by means of six clamped point fixings. Two of these fixings also transfer the self-weight of the IG units to the cables. The arrangement of the cables in pairs allows the efficient transfer of the self-weight via a force couple – tension and compression – into the prestressed cables.

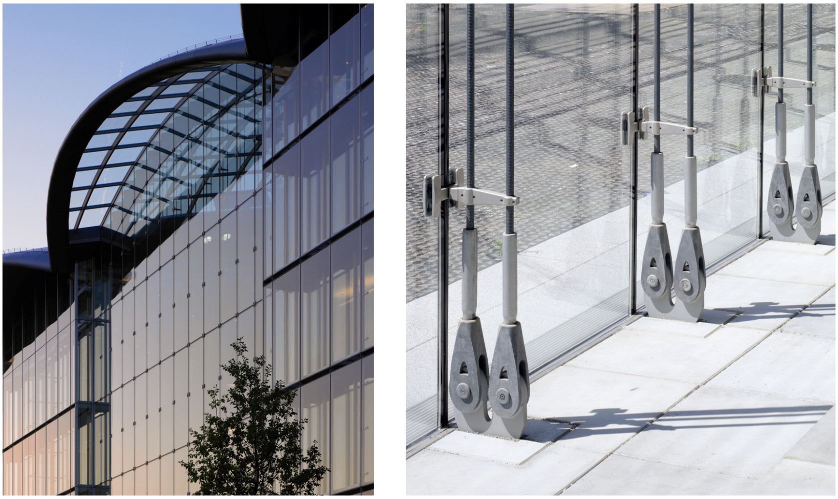

Figure 6: Lufthansa Aviation Center, Frankfurt

The 25 m high facade can deflect up to 40 cm under wind loading. A smooth transition between the rigid façades of the fingers and the flexible cable-stayed façades of the atrium is ensured by glass fins with brushes, an approach already used in the above-mentioned ZBUB project.

2.6. European Investment Bank, Luxembourg

The European Investment Bank in Luxembourg is another project of Werner Sobek with Ingenhoven Architects that uses cable-stayed glass facades. The largest façade within this project is 22 m high and 45 m wide. The primary structure consists of vertical cables (∅30 mm) that are fixed at the top to the bottom chord of a long-span underslung beam.

Figure 7: European Investment Bank, Luxembourg [4]

The argon-filled IG units (3.54 m x 1.75 m, FT) have six clamped point fixings – two in the horizontal joint and four at the corners. Two of the four corner supports transfer the self-weight of the glass pane to secondary stainless steel cables (∅14 mm) which are hidden in the vertical glazing joints.

The transition to the rigid parts of the building envelope is again provided by vertical glass fins. A double set of sliding gaskets between the moveable and the fix part of the glass fins ensures the required air and water tightness at the joint.

2.7. Emil Schumacher Museum, Hagen

The façade of the Emil Schumacher Museum in Hagen was designed by Lindemann Architekten together with Werner Sobek. A glass envelope encases a cube where the exhibition rooms proper are located. The 16 m high glass façade is supported by one-way oriented prestressed cables (∅30 mm) spaced 3 m apart. Flexible heating tubes in the glass joints shall prevent condensation water. The glazing consists of argon-filled IG units (1 m x 2.95 m, FT) with four clamped point fixings.

Figure 8: Emil Schumacher Museum, Hagen

3. Projects under Construction

3.1. Doha Convention Center, Qatar

The Doha convention centre and tower will bring a breathtaking aspect to the Doha skyline. Werner Sobek and his team designed together with Murphy/Jahn the facades of the convention centre using two different types of cable-stayed facades. The southern and western façade have only parallel horizontal prestressed cables. The IG units are hung with tension rods in the vertical joints to the roof girder. The eastern façade has vertical prestressed cables. The detailing of the facades required special attention as the facades are also inclined and curved [5].

3.2. Ferrari & Maserati Museum, Italy

The Ferrari & Maserati Museum in Modena was designed by Future Systems. Werner Sobek modified and improved the cable-stayed façade design and is in charge of engineering the whole façade of the museum up to construction.

Such a complex double curved façade, whose height varies from 6 to 11 m, has been solved by using only a set of vertical stainless steel cables (∅32 mm), located eccentrically. Special attention was paid to controlling the deflections of the whole façade as well as the warping of the most critical IG units (max. size 2.0 m x 1.25 m) by fine-tuning every single cable pretension force.

Figure 9: Ferrari & Maserati Museum, Modena

Figure 10: Ferrari & Maserati Museum, Modena - inside

4. Summary

Since 1995 Werner Sobek has continuously worked towards an ever-increasing transparency of the building envelope. The reduction of the façade primary structure to its bare essentials led to cable-stayed façades with only one-way oriented parallel prestressed tension members. Such cable-stayed glass façades allow to dematerialize the façade to an almost imperceptible glass envelope.

5. References

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