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Glass Works

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Today's demand for highly transparent building envelopes which are also adaptive and sustainable calls for innovative solutions in the glass design.

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1. Introduction

The expressive potential of glass in architecture is far from being realized to its full extent. A better use of the structural properties of glass – taking its brittleness into account – will allow for more dematerialized glazed building envelopes and glass structures in the future. However, the current architectural design intents for building envelopes do not only strive for transparency but also for translucency, adaptivity and sustainability. All these facts are key aspects of the work done by Werner Sobek and his team. A selection of current glass research topics and façade projects is presented in this article.

2. Glass Research - Institute for Lightweight Structures and Conceptual Design

For several years the Institute for Lightweight Structures and Conceptual Design (ILEK) has been actively engaged in the research and development of advanced glass structures and systems, including long-span glass arches, adhesively-constructed glass shells, adhesive metal steel connections, interlayer materials, reinforced laminated glass and adaptive glazing systems.

2.1. Laminated Glass

Within the field of laminated glass, especially the quantification of the shear-transfer through the interlayer material and possibilities for enhancing the residual load bearing behaviour through reinforcement within the interlayer were key research topics.

The shear-transfer through the interlayer material in laminated glass and its favourable influence on glass-stresses and deflections has been investigated considering load duration and temperature in [5]. This research led to a laminated glass design approach taking the shear bond into account and allowing for an economic design of laminated glass with reduced pane thickness.

The technologies of reinforced laminated glass lead to considerable improvements in the structural and aesthetic quality of glass architecture. By means of lamination combined with embedded reinforcement, it is possible to increase the residual strength of glass panes in the damaged state, thus counteracting the natural brittleness of this material [2]. The glass reinforcement may not only act as a structural but also as an architectural device. The envelope of a building may be textured with the fine pattern of the reinforcement. Depending on architectural as well as energy considerations, it is often desirable to control the transparency rate of a building envelope. The embedded reinforcement may therefore also act as an integrated shading system.

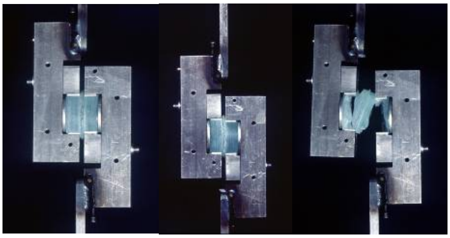


Figure 1: Testing of the shear bond.

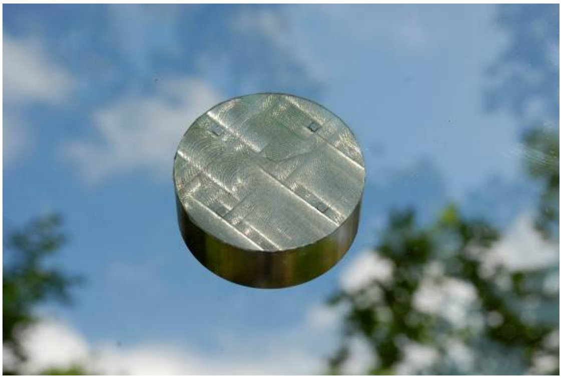
Figure 2: Laminated glass with and without embedded reinforcement in the damaged state.

2.2. Adhesives

A continuous joint is ideal to carry forces between glass panes, since peak stresses in glass are minimized. However, the search for unobtrusive joints has pushed the field from continuous metallic frames to point fixings, thus causing non-optimal stress distributions in the glass panes. Adhesive joints between glass panes are a promising alternative to existing joint technology, since they are continuous and yet do not dominate over glass.

Figure 3: Prototype of a frameless glass shell built at ILEK, University of Stuttgart.

The knowledge acquired on adhesive joints and laminated glass panes has allowed for the design and construction of a frameless glass shell, spanning 8.5 m by means of 1 cm thin laminated glass. The laminated glass units (8 mm annealed glass laminated with a 2 mm chemically strengthened glass) are only connected with epoxy butt joints thus achieving the highest possible rate of transparency for the glass shell [1].



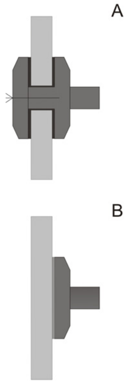


Figure 4: Adhesive glass-steel connections (B) instead of drilled point fixings (A).

Point fixings with adhesive glass-steel connections instead of drilled point fixings have been investigated to minimize the local stress concentration in the glass [8]. Transparent acrylates promise exciting new possibilities for this type of connection in the façade design.

The load bearing capacity of acrylate adhesives can be affected quite significantly by certain environmental conditions, but not all acrylate products are affected in the same manner. Standardized test methods and guidelines like the ETAG for structural sealants should be established to ascertain the durability of acrylate adhesive connections. Nevertheless, the transparency of these joints and the architectural and structural possibilities they offer give acrylate adhesive connections great potential to advance the field of glass design.

Figure 5: Delo glue, adhesive failure.

Figure 6: Bohle glue, fracture of glass pane.

Figure 7: Sika glue, cohesive failure.

With the introduction of SentryGlas, the company DuPont made available an interlayer material with superior stiffness properties at room temperature compared to commonly used interlayer materials. This allowed the glass pane thickness to be reduced. But the ability of SentryGlas to adhere well to metal has also presented the opportunity for new and innovative glass connection techniques. James O'Callaghan [4] describes, for example, the embedding of a metal insert into a four-pane glass laminate, with the metal insert acting as a connector to the surrounding structure after lamination. In this case, the interlayer acts not only as a bonding partner of the glass panes but also as an adhesive between the primary load carrying elements.

Supplementary to studies at the TU Delft concerning metal-to-glass bonding properties of SentryGlas [6], research conducted at the Institute for Lightweight Structures and Conceptual Design at the University of Stuttgart examines the load carrying behaviour and the load transfer of metal inserts embedded in glass laminates.

2.3. Adaptive Glazing Systems

Glazing Systems must satisfy numerous criteria, on the one hand allowing an unobstructed view of the exterior but also providing the desired amount of protection from direct sunlight and the associated heat transfer. In order to optimize the performance of glazing systems under varying conditions, much effort has been directed towards the development of adaptive glazing systems based on smart materials. By modifying conventional liquid crystal technologies used for display screens and introducing new materials and processes, a switchable glazing system with unique and promising characteristics was developed at the ILEK [3]. This switchable glazing system is currently further enhanced to obtain a solution ready for the market in the near future.

Figure 8: Adaptive Glazing System.

2.4. Glass Studio

One key seminar at the Institute for Lightweight Structures and Conceptual Design – the so called ILEK LAB – exposes students from the faculties of Civil Engineering and Architecture to one building material per semester. Within this seminar series, in the summer term of 2008 and the winter term 2009/2010 an explorative workshop focusing on new design possibilities with glass was held with technical guidance provided by the glass fabrication shop at the Stuttgart State Academy of Art and Design [7]. The students gained insight into the theoretical foundations of glass while simultaneously accumulating practical experience working with the material. Different fabrication approaches and technologies were used to create glass objects which reveal new design qualities beyond the aspect of transparency.

Figure 9: Glass-glass joint.

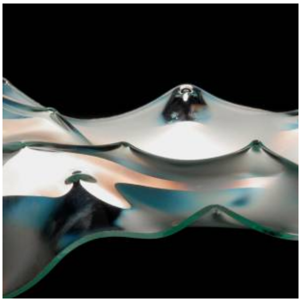


Figure 10: Deformed glass pane.

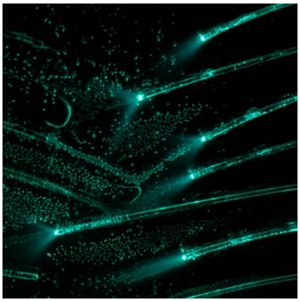


Figure 11: Integrated optical fibers.

The objects created are not intended for direct architectural application, but rather to serve as stimulus for a new and innovative design approach for glass elements

3. Design of glazed building envelopes - Werner Sobek Group

3.1. Serono Headquarter, Geneva - Openable Glass Roof

The new headquarters of the Swiss pharmaceutical company Serono in Geneva has been designed together with the architect Helmut Jahn. The atrium, the forum and most of the office facades are completely glazed. Even the roof of the forum is a fully glazed structure which can be opened hydraulically. Counter weights minimize the forces in the open state. The curved steel-glass structure of the forum's façade below has to be braced in the open state. Therefore prestressed cables are arranged in a radial manner to ensure lateral stability. Two revolving glass doors with a height of approximately 12 m are part of the curved forum façade.

Figure 12: Serono Headquarter, Geneva - Openable Glass Roof.

Figure 13: Serono Headquarter, Geneva - Openable Glass Roof above the Forum.

3.2. Qatar Education City Convention Center, Doha/Qatar – Glass Fin

The convention center building is part of the Qatar Education City complex located in Doha, Qatar designed by Arata Isozaki. The steelwork of the roof structure is based on the sidra tree which is native to Qatar and flourishes in the country's harsh desert climate. It is also the symbol of the Qatar Foundation. The complex tree-like steel structures supports the roof of the entrance foyer. A transparent glass façade with glass fins build up the southern foyer facade. This glass façade is 250 m long and 20 m high, with 15 m returns on the east and west side. The 20 m high and 800 mm wide glass fins are hybrid glass-steel structural elements spaced 4 m apart. The glass of the fins is adhesively bonded to stainless steel profiles with structural silicone. Secondary fins (180 mm wide) are arranged in between these primary fins.

Figure 14: Foyer Façade of Qatar Education City Convention Center – Detail of Fin.

3.3. Maritime Museum Lingang, China - Cable-Net Facades

The Maritime Museum in Lingang has been designed by Gerkan Marg und Partner together with Werner Sobek. The main component of the new museum is composed of a large-hall encompassing a volume of some 63.000 m³ and is formed by two dualcurved shell-shaped surfaces and two cable-net facades spanned between them. Designed as a two-layer steel-grid shell the framework is supported at a total of four pivoted points. The two entwined shells face in opposite directions and touch at just a single point at a height of 40 m. The overall height to the extended ‚wing tips‘ is approximately 58 m. Each of the respective opaque roof areas with aluminium panel cladding incorporates a highly transparent, dual-curved, pre-stressed cable-net facade with a width of up to 24 m and a surface area of 1.000 m².

Figure 15: Maritime Museum Lingang, China – Cable-Net Façade.

3.4. Cité du Design, St. Etienne – Adaptive Façade

The façade of the Cité du Design in St. Etienne has been designed by Finn Geipel and Werner Sobek. The Cité is made up of a huge building envelope, the so-called "platine" (circuit board). It has a three-dimensional surface which can act as an adaptive building envelope. It can thus adapt to changing requirements in the interior (e.g. by a change in the transmissivity of light), and it also acts as a solar power plant able to generate a major amount of the energy supply.

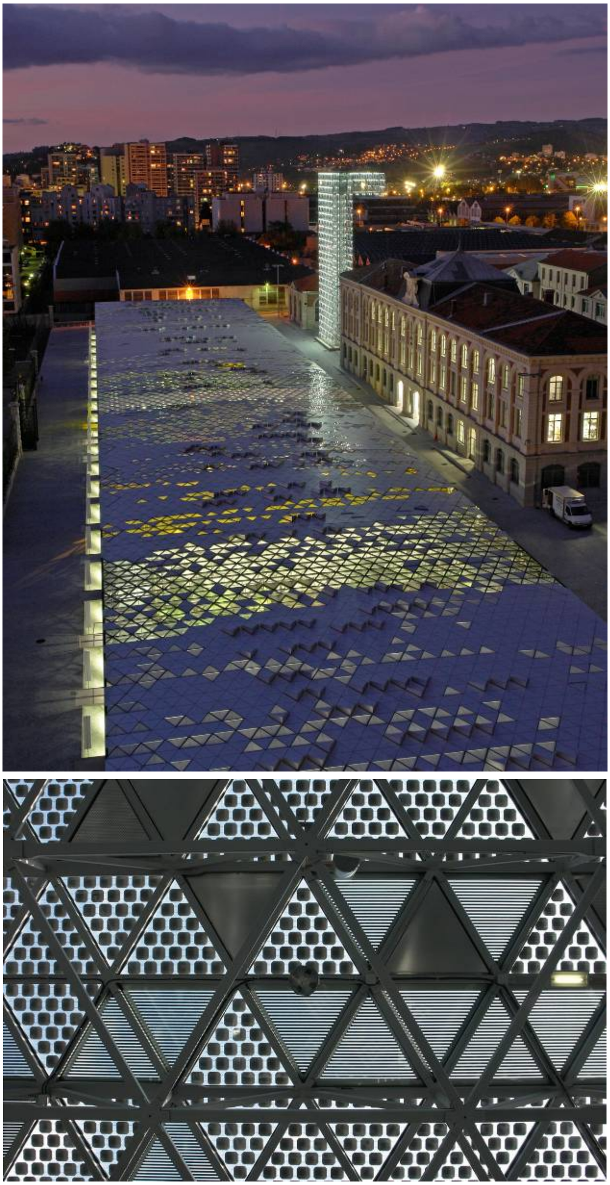


Figure 16: Cité du Design, St. Etienne – Adaptive Facade.

3.5. Doha Convention Center, Qatar - Cable-Stayed Glass Façades

The demand for dematerialized façades and highly transparent building envelopes has increasingly pushed architects and engineers to the limits of technical feasibility. 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 and cable trusses, this typology allows an increased transparency.

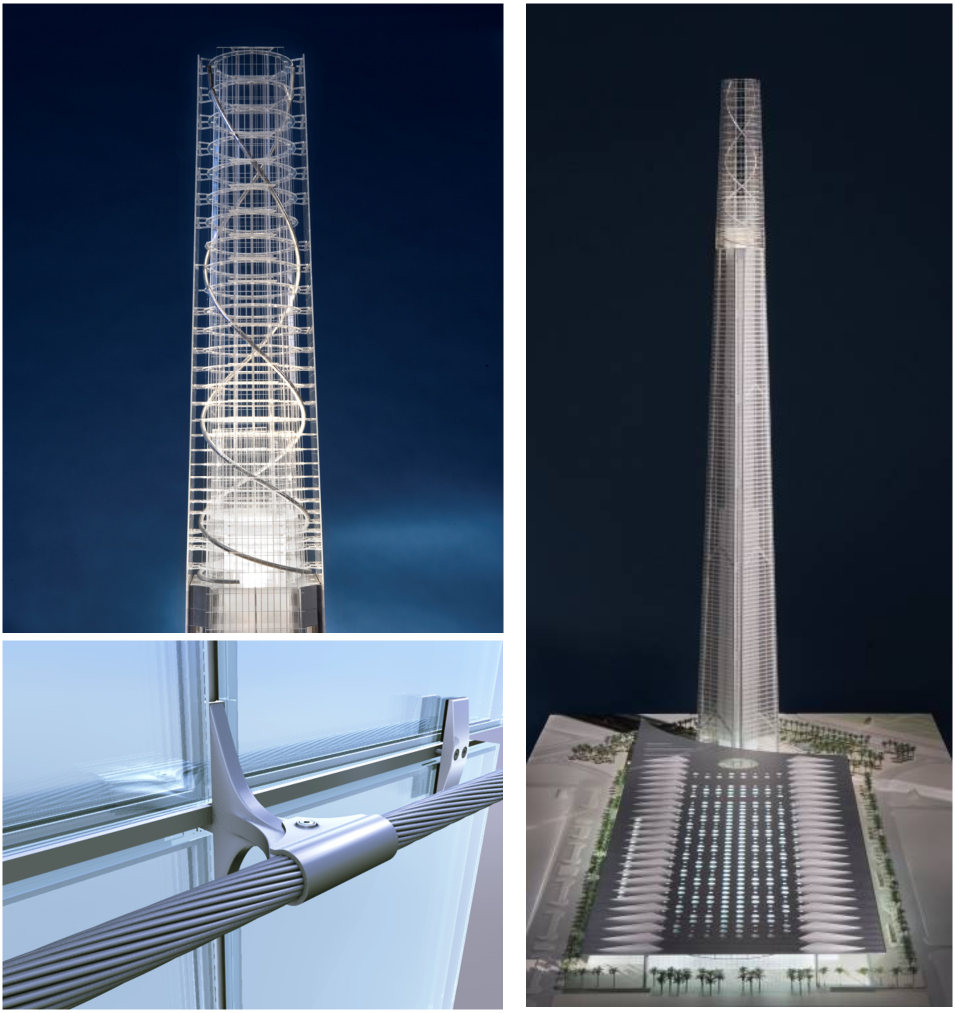


Figure 17: Doha Convention Center and Tower, Qatar – Special Façades.

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.

The Doha convention centre and tower will bring a breathtaking aspect to the Doha skyline. Werner Sobek and his team designed together with Helmut Jahn the façades of the convention centre using two different types of cable-stayed façades. The southern and western façade have only parallel horizontal prestressed cables. The insulating glass units are hung with tension rods in the vertical joints to the roof girder. The eastern façade has vertical prestressed cables.
The scope of work of Werner Sobek and his team included also the 125 m steel and glass spire structure, starting at height of 425 m above ground of the 550 m tall tower. The structure features two helix pipes spiralling up and diagonal cables attached to inner steel rings and 16 steel columns for lateral stability and load transfer. The outer glass screens are fixed back to inner rings with steel needles.

4. Vision

The results of the current glass research and the experience obtained with the realized projects combined with the rapid progress in the development of materials, nanotechnology and sensor technology will make it possible to realize new challenging projects like the house R 129 in the near future.

The idea of jettisoning traditional structures and methods of construction created the desire to design a building whose multi-functional façade would serve as a second skin for the residents. The building should be as independent of the surrounding landscape as possible; at the same time it was to be apt for a variety of uses, such as work and leisure, or accommodation for a single person as well as for a family. The search for the most suitable shape of such a building resulted in a lenticular spheroid which echoes archetypal aesthetic forms found in nature (e.g. dew drops). As a consequence the house R 129 does not feature traditional cubic forms dictated by the construction materials used. The transition between floor, wall and ceiling is fluid; the relationship between the enclosed volume and surface area of the building has been optimised.

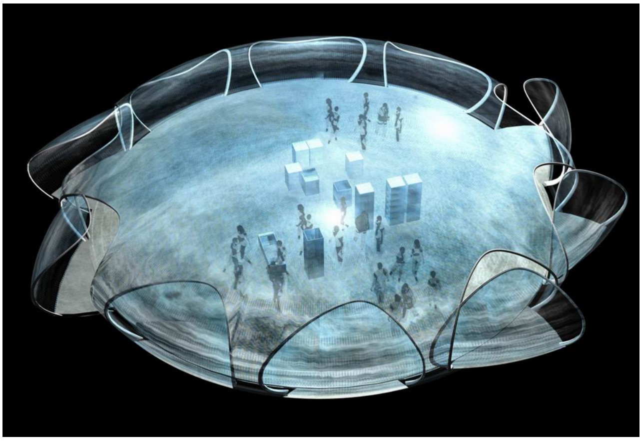


Figure 18: R 129.

The envelope of the building is extremely light and transparent. The skin has a “low e” coating which prevents radiation of heat into the interior (in summer) and to the exterior (in winter). Thanks to the application of an electrochromatic foil which can be controlled electrically, the envelope can be darkened or made completely opaque either in sections or as a whole. The external surface of the envelope also carries solar cells applied by means of vapour deposition. These cells reduce light transmission by only 20% but supply a large part of the electrical energy demand of the building.

5. References

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