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Glazing of the Light Eyes and Steel-and-Glass Gridshells at Stuttgart 21 Station

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Abstract

The new underground main station Stuttgart 21, designed by Christoph Ingenhoven with ingenhoven associates, is characterized by its distinctive reinforced concrete structure with iconic column-like “chalices” supporting large skylight openings, the so-called *light eyes*. These sculptural structures provide natural daylight and ventilation to the subterranean concourse and define the architectural identity of the station. In total, 23 regular light eyes consist of double-curved, anticlastic welded steel structures glazed with flat laminated glass panes. Integrated glass natural smoke and heat exhaust ventilators (NSHEV), as well as demanding requirements for maintenance accessibility and residual load-bearing capacity, posed particular challenges for design and verification. Four additional, flat light eyes feature enhanced glazing capable of withstanding exceptional loads caused by unforeseen crowd accumulation. Complementing these skylights are three lightweight gridshells made of steel and glass forming transparent access structures that connect the urban space with the underground platforms. The paper provides insight into the specific challenges related to the structural design of the glazing, the verification of extraordinary load cases, the approval process, and the complex procedures for fabrication and installation. Both engineering and regulatory solutions that enabled the realization of these unique glazed systems are discussed.

Keywords

Train station, Skylight, Glass, Structural Design

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1. Introduction

The project "Stuttgart 21" is a major railway and urban development project in the state capital of Stuttgart that involves extensive structural transformation. One of the main changes is replacing the existing terminus station with an underground through station. The centerpiece of the project is the train hall of the future central station, designed by Christoph Ingenhoven with ingenhoven associates.

Within this unique project, seele was commissioned to design and realize several structures, including the regular light eyes, the flat light eyes, and three entrance gridshells.

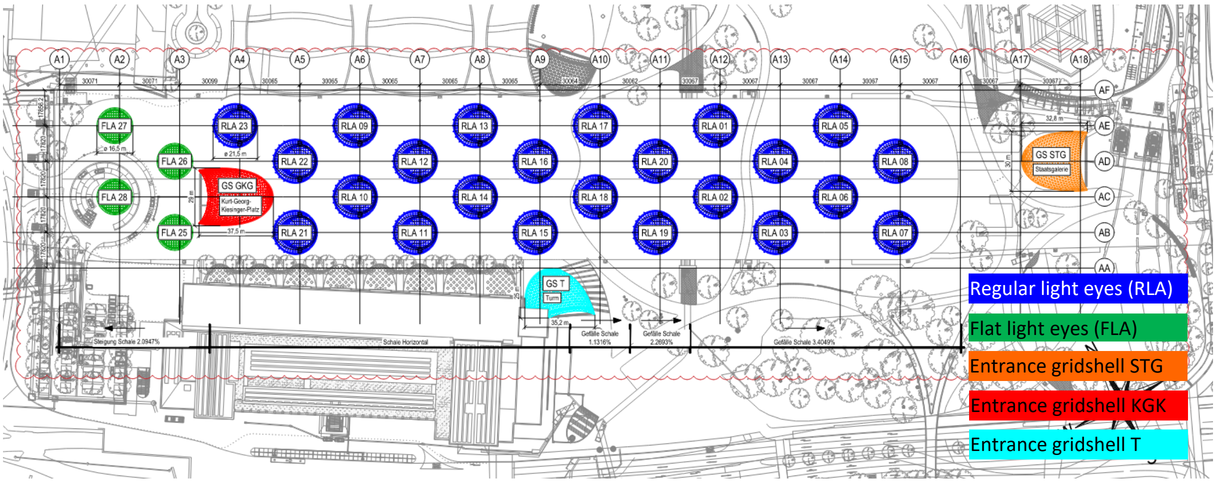

Fig. 1: Overview of seele scope ©IFM GmbH.

The new underground train hall consists of a shell structure formed by concrete chalice supports. Open at the top, the chalices are enclosed with steel-and-glass skylights – the light eyes – which provide natural daylight and facilitate passive ventilation.

In total, 23 light eyes were realized, all with a diameter of 21 m. Each unit comprises a rigid steel edge beam, infilled with steel beams and precision-milled nodes, fully welded to ensure structural integrity. The steel gridshell, approximating an anticlastic curvature, creates a square mesh that is covered with flat glazing elements to form the finished surface.

On the backside of the light eyes are integrated glass natural smoke and heat exhaust ventilators (NSHEV) consisting of movable glass lamellas.

Fig. 2: Light eyes and entrance gridshell of project Stuttgart 21 © plan b Stuttgart, Atelier Peter Wels, ingenhoven architects

The entrance gridshells are supported by a structure composed of triangular meshes made from steel profiles, connected by solid 3D amoeba nodes. The meshes are covered with triangular, flat glazing elements. The steel gridshell rests on a lower edge beam, while the free edge at the entrances is supported by an additional arched beam. The vertical entrance façade is integrated with the arch and features large operable doors at the base.

2. Glazing Types and Performance Requirements

2.1. Regular Light Eyes

The square mesh of the regular light eyes is infilled with transparent laminated glazing elements having edge lengths of around 1.2 m. The glazing system consists of an inner primary 2-ply laminate and an outer secondary 2-ply laminate. Each laminate consists of heat-strengthened glass (HSG) with SentryGlas® SG5000 interlayer. The inner primary laminate is designed to remain intact during impact tests, ensuring structural integrity, while the outer secondary pane including the protective layer can be replaced independently if damaged. This configuration protects the inner load-bearing pane from harm and prevents penetration by pedestrians.

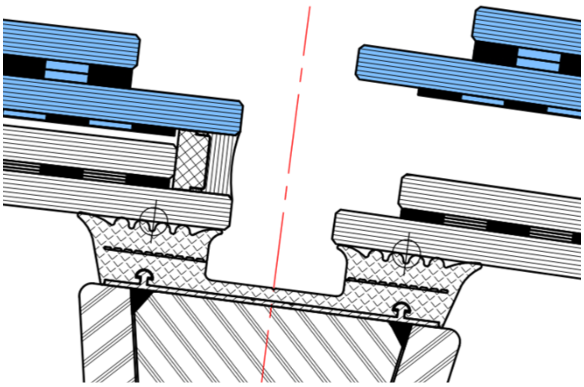

Fig. 3: Replacement of secondary laminate ©seele.

Although the light eyes are not intended for regular public access and therefore protected by a railing around the perimeter it cannot be ruled out that pedestrians enter the light eye. Additionally, the light eye needs to be accessible for maintenance and cleaning personnel. Consequently, the glazing design complies with DIN 18008-6 requirements for glass accessible for cleaning and maintenance and increased live load requirements which refer to DIN 18008-5 for safety reasons.

2.2. Flat Light Eyes

The glazing of the flat light eyes is similar to that used for the regular light eyes, with the exception that, due to higher loads, the primary laminate consists of three glass panes with SentryGlas® SG5000 interlayers. The flat light eyes are also accessible for maintenance only, but they are designed in accordance with DIN 18008-5 for walk-on glazing and additionally feature slip resistance on the surface.

2.3. Natural Smoke and Heat Exhaust Ventilators (NSHEV)

The glass lamellas for the NSHEV South of the regular light eyes are point-supported and, by design, neither walkable nor accessible. Each lamella measures approximately 1.2 × 0.2 m and consists of a triple-layer laminate. The SentryGlas® SG5000 interlayer incorporates embedded titanium rods to increase load-bearing capacity. For safety reasons, the lamellas are designed to prevent unauthorized access according to DIN 18008-6.

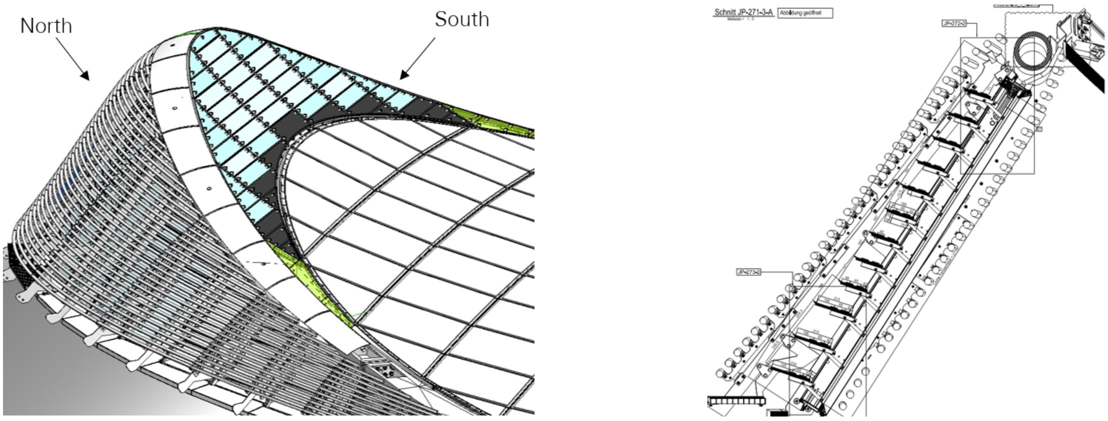

Fig. 4: a) regular light eye with NSHEV b) section showing open north lamellas ©seele.

2.4. Entrance Gridshell

The geometric concept of the gridshell leads to nearly isosceles triangular glass panes with edge lengths of up to 2.7 m. For fabrication reasons, the corners of the triangles are truncated.

Each panel consists of a triple-laminated glass build-up made of heat-strengthened glass with SentryGlas® SG5000 interlayers. Some panels are partially printed to meet architectural requirements. In addition to wind suction and pressure as well as snow loads, the glazing is designed to be accessible for maintenance and cleaning purposes.

2.5. Facades of Entrance Gridshells

Besides the roof glazing, the vertical façades of the steel gridshell are also infilled with laminated glass panels. While the structural concept of the glass build-up is identical to that used in the roof area, the support conditions and load transfer differ due to the vertical installation and the varying panel geometries.The standard panel width is approximately 2.3 m. In the entrance area, the glass panes are installed vertically with heights of up to 2.6 m. Above the entrance zone, the panels reach heights of up to 3.8 m and are inclined outward by approximately 6°. In the edge and corner areas of the façade, special geometries such as trapezoidal and triangular panes are required to follow the geometry of the gridshell.

3. Preliminary Calculations and Testing

3.1. Regular Light Eyes and Flat Light Eyes

Prior to the commencement of the works by seele, investigations for the dimensioning of the glass build-up were carried out by SUP Ingenieure. For the fixed glazing of the regular light eyes, these investigations included hard and soft body impact tests to verify impact resistance and residual load-bearing capacity in accordance with DIN 18008-5. A variant study was conducted on eight specimens for the regular light eyes and seven for the flat light eyes featuring identical primary panes and different secondary build-ups including different interlayer, glass and thicknesses. Fig. 5 shows the specimen (a), the test set up (b) and the specimen with unbroken primary pane (c, d) resulting in the final glass build up.

Fig. 5: a) specimen before testing, b) impact test, c) broken outer secondary glass pane , d) unbroken primary pane of chosen glass build up ©SuP Ingenieure GmbH.

3.2. Entrance Gridshell

For the gridshell these previous tests included impact tests to verify impact resistance and residual load-bearing capacity in accordance with DIN 18008-6. Four triangular specimen were tested with an edge length of around 1.8 m. The interlayer thickness and the thickness of the internal glass pane were varied. Compared to DIN 18008-6, an increased duration (up to several days instead of 30 min) for the residual load capacity test and impact tests with increased requirements were specified.

a)

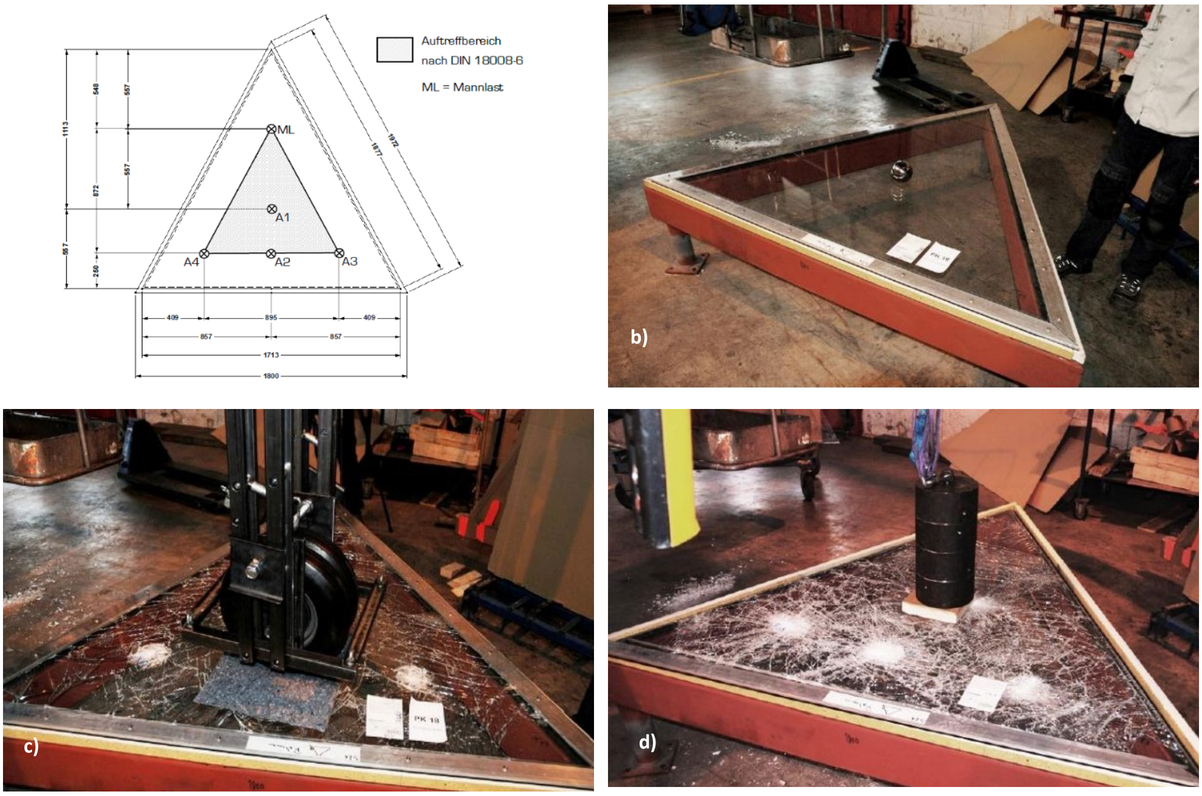

Fig. 6: a) geometry of specimen b) hard body impact test, c) soft body impact test, d) residual test ©SuP Ingenieure GmbH.

4. Final Design and Structural Calculation

4.1. Regular and Flat Light Eyes

The glass panels are continuously supported along their edges to ensure proper plate action under both positive and negative pressure loads. A distinctive aspect of the support concept lies in the way uplift forces are managed – only the primary laminate and the first pane of the secondary laminate are supported. The most outer pane is supported by the full-surface bond provided by the SentryGlas® SG5000 interlayer to the inner glass layers.

For the structural calculation of the glazing dead loads, wind loads, snow and live loads are considered. Seismic loads were not governing for the glazing itself compared to the other load cases.

Three different scenarios were considered in the analysis:

- **Failure of the secondary pane with the primary pane remaining intact:** In this case, the weight of the broken pane is treated as a permanent load on the remaining structure.
- **Failure of the secondary pane along with the top layer of the primary laminate:** This scenario represents an exceptional load case and is used to assess the structural behavior under extreme conditions.
- **All laminated glass layers intact:** This scenario ensures that, under the design loads, the secondary glass package remains fully functional and intact.

Furthermore, the expected maximum temperatures of the interlayer have been determined by analysis and therefore the ULS and SLS were analyzed with a shear modulus of the SGP of G = 1.5 MPa, which is applicable temperatures up to 60°C. The shear modulus was also confirmed by testing.

4.2. Natural Smoke and Heat Exhaust Ventilators (NSHEV)

The structural analysis was conducted using a shear-composite approach to accurately capture the interaction between components under load. To account for residual load-bearing capacity, a titanium rod was introduced as a reinforcement element. Titanium is particularly well suited to this application, as the coefficients of thermal expansion of glass and titanium are similar. A finite element (FE) model was developed in ANSYS incorporating this titanium rod, allowing for detailed evaluation of stress distribution and deformation behavior. The model enabled assessment of the combined performance of the original structure and the reinforcement, ensuring that the residual strength requirements were met.

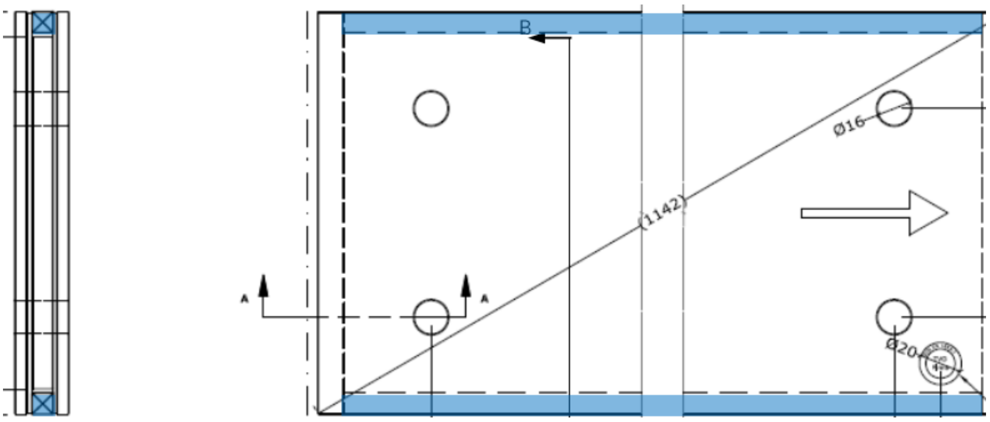

Fig. 7: Glazing of movable lamella with titanium rod (blue) ©seele.

4.3. Entrance Gridshell

The glass panels are supported continuously along their edges in order to allow proper plate action under both pressure and suction loads. A special feature of the support concept is the way uplift forces are resisted:

- Only the two inner glass layers are mechanically secured against uplift by pressure plates
- The outer glass layer is not mechanically fixed
- Instead, it is held in place through the full-surface bond provided by the SentryGlas interlayer to the inner glass layers

This results in a hybrid system of mechanical restraint and interlayer bond action.

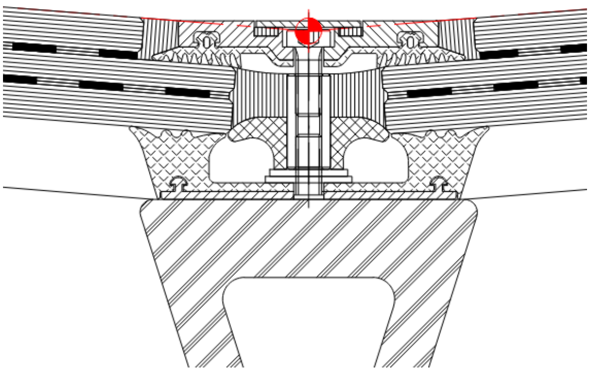

Fig. 8: Support detail for wind suction © seele.

To transfer in-plane shear forces resulting from self-weight, snow load, and maintenance loads, each pane is supported at three blocking points. For sealing reasons, only the innermost glass layer is mechanically blocked against sliding. The outer glass layers are again connected to the inner layer solely through the shear bond of the SentryGlas interlayer.

Due to the triangular shape of the panels, the geometry itself is highly favorable for carrying distributed loads. Consequently, during the structural design process, it was not necessary to assume a composite shear action between the glass layers for out of plane load transfer.

The specific support conditions lead to stress in the interlayer:

- Relatively low tensile stresses from wind loads
- Low shear stresses from self-weight, snow loads, and maintenance loads

4.4. Façade Glazing of the Entrance Gridshell

The façade panes are supported linearly along their horizontal edges at the top and bottom.

For the inclined panes above the entrance area, additional restraint is required. Depending on the geometry of the pane, one or two clamp holders are provided along each vertical edge to ensure adequate stabilization and load transfer.

In contrast to the roof glazing, the design of the façade glazing explicitly considers the shear composite action provided by the SentryGlas interlayer. This approach follows the provisions of the German General Building Approval (Allgemeine Bauartgenehmigung) for laminated glass with ionoplast interlayers. The interlayer is therefore structurally activated to transfer shear forces between the glass layers, allowing the laminated unit to act compositely under wind loading.

The façade glazing fully complies with the normative requirements of DIN 18008 for vertical glazing.

5. UiG/ZiE Project Specific Approvals

In Germany in general every product and type of construction used in buildings has to comply with the listed codes or requires a general German building approval or an European Technical Assessment (ETA). In case of deviation from those requirements, a project specific approval issued by the building authorities becomes necessary.

The Eisenbahn Bundesamt (EBA) is the responsible authority that would issue the project specific permit. Prior to that, the Deutsche Bahn itself has to agree to the deviations from any regulation and hence the project specific approval. In the course of this process all safety related aspects of the deviation from the codes have to be considered and proofed. In consequence the description of the deviation, evaluation of all risks, coordination with experts of DB and EBA, structural calculations, testing and appraisals issued by certified engineers is required. The full documentation is the basis for the application of the project specific approval.

For the glazing of the light eyes and lamellas of the NSHEV following deviations from the codes had to be approved: The fixation, the high structural requirements and the consideration of the shear compound by the interlayer under live loads. Therefore extensive testing was demanded in advance.

For the overhead glazing of the entrance gridshells, the type of fixation and support coming along with shear and tension transfer through the interlayer was assessed as part of the project approval process.

An expert engineering assessment confirmed that the interlayer performance is sufficient for the given stress levels and support conditions based on testing, calculation and long time experience.

To realize the architects vision of the entrance façades, no deviations from the standard regulations were necessary. As a result, no project-specific approval or special building permit was required for the façade glazing.

6. Testing

seele conducted the final testing for the regular light eyes, the flat light eyes and the entrance gridshells at its own testing facility in Gersthofen, Germany. The company gbd LAB GmbH was on site as an external and independent testing laboratory.

Following tests were conducted:

- Air permeability according to DIN EN 12152
- Water tightness under static pressure according to DIN EN 12154 and DIN EN 12155
- Water tightness under dynamic pressure according to DIN EN 13050
- Wind resistance according to DIN EN 12179

Fig. 9: Performance mock-up of the gridshell: a) view from outside with spraying system b) view from inside c) overview of mock-up d) water tightness test © seele.

7. Conclusion

The project required precise planning in close coordination with the glass manufacturer, including rigorous testing, detailed structural calculations, and expert evaluations. Close coordination with the relevant authorities was essential throughout the whole process.

The result is an architecturally striking and technically sophisticated project, demonstrating innovative approaches in structural glass design and precision engineering. Beyond its immediate functionality, the project sets a benchmark for future railway and urban developments, combining aesthetic excellence with long-term durability and adaptability.

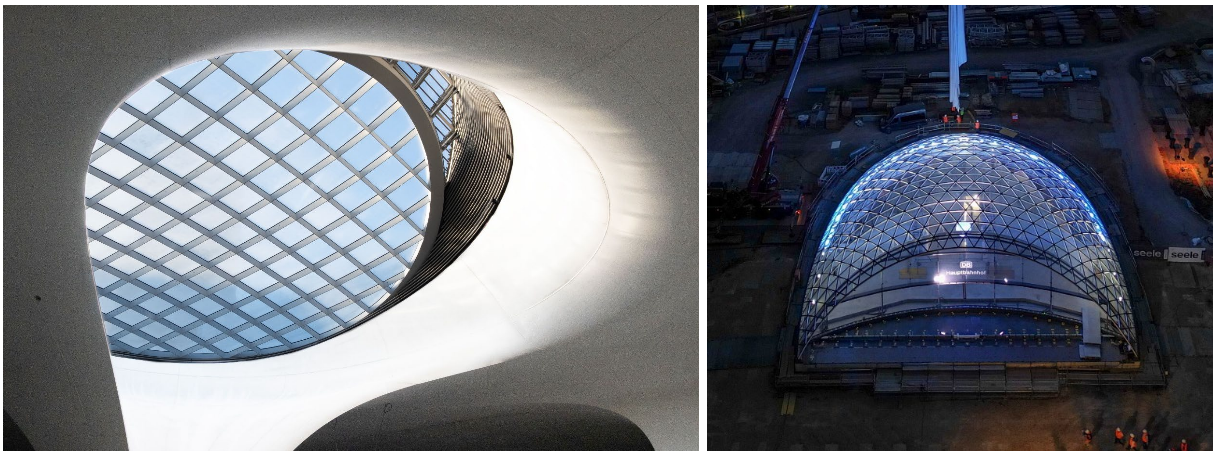

Fig. 10: First pictures of an unveiled light eye and an entrance gridshell (left: © seele; right: © DB Projekt Stuttgart-Ulm GmbH).

References

DIN 18008-5:2013-07, Glass in Building - Design and construction rules– Part 5: Additional requirements for walk-on glazing

DIN 18008-6 2018-02, Glass in Building - Design and construction rules – Part 6: Additional requirements for walk-on glazing in case of maintenance procedures and for fall-through glazing

DIN EN 12152:2002-08, Curtain walling - Air permeability - Performance requirements and classification

DIN EN 12154:2000-06, Curtain walling - Watertightness - Performance requirements and classification

DIN EN 12155:2000-10, Curtain walling - Watertightness - Laboratory test under static pressure

DIN EN 13050:2011-09, Curtain Walling - Watertightness - Laboratory test under dynamic condition of air pressure and water spray

DIN EN 12179:2000, Curtain walling - Resistance to wind load - Test method

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