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The All-Glass Entry Box

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Abstract

Vitroplena designed and installed an all-glass pavilion serving as the entrance to a public school. The structure consists of a 3 m by 1.8 m glass box with a height of 2.5 m, constructed from 1010.2 (TTG,sPVB) laminated glass panels—combining thermally toughened glass (TTG) with structural PVB interlayers (sPVB)—that were adhesively bonded on site using a black structural silicone. One side of the pavilion is connected to the existing school façade, while the opposite side remains free-standing, and a door is integrated into one of the side panels. The roof panel is slightly inclined to facilitate rainwater drainage. The pavilion is entirely self-supporting: all acting loads are transferred through the glass walls and roof via the structural adhesive joints, allowing the box to behave as a single stable entity. Transparency is maximised by eliminating steel connectors and relying solely on glass and adhesive bonds. The design of the glazing and joints was carried out using finite element analyses that accounted for the viscoelastic behaviour of both the interlayers and the structural silicone. This paper presents the design process, structural calculations, and on-site installation, and discusses the key challenges encountered. The resulting all-glass pavilion establishes a new benchmark in advanced structural glass engineering.

Keywords

All-glass, Structural, Laminated, Adhesives, In-situ bonding

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1. Introduction

The local public school in Kortemark, a small municipality in West-Flanders, Belgium, required a new entrance pavilion that would provide both a clear point of access and a contemporary architectural identity. In response, Vitroplena designed and installed an all-glass pavilion: a transparent entry box measuring 3 m by 1.8 m with a height of 2.5 m. The pavilion is built against the school's external wall and consists of 1010.2(TTG,sPVB) laminated glass panels, comprising thermally toughened glass (TTG) panes and structural PVB interlayers (sPVB), adhesively bonded on site using a black structural silicone. A minimally inclined roof panel facilitates rainwater drainage, while a door integrated into one of the side panels provides access. The pavilion is conceived as a self-supporting structure in which all acting loads are transferred through the glass panels and the adhesive joints, allowing maximum transparency by eliminating conventional steel connectors. Fig. 1 depicts a visualisation of the design concept of the all-glass entry box, as well as the all-glass entry box after completion.

Fig. 1: Visualisation of the design concept of the all-glass entry box and the all-glass entry box after completion.

This paper presents the architectural and structural concept of the all-glass entry box, the numerical design and verification of the glass panels and adhesive bonds, and the on-site construction and installation process. Particular attention is given to the finite element analyses used to account for the viscoelastic behaviour of the interlayers and structural silicone, as well as to the practical challenges encountered during execution. Among other projects designed and engineered by Vitroplena (Van Lancker and Martens 2022; 2024), this project illustrates how advanced structural glass engineering (Martens 2018; Van Lancker 2020) can be applied to create self-supporting all-glass structures.

2. Challenges

The development of the all-glass entrance pavilion involved several challenges linked to the use of laminated glass as a structural material, the reliance on structural bonding as the sole connection method, and the overall concept of a fully bonded glass box acting as a primary load-bearing system. These aspects are inherently interdependent and collectively shaped the design, modelling, and construction process.

2.1. Laminated glass

Designing a self-supporting pavilion made entirely from 1010.2(TTG,sPVB) laminated glass required careful consideration of both the brittle behaviour of glass and the time-dependent behaviour of the structural PVB interlayer. The laminate had to provide sufficient stiffness and strength to resist both in-plane and out-of-plane actions, whilst ensuring robustness in case of local damage. A fracture limit state (FLS) and post-fracture limit state (PFLS) needed to be assessed in the design in correspondence with CEN/TS 19100 (CEN 2021) due to the consequences in case of glass fracture. Ultimate limit state (ULS) and serviceability limit state (SLS) verifications were required for the design of the intact structure. The viscoelastic nature of the interlayer influenced global deformations, load distribution between panels, and long-term performance under sustained loading. These effects required advanced numerical modelling to capture realistic stiffness values under different temperatures and load durations. The structural concept, where walls and roof act as a single entity, results in a global stability depending directly on the combined stiffness of the bonded glass panels.

2.2. Structural bonding

Because the pavilion contains no steel connectors, all load transfer relies on structural silicone joints. This introduced challenges related to joint geometry, stiffness, and durability. The adhesive had to accommodate differential movements between panels while simultaneously providing sufficient shear and tensile capacity to stabilise the entire structure. The viscoelastic behaviour of the silicone, similar to that of the interlayer, required appropriate material modelling to ensure that joint stiffness and load-sharing were correctly represented in the finite element analyses. Achieving uniform joint thickness and precise alignment during installation was essential, as deviations could lead to stress concentrations or reduced structural capacity. The fully bonded concept also meant that the adhesive joints had to be designed not only for ultimate and serviceability performance, but also for long-term environmental exposure and repeated loading.

2.3. On-site bonding and construction

All structural joints were created on site, which introduced practical constraints regarding handling, positioning, and environmental conditions. The glass panels had to be installed with millimetre-level accuracy to ensure consistent joint dimensions and proper load transfer. Surface preparation was critical, requiring strict cleaning and priming procedures to guarantee durable adhesion. Although no temporary enclosures were used, bonding operations had to be carried out under sufficiently stable conditions to ensure proper curing of the silicone. The integration of the door opening and the inclined roof panel added further complexity, as these features interrupted the load-bearing surfaces and required careful detailing to maintain structural continuity.

3. Structural design

The structural design of the all-glass pavilion was carried out in accordance with EN 1990 (CEN 2002) and EN 1991 (CEN 2002) complemented by Belgium's national annexes, and EN 16612 (CEN 2019) and CEN/TS 19100 (CEN 2021). The laminated glass panels and the structural silicone joints were first assessed using a combination of analytical calculations and detailed finite element modelling. A full finite element model of the complete glass box was developed to evaluate the global structural behaviour, including the interaction between the bonded glass walls and the inclined roof panel. This model was used to assess the adhesive joints, verify the stiffness and stability of the self-supporting system, and evaluate the structural performance of the pavilion under all relevant load combinations. Modal analyses were performed to determine the lowest natural frequency of the pavilion to ensure dynamic performance.

3.1. Actions, load combinations and criteria

The all-glass pavilion was designed as a primary load-bearing structure, requiring verification of the fracture limit state (FLS) and post-fracture limit state (PFLS) in accordance with CEN/TS 19100 (CEN 2021), in addition to the traditional ultimate limit state (ULS) and serviceability limit state (SLS) defined in EN 1990 (CEN 2002). According to EN 1991 and the Belgian National Annex (CEN 2002), the structure is subjected to self-weight ($g_{k,glass} = 2500$ kg/m^3), wind actions ($q_p = 800$ Pa), snow loads ($s_k = 0.4$ kN/m^2) and thermal actions ($\Delta T = 60°C$). The fundamental, characteristic and accidental load combinations used for ULS, SLS and PFLS verifications follow EN 1990 together with the provisions of the Belgian National Annex (CEN 2002).

The criteria for ULS and PFLS depend on the material. For thermally toughened glass, the design strength is determined in accordance with EN 16612 (CEN, 2019) and equals 87.5 MPa. For the structural silicone joints, a safety factor of 6 is applied in initial design calculations involving single stress states (tension or shear). When more complex stress states (combined tension and shear) are assessed using detailed finite element models, a safety factor of 4 is adopted, in line with ETAG 002 (EOTA 2012), EAD 090010-00-0404 (EOTA 2018) and manufacturer recommendations. For the PFLS, a VB3A scenario according to the Swiss standard SIA 2057 (SIA 2021) is applied, meaning that accidental load combinations are evaluated assuming fracture of one glass ply of one panel. The latter suggests the investigation of several accidental cases in which each time a different panel contains a broken glass ply. Additionally, one accidental load case was considered with two panels that simultaneously contained one broken glass ply each. In general, such fracture may occur due to dynamic impact in the FLS. The laminated configuration with structural interlayers provides residual load-bearing capacity after fracture. Furthermore, all glass elements were heat-soak tested to minimise the risk of spontaneous fracture due to nickel-sulphide inclusions.

In the SLS, deformations and vibrations are limited according to the applicable criteria, with the centre-of-pane deflection limited to L/300, the overall sway movement of the glass box restricted to L/300 and the natural frequencies obtained from the modal analyses required to exceed 5 Hz.

3.2. Structural analyses

The design process began with a simplified calculation of the required dimensions of the structural silicone joints, assuming linear-elastic material behaviour and uniformly distributed loads, using the simplified formulas provided in ETAG 002 (EOTA 2012) and EAD 090010-00-4040 (EOTA 2018). This resulted in a preliminary joint geometry consisting of a 20 mm joint width and a 10 mm joint thickness. A finite element model of this silicone joint was then developed and subjected to uniform tensile and shear load of 0.14 MPa, corresponding to the allowable design stresses for the adhesive in the considered load case, including a safety factor of 6. Fig. 2 shows the resulting out-of-plane and in-plane deformations of the joint, from which the joint stiffness values k_x and k_y were derived.

$$k_x = 3.186\ MN/m^2\ and\, k_y = 1.055\ MN/m^2$$

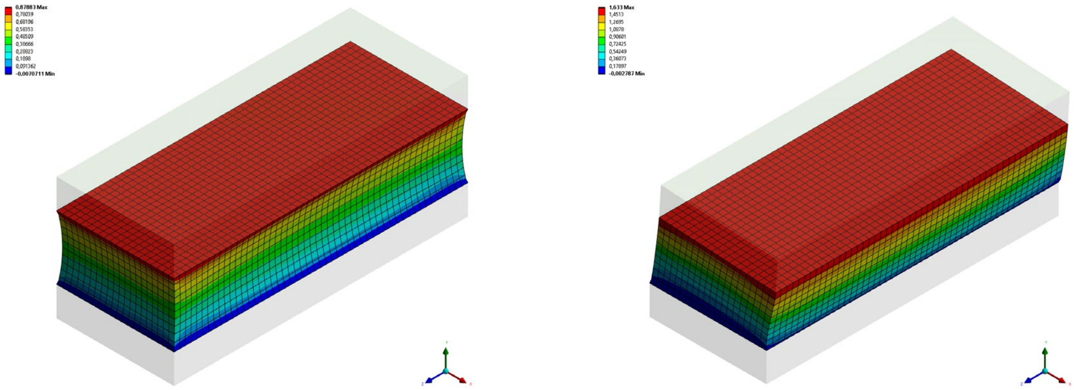

Fig. 2: deformations (mm) of a 20x10 structural silicone joint subjected to tension (0.14 MPa) and shear (0.14 MPa).

The joint stiffness values k_x and k_y were subsequently implemented in a finite element model of the individual glass panels subjected to out-of-plane actions such as self-weight, wind and snow. Fig. 3 shows the maximum principal stresses and the out-of-plane deformations of the 1010.2(TTG,sPVB) roof panel under the governing load combination in both the ultimate and serviceability limit states, with snow acting as the principal variable load. The following applies:

$$\sigma_{max} = 10.1\ MPa < 11.0\ MPa$$

$$u_{max} = 5.8\ mm\ < 6.0\ mm$$

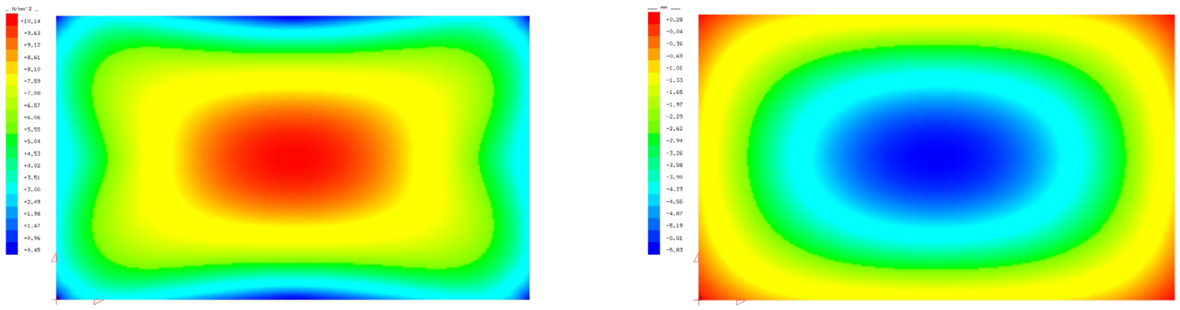

Fig. 3: maximum principal stress (MPa) and out-of-plane deflection (mm) of the 1010.2(TTG,sPVB) roof element subjected to the governing load combination in the ultimate limit state and serviceability limit state.

Based on the 1010.2(TTG,sPVB) glass configuration and the joint dimensions of 20 mm by 10 mm, a global finite element model was developed to assess the overall structural behaviour of the pavilion, the global stress state in the adhesive joints, and the required in-plane resistance of the glass panels.

Fig. 4 demonstrates the relative deformations of the glass panels under action of the governing load combination in the ultimate limit state. The relative displacements of the glass panels result in stresses in the joints which are calculated based on the joint stiffness as previously derived. The individual tensile and shear stresses and the resulting principal stress in the most loaded joint equal:

$$\sigma_x = 0.112\ MPa < \sigma_{des} = 0.14\ MPa$$

$$\tau_{xy} = 0.079\ MPa < \tau_{des} = 0.14\ MPa$$

$$\sigma_I = 0.153\ MPa < \sigma_{all} = 0.21\ MPa$$

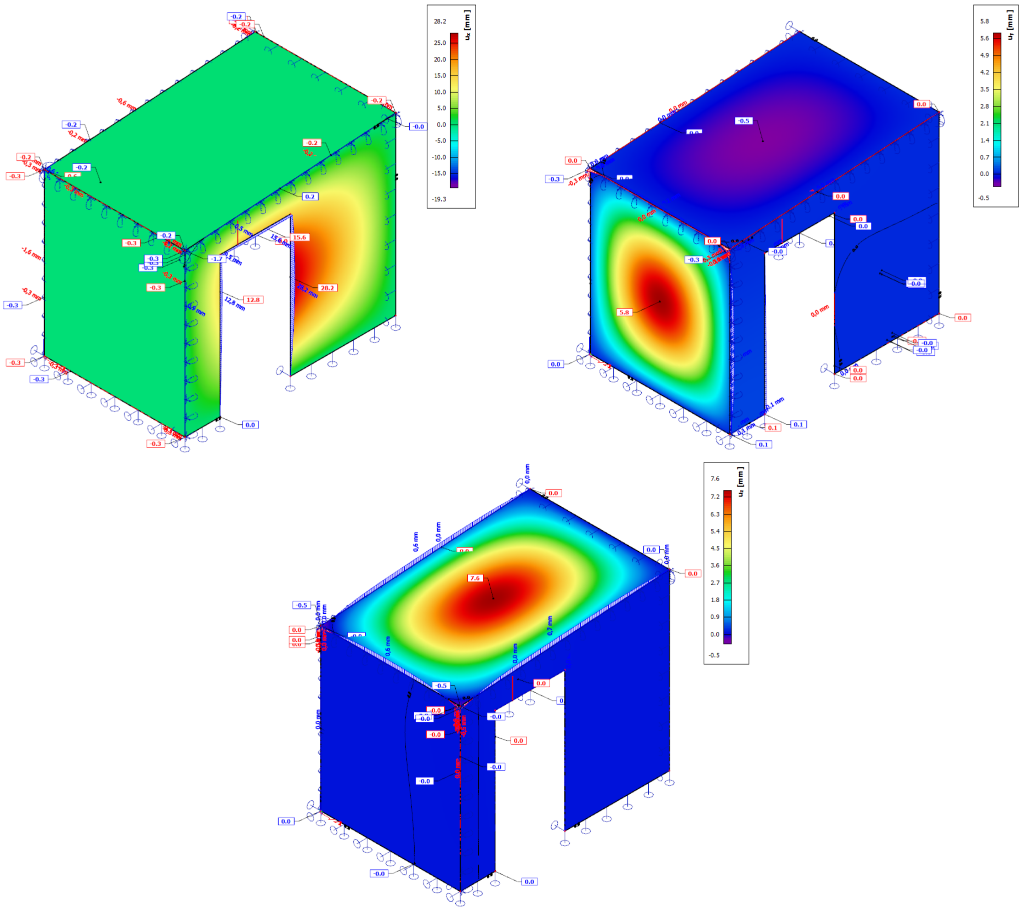

Fig. 4: x-, y- and z-deformations (mm) under action of the governing load combination in the ultimate limit state.

Additional verifications of the in-plane load-bearing capacity of the glass elements confirmed that the design satisfies all structural requirements. Also the modal analyses demonstrated that the all-glass entry box fulfilled the necessary requirements, as depicted in Fig. 5 ($f_{n,1}$ = 7.54 Hz > 5 Hz).

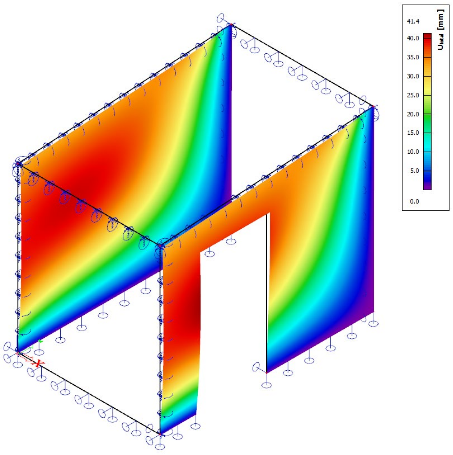

Fig. 5: total deformations (mm) of the side panels for the first eigenmode ($f_{n,1}$ = 7.54 Hz).

The adopted design procedure resulted in a structurally sound configuration for the fully bonded glass pavilion. The long-term performance of the structure as a single load-bearing entity will, however, depend on regular inspection and quality control of the adhesive joints. Such monitoring is essential and unavoidable for self-supporting all-glass systems in which structural bonding plays a critical role.

4. Construction

The installation of the all-glass pavilion required careful preparation, precise handling of the laminated glass panels, and strict control of the bonding process. All works were carried out on site, as every structural joint of the pavilion was formed through in-situ silicone bonding. The installation sequence was therefore planned in detail to ensure correct positioning, clean bonding surfaces, and uninterrupted curing.

The glass panels were manipulated using vacuum suction lifters, allowing controlled lifting and rotation despite the confined space near the school entrance. Before (and after) placement, all bonding surfaces were thoroughly cleaned using acetone, isopropyl alcohol and foam cleaners applied with lint-free cloths to remove dust, grease and residues.

First, the two wall panels perpendicular to the school's façade were positioned. At the bottom the panels were inserted in steel U-profiles onto setting blocks. In the school's façade also steel U-profiles were fixed to enable the support of the sides of these glass panels. Next, the front glass panel was positioned into its bottom support. Auxiliary tools enabled the positioning of the glass panels relative to each other to ensure the correct dimensions of the joints between the elements. Lastly, the roof panel was positioned on top using spacers to ensure correct joint dimensions. After final cleaning of all bonding surfaces, the black structural silicone was applied continuously along the length of the joints, filling the cavities between the glass elements. Afterwards, the joints were tooled to achieve uniform geometry and a clean visual finish.

Several challenges were encountered during installation:

- the minimal tolerances of laminated glass required extremely accurate positioning;
- handling large glass panels in a confined school environment demanded careful logistics;
- the relative positioning of panels had to be controlled precisely to achieve correct joint dimensions;
- environmental conditions during bonding and curing had to remain sufficiently stable;
- quality control was essential, as each adhesive joint is structurally critical;
- the entire bonding process had to be prepared meticulously, as there is effectively only one opportunity to execute the joints correctly.

Despite these challenges, the installation process resulted in a structurally sound and visually seamless all-glass pavilion, demonstrating the feasibility of on-site bonding for primary load-bearing glass structures as depicted in Fig. 6.

Fig. 6: The all-glass entry box.

5. Conclusions

The all-glass entrance pavilion demonstrates how laminated glass and structural adhesive bonding can be combined to create a fully transparent, self-supporting structure without the use of conventional mechanical connectors. By relying solely on 1010.2(TTG,sPVB) laminated glass panels and structural silicone joints, the pavilion functions as a single structural entity in which all loads are transferred through the bonded glass walls and roof. This approach maximises transparency while simultaneously showcasing the potential of advanced structural glass engineering in architecture.

The project required a careful balance between architectural intent, material behaviour and structural performance. The brittle nature of thermally toughened glass, together with the viscoelastic response of the structural PVB interlayer, demanded detailed numerical modelling and verification across multiple limit states, including fracture and post-fracture scenarios. The structural silicone joints, acting as the primary load-transfer mechanism, introduced additional complexity due to their own viscoelastic behaviour and the need for precise joint geometry. The resulting design reflects a realistic representation of the global stiffness and stability of a fully bonded glass system.

The on-site installation further highlighted the practical challenges of building with large laminated glass panels and executing structural bonding in situ. Accurate positioning, strict surface preparation, and controlled curing were essential to achieve durable adhesive joints and to ensure that the pavilion behaved as intended. Despite the minimal tolerances and the confined construction environment, the installation process resulted in a seamless and structurally robust glass box.

Overall, the project sets a new benchmark for all-glass applications using structural bonding as the sole connection method. It demonstrates that, with appropriate modelling, detailing and execution, fully bonded laminated glass structures can serve as reliable primary load-bearing systems while delivering an exceptional level of transparency and architectural refinement.

References

CEN/TS 19100:2021: Design of Glass Structures, European Committee for Standardisation, CEN (2021).

EN 16612:2019: Glass in building – Determination of the lateral load resistance of glass panes by calculation, CEN (2019).

EN 1990:2002: Eurocode 0 – Basis of structural design. European Committee for Standardisation, CEN (2002).

EN 1991:2002: Eurocode 1 – Actions on structures. European Committee for Standardisation, CEN (2002).

ETAG 002:2012: Structural Sealant Glazing Systems, EOTA (2012).

EAD 090010-00-0404: European Assessment Document for Bonded glazing kits and bonding sealants, EOTA (2018).

Martens, K.: Statically indeterminate reinforced glass beams. Doctoral dissertation, Ghent University, Belgium, ISBN 9789463551328 (2018).

SIA 2057:2021: Constructions en verre, SIA (2021).

Van Lancker, B.: Experimental and numerical investigation of two-sided bonded glass-steel façade units. Doctoral dissertation, Ghent University, Belgium, ISBN 9789463554282 (2020).

Van Lancker, B., Martens, K.: Design of a curved duplex façade for a 67 m high residential tower at the Belgian coast. Proceedings of Challenging Glass Conference 8, 23-24 June, Ghent, Belgium (2022).

Van Lancker, B., Martens, K.: Design of a 5m span all-glass walkway. Proceedings of Challenging Glass Conference 9, 20-21 June, Delft, The Netherlands (2024).

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