

Zipper Meets Glass: Development of a New Joining Technology for Flat Glass

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Abstract

Zippers are familiar to everyone from their daily use. In architecture and construction, their use is primarily for temporary protective measures in conjunction with textile structures. A view at the product diversity of zipper systems shows how much this development has expanded into applications beyond the classic textile industry. The zipper, consisting of the tapes and teeth, can be modified for very specific applications using a wide variety of material combinations. With sufficient UV resistance, fire resistance, high tear strength, and bonding durability, zippers are also suitable for applications in the construction sector. Basic tests on thin concrete precast elements revealed completely new fields of application for the concrete industry. Transferring this to glass structures, particularly facades or folded glass, led to hinge connections of the zippers in laminated glass. This paper presents a feasibility study of a new joining technique between flat glass and zippers. The realization is done via a lamination process. The paper shows results regarding the practical realization, performance tests (e. g. pull tests, creep tests) and potential applications with this new joining technique.

Keywords

Glass zipper, foldable glass, glass joint, demountable glass, glass lamination

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1. Use of Zippers in the Construction Industry

Zippers are familiar to everyone from everyday use. In architecture and construction, however, they are primarily used for temporary protective measures in combination with textile structures.

A look at the wide range of zipper systems shows how much their development has expanded into applications outside the textile industry. A zipper—consisting of the tape and the teeth—can now be modified with a variety of material combinations tailored to very specific applications. Plastics and metals are used for the teeth, which create the mechanical interlock. The size of the teeth indicates the robustness and the mechanical load capacity. The load-bearing capacity of a zipper is determined either by the tensile strength of the tape or by the clamping resistance of the teeth. Industry standards define load capacity using standardized tests and specify tensile strength per 10 cm length. The tapes are consistently made from synthetic fibers, which can be adjusted to achieve virtually any material property depending on the manufacturing and finishing processes. As a result, zippers are available for high-quality textiles in the fashion industry as well as for functional systems designed for personal protection—especially fire protection. From the wide range of available products, those with mechanical load capacity and robustness are particularly important for the construction sector. UV resistance, fire performance, and high tensile strength, along with long-term bond stability of the tapes, are also essential requirements for their use in building applications.

2. Laminating Zippers into Laminated Safety Glass

Laminating textiles, mesh fabrics, or thin metal sheets as additional interlayers alongside PVB films is already common practice. At the edges of glass panes, this technique is mainly used to integrate metal fittings that enable mechanical connections. Building on this approach, the textile zipper tapes were incorporated directly into the glass laminate. The tape thickness must be compensated for by adding extra PVB layers into the glass. Attempts to omit these additional layers consistently resulted in glass breakage during the lamination process. As part of preliminary tests, various tape widths and materials were evaluated. Fabric tapes with plastic coatings showed the most promising results in both handling and load-bearing behavior. For the initial load tests, extra-wide tapes were used so that a bond length of 35 mm could be incorporated into the glass edges. In some cases, the tapes were perforated at different intervals to examine whether mechanical interlocking with the PVB film affects the performance. Figure 1 shows sample specimens with the laminated-in zippers. Specimens with only two PVB layers already exhibited cracks immediately after lamination.



Fig. 1: Test specimens for the tensile tests.

2.1. Test Results

The first tensile tests were designed solely to identify the failure mechanisms of this novel glass connection and to obtain initial benchmark values for the transferable tensile forces. Four series of tests were carried out using identical glass dimensions (100 × 200 mm, laminated from 2 × 6 mm float glass) and identical zippers. The only variables were the number of PVB layers (2 or 3) and the perforation of the tape (1, 2, or 4 holes, Ø 8 mm over the 100 mm bond length).

Table 1: Test series overview.

Test series	A1	B1	B2	C1	C2
Number of PVB-layers	3	3	2	3	2
Holes in the zipper tape	1	2	2	4	4

The specimens were clamped using 60-mm wide jaws in the tensile testing machine. The tests were displacement-controlled at 5 mm/min. A maximum deformation of 30 mm was set as the termination criterion. At the beginning of each test, marks were applied at the transition between the tape and the glass to detect slippage out of the glass lamination. Only two tests showed slippage of about 2 mm; in all other cases, deformation was caused solely by tape elongation or slow zipper opening. All failures occurred at the clamping side due to tape tearing, likely a result of the short 60 mm clamping length, which is significantly shorter than standard zipper load tests. Future test setups will use longer clamping lengths. The force-displacement curves were nearly identical across all tests, indicating that neither the cracked glass (fixed in place by the PVB layers) nor the perforations had a relevant impact on performance. Table 2 summarizes the maximum loads (F_{max}) recorded at 30 mm deformation.

Table 2: Results of the tensile tests.

Test series	Type of failure	F_{max} (N)
A1-1	upper tape	2350
A1-2	upper tape	2300
A1-3	zipper	1480
B1-1	lower tape	2060
B1-2	zipper	481
B1-3	upper tape	2290
B2-1	lower tape	2320
B2-2	lower tape	2320
B2-3	upper tape	2350
C1-1	upper tape	2210
C1-2	upper tape	2100
C1-3	upper tape	2070
C2-1	lower tape	1780
C2-2	upper tape	2240
C2-3	lower tape	1870

Legende

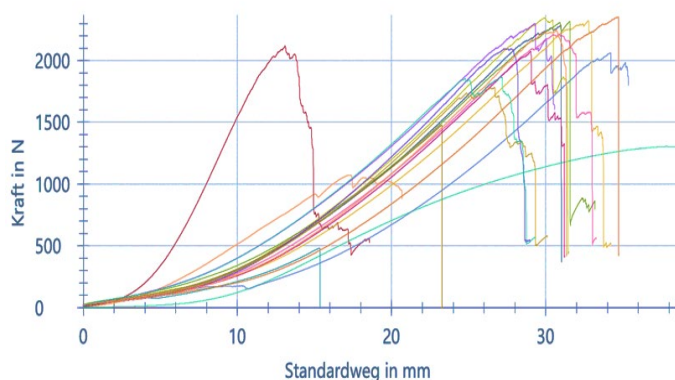




Fig. 2: Tape failure within the clamping zone.

3. Structural Behavior of Folded Glass Structures

Folded structures are known in architecture for their efficiency and aesthetics, enabling large spans with minimal material use. They typically consist of panels or membranes connected by articulated joints along their edges, reinforced at highly stressed points. These structures are usually made from steel, aluminum, timber, concrete or composite materials. Material choice depends on factors such as load-bearing capacity, weight, and workability. Their load-bearing behavior relies exclusively on membrane forces (tension and compression), which are redirected through the folded geometry. This makes them part of the family of vector-active structures, characterized not by bending stiffness but by their three-dimensional form. Folded plate structures are typically analyzed using the Finite Element Method (FEM), which allows for a detailed simulation of complex geometries and stress distributions. Using laminated safety glass for folded structures has been considered only in rare cases. Glass is typically used as infill between spatial, triangulated frame structures. To expose glass panes to membrane stress states, they require a suitable mechanical connection capable of transferring tension and compression forces at their edges, ideally through linear, articulated joints. The connection should also be lightweight, easy to assemble, and reversible.

4. Zippers in Folded Glass Structures – “Zipper Meets Glass”

The idea of quickly and easily joining individual panes of glass into a folded structure using zippers, and later disassembling them without leaving any residue and making them reusable, is the core concept behind several model constructions developed as seminar projects at TU Darmstadt and Frankfurt University of Applied Sciences. The following illustrations demonstrate the versatility and potential that this new joining technology will enable. Figure 3 shows the construction process and the geometrically developed glass structure.

The following figures illustrate the diversity and potential of this new joining technology.

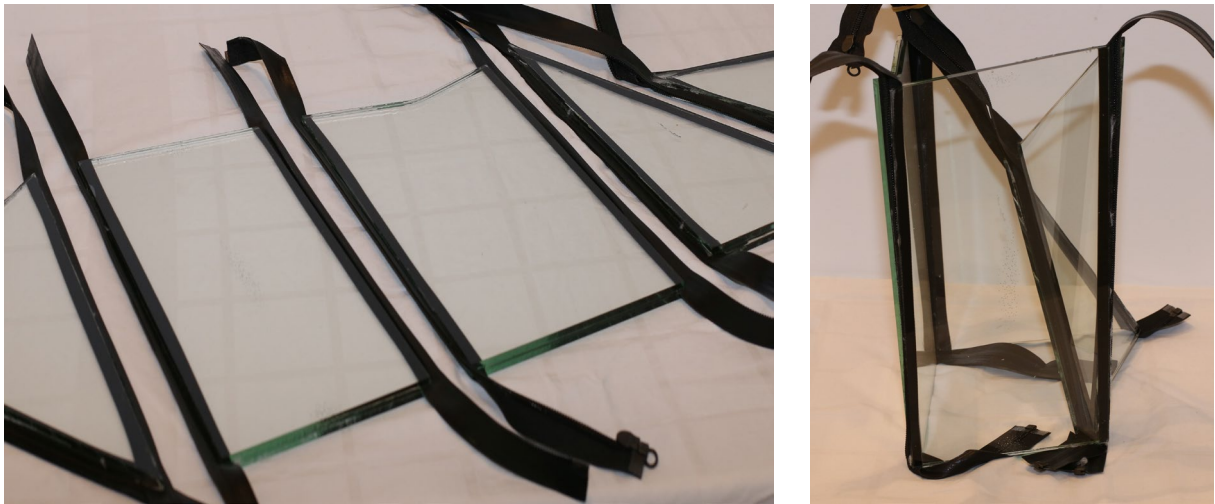


Fig. 3: Sculptural glass folded structure © Altarwnah, Al-Balbasi, Al-Daoud.

The low buckling resistance of glass panes is significantly increased by the interlocking design of adjacent panes. In this case, stabilizing loads are transferred via the zipper, generating both tensile and compressive stresses. Glass columns made from single panes increase their buckling loads via the edge seal using zippers and can thus be used as load-bearing supports for a pavilion roof.



Fig. 4: Glass columns assembled from individual panes using zippers supporting a pavilion roof
© van Zütphen, Fernandez, Merkel.

As an alternative to elaborate substructures, 3-dimensionally deformed glass facades can be folded using zippers to create a geometrically stable structure.



Fig. 5: Folded glass façade structure connected using zippers © Bouwman, Klein, Kujus.

This rotationally symmetrical roof, consisting of a central, fixed support with radially arranged cantilever beams, is covered by tension-stressed glass panes. Two panes are prefabricated using laminated straps and joined together with a zipper to form the complete roof covering.

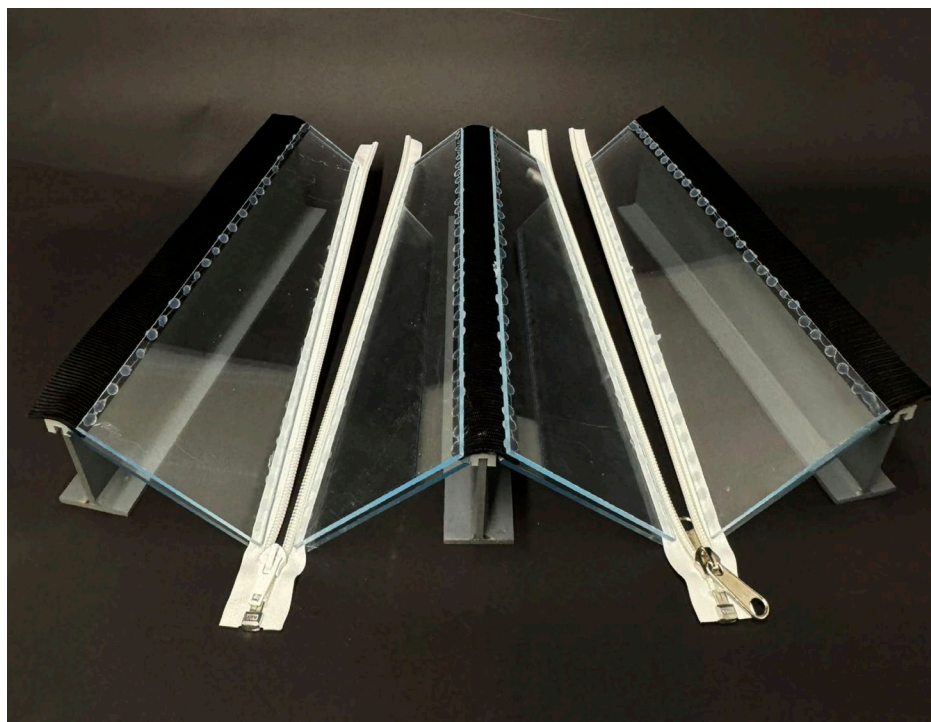


Fig. 6: Glass folded structure serving as a roof canopy © Huhle, Lob, Riebe.

5. Conclusion

Zipper offers a remarkable solution for a wide range of challenges in the construction sector, enabling a flexible and low-maintenance connection technology. Based on simple mechanical principles, zipper systems can be used across numerous applications. Although some challenges and limitations exist, the benefits outweigh them in many cases. The innovative use of zippers in combination with glass is still in its early stages, but it will undoubtedly help open new pathways in structural glass engineering. This new method enables the transfer of normal forces, parallel and perpendicular to the glass edge by the zipper connection.

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