Challenging Glass 5 – Conference on Architectural and Structural Applications of Glass
Belis, Bos & Louter (Eds.), Ghent University, June 2016.

ISBN 978-90-825-2680-6

Connections in Glass

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Enclosed envelopes without any visible supporting structure or stairs which seem to float on air are the dreams of many architects and designers. Glass is one of the few materials that can allow this dream to become a reality. For this reason full glass structures can appear to be practically invisible and the observer experiences the wonderful sensation of seeing a floating, weightless and totally transparent structure, as if it's almost not there. To fulfill these demands but also to enable the integrity of the whole glass structure, the connections between the elements represent one of the most critical aspects for this type of glass design. These connecting elements represent the “remaining visible” parts and therefore these details become the central focus of interest when looking at an all glass structure. Simple borehole connections often do not satisfy the architect’s demands these days. In this article we will show a few of our recent all glass structures with a keen focus on the all important "connecting parts". There will be shown a solution with special glass treatment for a customized structure as well as applications for transparent glued connection elements which can be used by the industry in general product applications. The generalization of connecting details in the use of load carrying full glass structures could open new fields of application for full glass structures apart from the typical and well known façade industry.

Keywords: Glass, metal to glass connections, laminated, bonded

1. High loaded customized mechanical glass to metal connections

The glass canopy of the main entrance is located on the north side of the building 20 Fenchchurch Street in London (Figure 1). The free cantilever length of the glass roof measures 5.2m. The cantilever glass fins have a distance of 3.0 m between each other and they are built up by 5 layers of fully tempered glass laminated with SentryGlas. The glass thicknesses are as follows: 10-10-15-10-10. The roof glass has a maximum width of 3.2m. The length of the glass is approx. 5.2m. Each panel is freeform shaped. The laminated panels consist of a quadruple glass made of heat strengthened glass with the thicknesses of 8-12-12-12 (top to bottom) all laminated with SentryGlas. The ceramic frit is located at position 2 from top side. The front edge of the canopy is generated by a so called “fascia panel” with an identical build up to the roof glass.

Fig. 1 Total view of the glass canopy, Design by: Rafael Viñoly

Glas Trösch was commissioned by Josef Gartner GmbH to supply the glass for the canopy. In addition to this, Glas Trösch was intensely involved in the design phase of the detailed connections. Beside the high architectonical demands the details had to be designed in a way so that they were able to fulfill the requested long term requirements in regards to load transfer and sliding ability.

Part of the glass supply was the precise positioning and grouting of the detail for the connection points. Due to the early collaboration of all parties which were involved in the realization of the project it was possible to coordinate the planning in an optimized way, so that the production of the glass in combination with positioning and grouting of the details worked supremely well.

An essential point of the structure is the constraint connection of the glass fins to the main steel structure (Figure 2). Here the decision was taken to fix an “inner” steel shoe to the glass already in the glass production facility. Beside the protection of the glass this solution provides the execution of a tolerance free connection, which ensures that the enormous loads due to the constrained connection will be transferred exactly at the defined locations from the glass fin into the steel structure.

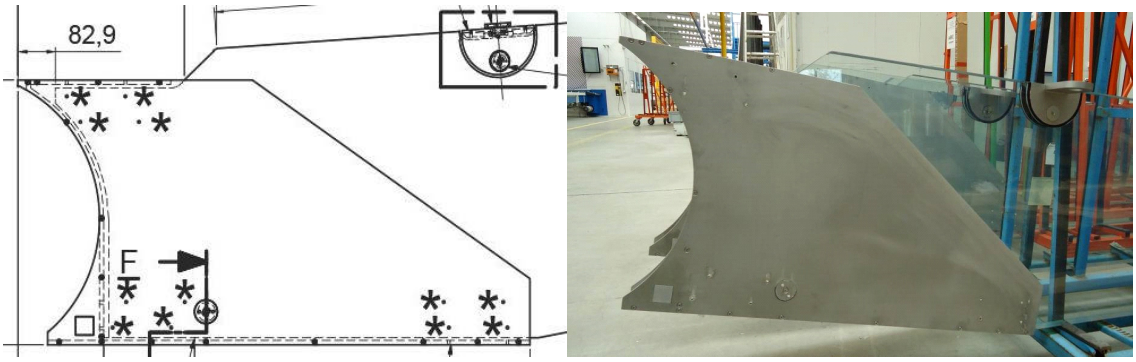

Fig. 2 connection of the cantilevering glass fin

The Figure 3 shows the glass fin at the location of the front edge connection between the glass fin, the roof glass and the front fascia panel. The outer glass layers of the glass fin are milled according to the shape of the metal shoe. The offset between the single layers in the laminated fin is < 1 mm. The wall thickness of the steel shoe of 10 mm illustrates the intensity of the loads which are transferred through the connection details into the glass and this explains why the tolerances in the connection had to be reduced to a minimum.

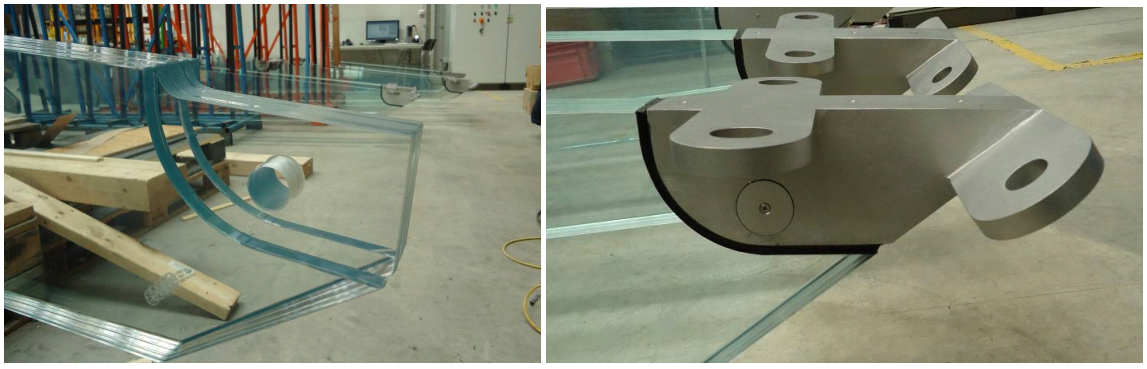

Fig. 3 front connection point between the glass fin – roof glass - fascia panel

The connection of the roof glass to the glass fin is realized by laminated countersunk point fixings. As shown in Figure 4, the top glass layer is not penetrated by the point fixing, and the ceramic frit on Pos. 2 hides the connection element partially so that the optical appearance is reduced. The defined space for displacement of the point fixings allows for the compensation of tolerances and movement due to temperature changes. The connection however also provides the stabilization of the glass fin by the roof glass.

Fig. 4 laminated countersunk point fixing in the roof glass

2. TSSA connections for glass stairs and bridge applications

An alternative connection technique which deliberately resigns to use mechanical connection elements is the transparent gluing technique with TSSA. The abbreviation "TSSA" stands for "Transparent Structural Silicone Adhesive". The material is developed by Dow Corning. Glas Trösch is one of the leading processors of TSSA worldwide. The special optical attraction which can be realized by this type of connection is the precise reason why there exists increasingly high demand by architects and designers. Besides the high structural capacity, this type of gluing technique is characterized by excellent strength and durability. In addition to the classical façade applications we consider this gluing technique in particular for the use in the Interior Design and Exhibition Stand Construction where structural requirements need to be fulfilled. Due to the close distance of the user to the detailed connections (for instance in stair applications), the outstanding optical appearance is fully acknowledgement and appreciated. Glas Trösch has realized several stairs with this technique in Switzerland as well as a complex exhibition project.

2.1. TSSA application in full glass stairs

First we will introduce a glass bridge which is a "Pilot Project" in our fabrication facility in the Swisslamex in Bützberg from 2013.

Fig. 5 Pilot Project of a full glass bridge with structurally bonded connection elements.

The glass bridge spans across the fabrication line of the Glas Trösch AG Swisslamex in Bützberg. The width of the bridge is approx. 4.5m. The side stringers are manufactured from triple laminated glass. The connection of the treads and the glass floor between the stainless steel angles and the glass is realized utilizing the aforementioned TSSA gluing technique. The image below on the left shows the used connection type in this application. The stainless steel angle seems to float in front of the glass stringer. The gluing is crystal clear and even the finest surface texture of the metal is distinct and plainly visible. The clarity of such a connection cannot be achieved by any other type of connection (Figure 6).

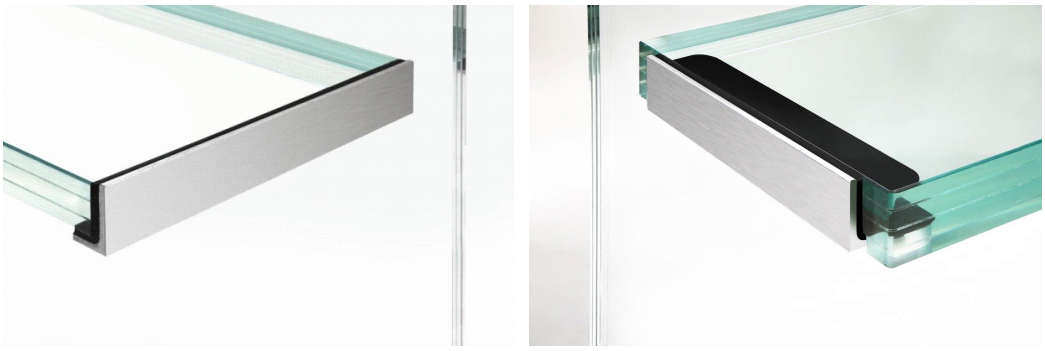

Fig. 6 Examples for connections between glass treads and glass stringers

The detailing in the connection between the glass tread and the stainless steel angle, and between the angle and the glass stringer can be shaped in many ways. As shown in the pictures the connection can be modified geometrically. Glass Trösch can assist the design phase to coordinate the architectural demands with the structural and manufacturing requirements. Apart from the examples detailed in this article it is also possible to create completely different structural types of connection.

3. Bonding techniques and laminated inserts in full glass structures

To laminate metal parts into the glass is an excellent method to generate connection details with the highest architectonical demands. These details give an impression of a perfectly smooth connection element. On the basis of an extraordinary full glass structure there are shown some examples how TSSA bonded elements and laminated inserts can be used. The full glass structure (model shown below) is part of an exhibition stand which is assembled every year for a one week usage during the exhibition “Basel World” in Basel / Switzerland. On the basis of the architects design ideas Glas Trösch developed the overall structural system and the concept for all details. See Figure 7. Glas Trösch performed the full design of the glass structure including the assembly and replacement strategy.

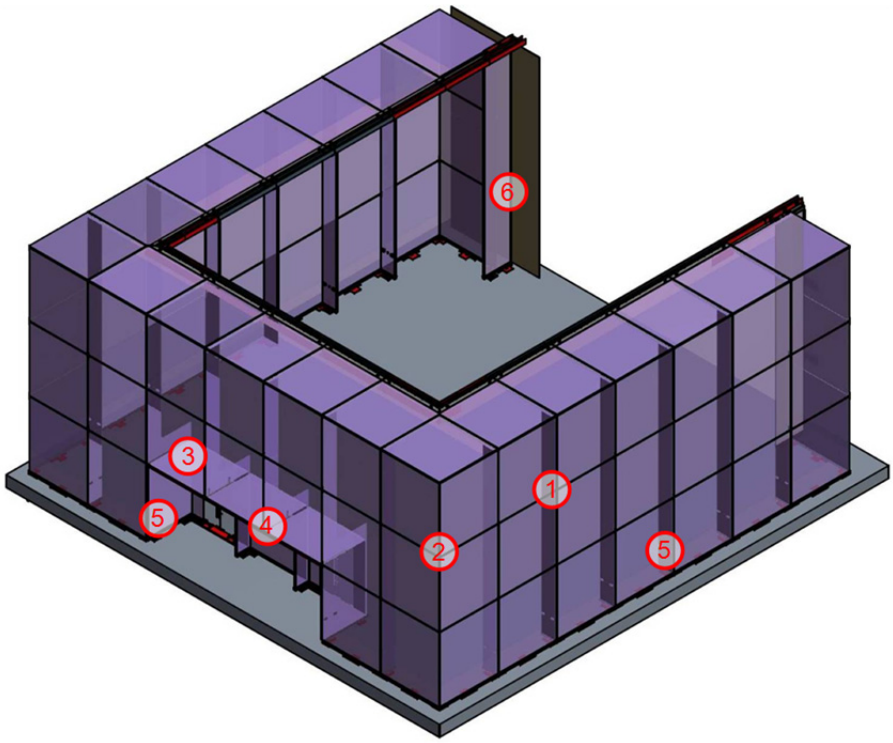

Fig. 7 Model of full glass structure for a exhibition stand, Architectonical idea by Ottavio di Blasi.

The red numbers indicate the locations of connection elements which will be explained on the following pages. The details are TSSA bonded elements and laminated inserts or combinations of both techniques in one connection element.

3.1. Point 1, glass fin façade with laminated inserts in the façade panels and the supporting glass fin

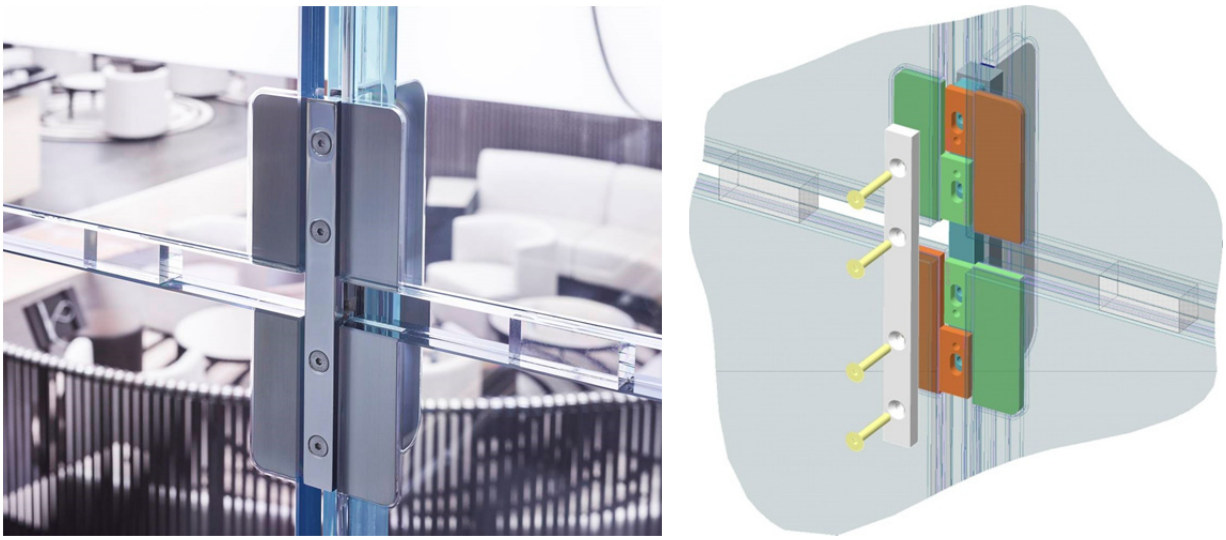

Fig. 8 Standard connection between four façade panels and a glass fin with laminated inserts.

The very high precision in positioning the details enables to reduce the tolerance dimensions to a minimum. Although the connecting elements in Figure 8 look extremely simple the reality may be different. The internal "live" of the details sometimes is made of little machines to allow for tolerances and defined sliding movements or rotational degree of freedom. Therefore very often complex milling parts are necessary to achieve the desired functionality. Also the internal stress stage in the glass and the interlayer needs to be analysed especially when annealed glass shall be used. The shape, geometry and size of the laminated inserts are the parameters regarding the internal stress stage of the laminated inserts.

3.2. Point 2, self-supporting full glass edge generated with laminated inserts

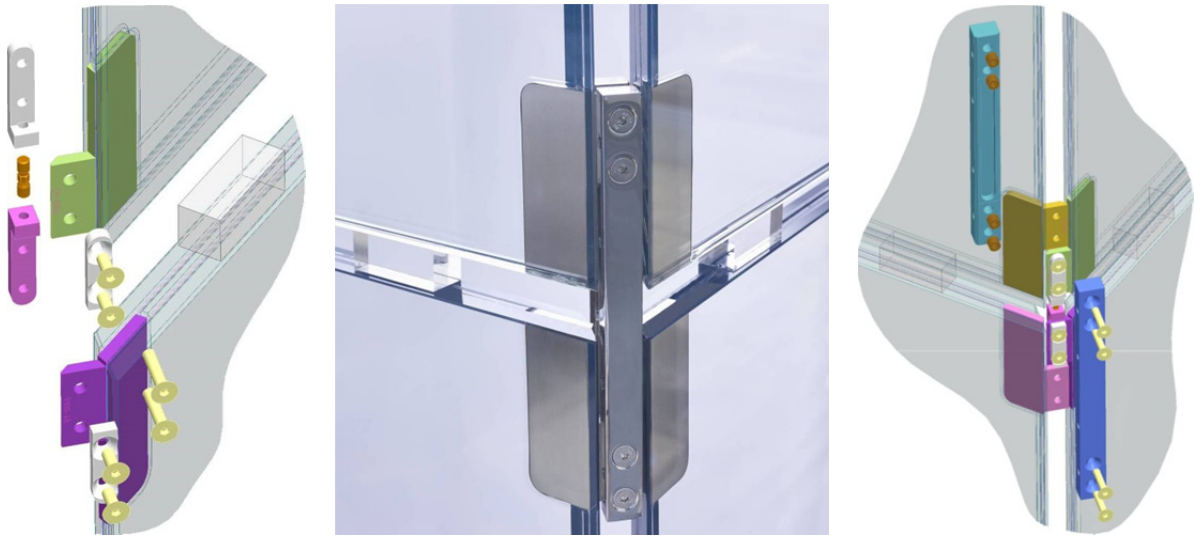

Fig. 9 Edge connection between four façade panels, self-stabilizing.

To enable the structural integrity of the complete full glass structure without a glass fin behind the façade panels it is required to connect the façade panels in a certain manner. Each glass panel column (three façade panels on top of each other) at the corner is connected together so that in the façade plane these three panels act as one big element. This requires that the connecting detail is able to transfer compression and tension forces between the panels in one column but may slide free towards the adjacent edge panels due to slab movements. Shear forces between the corner panels needs to be transferred so that the panels are able to stiffen each other.

3.3. Point 3, door fixings with TSSA bonding and laminated inserts

Very nice detailing can be achieved also if the TSSA bonding method is combined with laminated inserts for instance to generate the very simple and elegant façade panel and door fixings which were used in the entrance area of the exhibition stand.

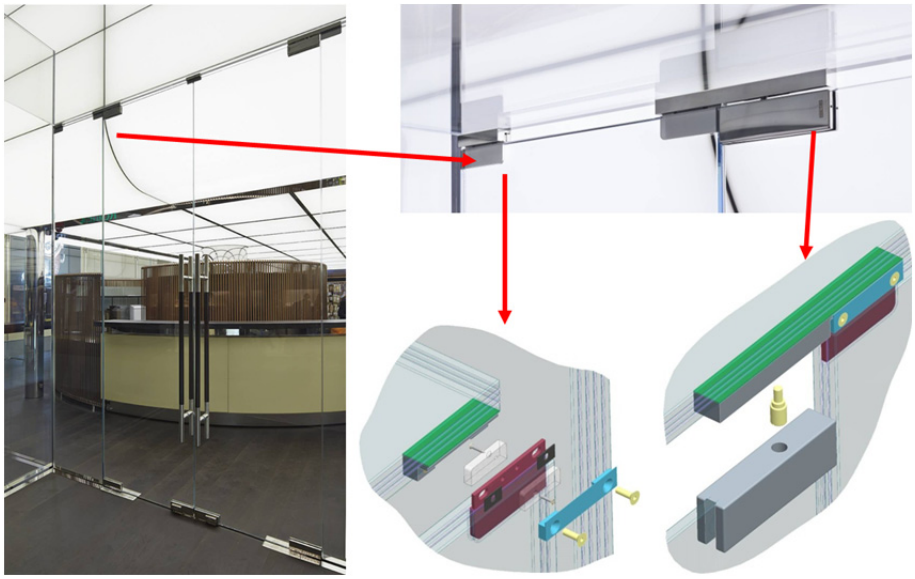

Fig. 10 Door and glass panel fixing using TSSA details in combination with laminated inserts.

Figure 10 shows a glass entrance where the roof glazing provides the lateral support for the façade and door panels. The fixing point is bonded with TSSA to the bottom surface of the roof glass. The façade panels are connected by laminated metal inserts to the bonded metal part at the roof. The door is connected by using a standard door fitting assembly. This shows that these highly customized design elements can easily be combined with standard connection components if required.

3.4. Point 4, laminated insert for a heavily loaded element with residual strength requirement

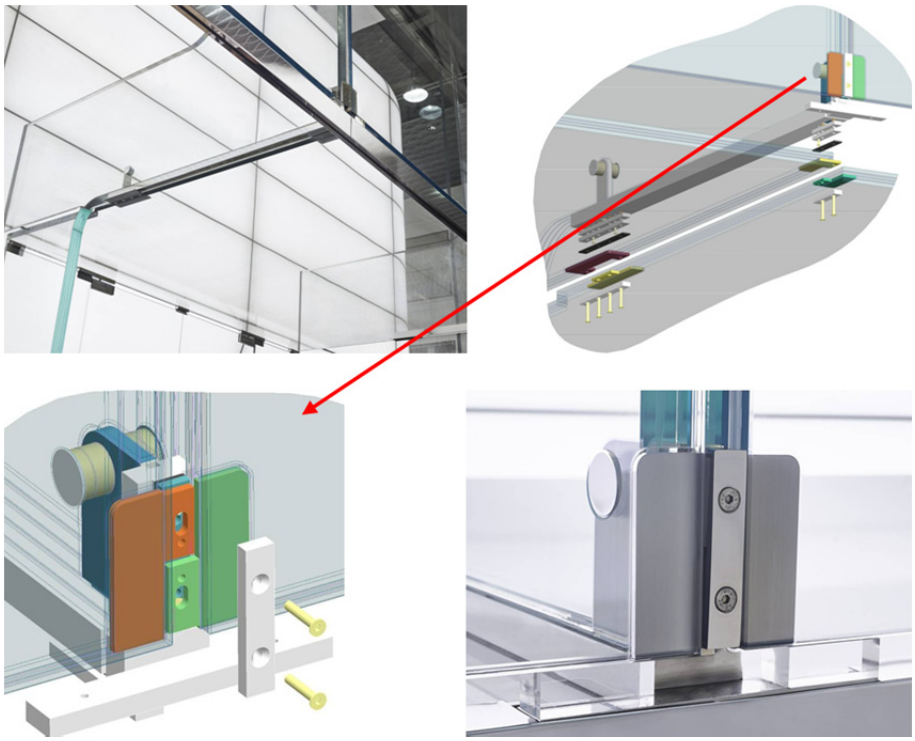

Fig. 11 Glass fin with Z-shape with laminated inserts to connect the roof and façade glazing.

This detail shows a highly loaded laminated insert which is additionally secured with a pin in the borehole. The detail (bottom left) is vertically loaded with 2.1 tons permanently. The load comes from the façade glazing above the entrance area with the dimension of approx. 6m x 3m and the horizontal overhead glazing which spans between the

special shaped (Z) glass fins. Therefore this point needs to be considered as an overhead condition. This is why there was decided to use an additional borehole fixation for residual strength criteria's. The structural design considered a total loss of adhesion so that the complete loading also could be transferred through the borehole in case of an extraordinary load case.

3.5. Point 5, TSSA application in high loaded exhibition shelves

Figure 12 shows the connection of a showcase. The maximum load of one connection point is designed to withstand more than 500 kg. The numerous showcases also are installed within the glass structure. This underlines in an impressive way a globally versatile solution but also the robustness of the connection as this is required for the use of the detailing in international trade fairs. The use of TSSA was not only decided to achieve the highest level of optical appearance at the detail connection but also to enable the use of annealed glass for the glass fins. A borehole connection would have required to use heat treated glass which was no option for the client's architectonical demands.

Fig. 12 High transparent TSSA glued connection of a show case to a full glass structure in an exhibition stand.

3.6. Point 6, TSSA bonded glass fin connection combined with laminated inserts

In figure 13, a glass fin connection which is bonded with TSSA is indicated. The double sized glass fin forms the end of the glass structure and the passage to the larger part of the adjacent part of the exhibition stand.

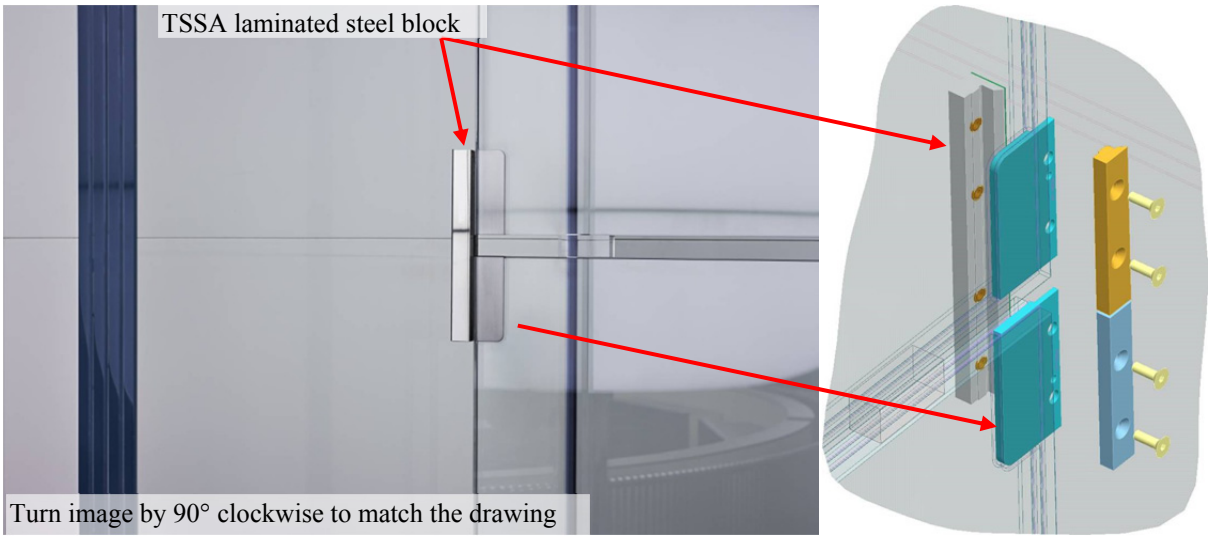

Fig. 13 TSSA bonded elements in substitution with laminated inserts.

This detail shows again that the laminated inserts and the TSSA bonded elements complements perfectly in many different application. Very often end field situations or corner situations cannot be properly resolved only strictly using one technique. The picture above tells us that the use of both bonding techniques perfectly fits together in one detail.

4. Conclusion

The connection methods shown in above applications give an overview of possible solutions for structural connections between glass elements using metal connectors. The decision which of the connection methods may be used is mainly based on the architectonical demands and the structural requirements. However, besides these elementary criteria further criteria such as structure movements, tolerances resulting from fabrication and onsite assembly, fabrication methods, internal or external application of the structure and finally also costs should be considered.

To achieve an optimized solution regarding all these parameters it is essential that the glass fabricator is incorporated in the design process at an early stage of the project. Glas Trösch can provide substantial design support respectively if requested also a full structural design for these highly specialized connection methods.