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Glass façade upper floor, exhibition stand TOYOTA, IAA 2005

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Modern designs of exhibition stands, especially for motor shows, require more and more transparency. To meet the designers‘ demands, it becomes necessary to use glass not only as an element of design, but also as a load bearing element of the structure. To give an example how the use of glass leads to an impressive result, the structure of the glass façade around the upper floor of the exhibition stand TOYOTA at the IAA 2005 will be described. The façade had a height of 2.8m and was built over a length of 13.5m without any supporting elements. Glass panes at the short side braced the structure by structural silicone bonding glass/aluminum. In the corners curved glass elements with a very small radius of 465 mm were used. All glass panes worked as glass to prevent from falling. The results from the pendulum impact test of the curved glasses will be shown. Finally the experiences with the structure related to production, mounting etc. will be concluded.

Keywords: Exhibition Stand, Silicone Bonding, Pendulum Impact Test, Curved Glasses, FEA

1. Introduction

Glass structures in exhibition stands enjoy great popularity, especially in the area of complex designed structures for motor shows. In general these temporary constructions are subjects to conditions of the same standards as general building constructions. But in contrast to general building constructions, innovative glass structures for exhibition stands are normally planned for a considerably shorter time span, and lesser loads, which partly reduces the amount of testing and inspection.

This gives the opportunity to realize novel constructions faster and with lower costs. Experiences made with this temporary structures, potentially can help to realize also structures of different fields easier.

2. Description of structure

For the automobile producer TOYOTA a two storied exhibition stand with an upper floor area of about 450m² was designed for the IAA 2005 in Frankfurt. The most important aspect of design was to get a balustrade and façade of highest transparency around the first floor, except for two LED-walls at the longitudinal sides. The façade should work as an element to prevent from falling as well as an element to keep the noise of the exhibition hall from the meeting area (Fig.1).

Figure 1: Front view of the exhibition stand.

This led to a solution with a line bearing glazing with a height of 2700 mm, acting as glass to prevent from falling. All panes should only be supported at the top and bottom edge to get no vertical non-transparent structural elements. Because no ceiling structure was available to fix the top edges of the glazing, a revolving steel frame was applied to the top edges to take horizontal loads acting perpendicular to the surface of the panes. The steel frame was fixed on two bracings at the longitudinal side of the stand behind the LED-walls and to three bracings in cross direction of the stand. At the edges of the short sides the glass panes had to work as bracings. So the glass at this area was not only forced by vertical loads perpendicular to their surface, but also by loads parallel to surface, coming from the horizontal reaction forces of the 13.50m spanning steel frame (Fig.2).

To guarantee a proper application of horizontal forces from the steel frame at the top edges of the panes at the narrow sides, a two-component silicone bonding with DC 993 was used to fix an aluminum U-section to the glass. The aluminum profile was fixed to the U-section U180 of the steel frame by a bolted connection (Fig.3).

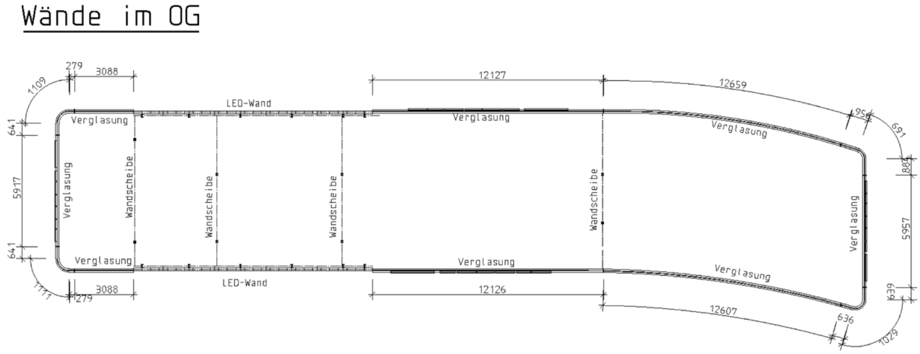

Figure 2: Top view façade on upper floor.

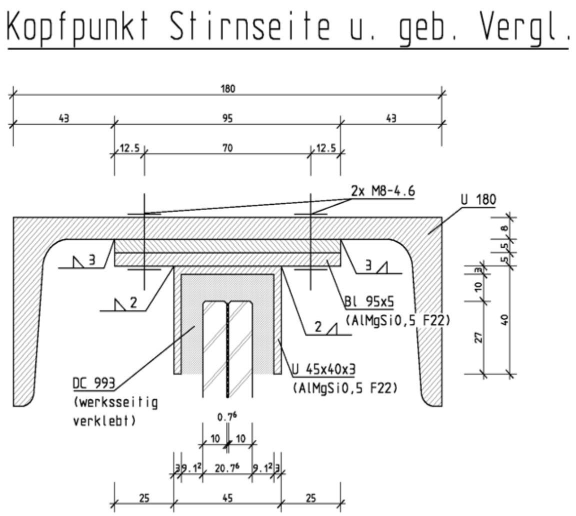

Figure 3a: Detail at the top edge and bonding - drawing.

Figure 3b: Detail at the top edge and bonding - realization.

The curved panes implemented in the corners were also glued on a U-profile for reasons of easier mounting, but did not have to take loads from bracing the structure.

For the flat panes a laminated safety glass made of 2x 10 mm tempered glass with a PVB-inlayer of 0.76 mm was applied. This panes had a width of 1400 mm. Due to production restrictions the curved glazing at the corners had to be made of a laminated safety glass of 2x 10 mm float glass, also with a PVB-inlayer of 0.76 mm. The curved panes, two pieces in each corner, had a very small bending radius of up to 465 mm.

3. Calculations

The safety proof of the structure was done according to [1] with the assumption of a reduced wind load according to [3]. So wind loads were assumed to be 0.25 kN/m², and the loads to runner to be 1.00 kN/m in a height of 1.0 m.

The steel frame was calculated as a plane framework according to DIN 18800. The resulting reaction forces were put as loads to the top edges of the bracing glass panes. For the calculation of the glass panes, elements at the narrow sides were decisive, because they had to take vertical loads from the self weight of the steel frame, horizontal loads in plane and horizontal loads perpendicular to surface from loads to runner and wind loads.

To get maximum stresses in the glass and the silicone bonding, a non-linear Finite Elements Analysis (FEA) using the software ANSYS 9.0 was conducted. To limit the size of the model, the complete glass pane and the bonding were analyzed in separate calculations.

The glass pane was generated by a shell element of the type shell63, and the horizontal load at the top edges and the loads to runner were applied as nodal loads. The nodes at the upper edge were supported in translational and rotatory direction, nodes of the lower edge were supported translational in all directions. A composite action of the PVB-inlayer was not assumed.

A separate static calculation of the curved glass was not required, because the results of the plane panes only showed values a minimum higher than permissible stresses for float glass, but the positive effect of shell action was not assumed.

For the static analysis of the silicone bonding an FE-model with volumes was generated. Every structural element was generated with eight-nodes-volumes (Fig.4).

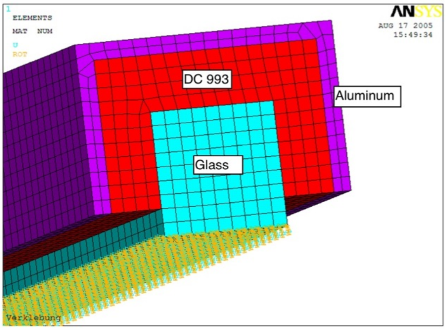

Figure 4a: FEA model, bonding.

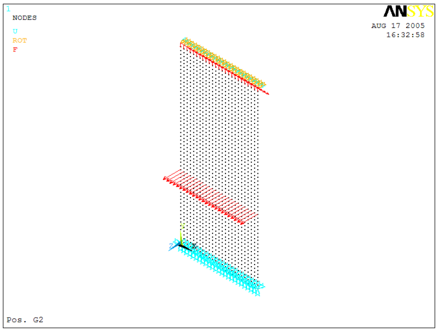

Figure 4b: FEA model, complete glass unit.

For the silicone bonding a linear elastic material behavior was assumed, the values for the Young‘s-modulus and the Poisson‘s ratio were taken from [2]. It was not necessary to use a hyper-elastic material data, because only very small deformations in the area of the bonding were expected.

4. Approvals and pendulum impact test

It was required to receive a „Einbaugenehmigung im Einzelfall“ according to [1], because the glass construction could not be calculated according to any current German technical standard. This special agreement had to be given by the inspection engineer of the trade fair company in Frankfurt. To assure a smooth procedure at an early stage, the engineering office Dr. Hofmann, Mülheim a.d. Ruhr, inspection engineer by himself, was commissioned to prove the calculation of the complete structure made by IB KRAMER. Additionally the engineering office Wörner und Nordhues, Darmstadt, was employed to prove the calculation of the glass components, and to certify an adequate remaining lifting capacity of the glass structure after breakage.

Because of already existing results, it was not required to make further experiments to proof impact resistance of the plane panes. For the curved glasses, a pendulum impact test had to be performed with two glass units to make sure that the function of this glazing to prevent from falling would be adequate, even in case of breakage.

Previously it was expected, that the curved glass panes would not be able to take the impact energy, because of their high stiffness, due to the quite small bending radius. But both test pieces showed a very good behavior. The pendulum impact test was performed with a height of 900 mm, to four significant impact areas, in the centre of the pane, near the edge in a height of 1000 mm and near the bottom supporting, also in the centre and near the edge. According to real impacts in the building, the concave surface was loaded.

All four impacts did not effect any damage to any of both glass units. After this, the inner pane at the concave side (impact surface), was damaged before the following impact tests by hitting the edge (Fig.5).

The pendulum impact test to the damaged glass unit effected only an additional breakage at the impact areas in the centre and near the edge of the pane (Fig.5), while the outer pane was faultless. The complete pane collapsed not unil the outer pane was damaged by hitting the edges before an additional pendulum impact test (Fig.6).

Based on the results of the tests, an adequate safety in using this glass unit as glass to prevent from falling could be certified. For the bonding tests were not required, because the bonding was made by a certified company under defined conditions in the factory.

Figure 5: Hitting the inner pane at the edge before impact test and breakage effected by impact.

Figure 6a: Construction of pendulum impact test.

Figure 6b: Collapsed glass unit.

5. Mounting

To adhere the aluminum profiles to the top and bottom edges of the glass panes, the U-section was filled with silicone to its half and applicated to the panes. After waiting 8 hours, the remaining areas were filled (Fig.7).

Figure 7: Adhering aluminum profile to glass panes.

To mount the structure at the fair ground, first the steel frame at the top of the façade was installed using mike booms. Then the curved glass elements and the panes with the bonded aluminum profiles at the narrow sides of the stand were mounted and the steel frame was dropped. This effected a good stability in horizontal direction so that the structure could be adjusted properly (Fig.8).

Figure 8: Steel frame with mike booms and mounted glasses at the narrow side.

The plane panes at the longitudinal sides were mounted conventionally by being inserted into the upper support profile, bringing it into vertical position and dropping it down (Fig.9).

Figure 9: Plane panes at the longitudinal side.

6. Conclusions

The described structure was proofed to be easily raised at the fair ground. Especially the glass panes with the adhered U-profiles had the great advantage that the façade could be adjusted precociously and horizontal stability was guaranteed during the mounting process without further temporary bracing elements.

With regard to the use of curved glass elements the made experiences had been very positive. Although no annealed glass could be used due to production restrictions, the impact load bearing resistance was impressive. Further the remaining lifting capacity of the damaged unit was convincing. Only the differences of production tolerances between the curved glass and the aluminum profiles caused some problems. It could be advised to consider this aspect in the planing process more intently.

As this example of a realized structure shows, designer‘s demands of most possible transparency could be completely fulfilled by using glass elements consequently as a structural elements without any reduction of safety.

7. References

[1] Deutsche Messe AG Hannover, Köln Messe GmbH, Messe Berlin GmbH, Messe Düsseldorf GmbH, Messe Frankfurt GmbH, Messe München GmbH, Use of glass and acrylic glass in stand construction and design inside fair halls, July 1st 2005.
[2] European Technical Approval ETA-01/0005: DC993 and DC 895, EOTA 07.03.2001
[3] DIN 1055: Loads