All glass balustrades made of glass

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Summary

Glass becomes more and more popular for applications in building structures. Examples are facades, large overhead glazing`s and constructions completely made of glass. On the one hand side the architect wants to design an elegant and transparent structure; on the other hand side the engineer wants to design a robust and safe structure. Also for "small" applications like balustrades and railings it is important to design a safe structure. If person are falling against the balustrade it is not allowed that the railing collapses. With the use of new materials (e.g. new interlayer materials between the glass panes) it is possible to realize very transparent solutions with a minimum amount of metal. Often tests (pendulum impact tests) are necessary.

Keywords: glass structure, railing, Pendulum impact test, Finite element analysis.

1. Regulations

In End of 2014 there will be a new German DIN standard for glass, the DIN 18008 [2]. Part 4 of this standard deals with balustrades and anti-drop devices. According to these standards on the one hand side it is necessary to do a static analysis of the railing (dead load, wind-load and capping-load). On the other side it is necessary to look to the remaining load capacity. On the European level the committee for a Eurocode glass started to work in end of 2012.

2. Static analysis and testing

In case of line supported glazing the calculation is easy. If the glass panes are supported at all 4 edges, it can be important or useful to consider the geometric nonlinear effects. Because the deflection of the glass-pane is usually large in relation to its thickness, linear theories of calculation might lead to uneconomic results. Unwanted in-plane restraint forces can be avoided by offering sufficient clearance between glass edges and screwing. Because of the brittle behavior of glass the static analysis has to be done very carefully especially in case of point fixed constructions. Contact formulation between point fitting and glass is necessary. .In case of all-glass balustrades category B, acting as a cantilevering element, clamp supported at the lower edge and with a handrail at the top edge connecting adjacent glass-elements. With the simplified calculation of only one pane of the balustrade it is often not possible to do the static calculation successful. So it is often necessary to determine the complete structure with an Finite Element analysis with different failover scenarios like shown in Figure 1. It is necessary to ensure that a glass construction cannot collapse in case of breakage of glass, so that the safety of people, e.g. falling against a glass façade or standing under a glass roof at the moment of breakage, is guaranteed. Depending on the kind of application the testing of remaining load carrying capacity is done with different testing methods. In case of glass-panes of balustrades a pendulum impact test is done. The behavior after breakage of a glass pane depends on many factors. The kind of glass or the geometry of the point fixing have influence. The interlayer between the glass panes are not only PVB-foils, so often tests in laboratory are necessary. Depending of the Category the drop height of the pendulum is different: For category A 900mm, for category B 700mm and for category C 450mm. In case of free edges on the top of the glass without any handrail, the requirement is to destroy the glass edge with an impact of a metal ball and do the pendulum-test with a drop height of 900mm. Figure 2 shows a remaining load carrying test of an all-glass railing using the ionoplast interlayer. For the tests it was necessary to destroy the glass and do the pendulum-test with a drop height of 900mm.According the E-DIN 18008 it is possible to proof the impact resistance with calculation. Depending of the constraint situation is possible to do this with a simplified procedure or a dynamical transient simulation of the impact.

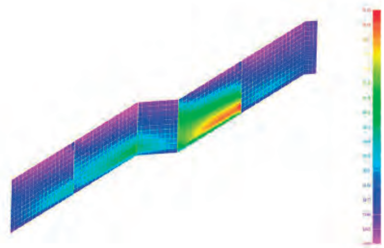

Fig.1: example of a complex calculation

Fig. 2 Test railing

Fig. 3: Adidas Laces

3. Example: Adidas Laces

The newest building at the ADIDAS headquarters in Germany – the so-called „adidas laces" – was constructed to enlarge space for product development. The roofed atrium is crossed by various pedestrian bridges that connect the different divisions on several floors. High transparent glass balustrades preserve the sculptural character of the slender structures. The bridges are supported by suspension rods that are fixed on the large framework girders above roof level. Therefore detailed information on the various states of deformation was requested to determine the required spacing between the single glass panes. The pedestrian bridges are very slender steel constructions supported by suspension rods.. The width of the glass elements varies whereas the height of the railing is continuously 1100 mm above the walking surface. It is used laminated glass consisting of two panes 10 mm thick tempered safety glass connected by 1.52 mm PVB-foil. To fulfill the demands of remaining load capacity a pendulum impact test was done for the decisive dimensions like the curved glass panes or some non-rectangular ones (staircase). The drop height of 700 mm was chosen according to German technical rules. Beyond mandatory test procedure several pre-damaged conditions were investigated. Above all the curved glass elements showed remarkable impact resistance.

4. Conclusion and summary

For balustrades the material glass is used more and more. Beginning from simple "fillings" with glass up to constructions completely made of glass it seems that nearly all is possible. In case of slender structures like pedestrian bridges deformations can lead to unforeseen stress peaks in the glass, if i.e. two adjacent glass elements contact directly. So on one hand it is very important to know the basics of the material glass to use the right kind of glass and carry out the static calculation of the glass closed to reality because of the brittle behaviour of the glass. It is necessary to consider the deformation in the substructure for the analysis of the glass pane. On the other hand it is important to look at the behavior after breakage. With new materials it is possible to improve the construction concerning the load ability and the remaining load bearing capacity.

5. References; See full paper