Design and Calculation of Modern Glass Constructions

Barbara SIEBERT
Dr.-Ing.
Ingenieurbüro Dr. Siebert
Munich, Germany
mail@ing-siebert.de

Born 1967, received her civil engineering degree from TU München. After some years as employee in a consulting office, she is now working in her own consulting office Ingenieurbüro Dr. Siebert with special field of application of glass. The doctor's thesis about the calculation of point helded glasses was accepted 2003.

Geralt SIEBERT
Univ.-Prof. Dr.-Ing.
Universität der Bundeswehr
München, Neubiberg, Germany
geralt.siebert@unibw.de

Born 1966, received his civil engineering degree from TU München. The doctor thesis about the application of architectural glass as load carrying structural element was accepted 1999. Since 2003 he is professor and owner of the chair of structural design and building physics in Munich.

Summary

The use of glass in structural engineering opens a wide field for interesting applications. As it is a quite new subject only few regulations and design rules exist. So it is very important to know the basics of the material glass to build safe and economic constructions. In this paper an overview is given about the different kind of glass with the different behaviour concerning load carrying capacity and remaining load capacity. Results of testing of the different kind of glass with their different behaviour are presented. The requirements due to safety aspects for the application of glass in Germany and Europe will be presented. Other points are the characteristic of the different kind of bearing (linear and point fixings) and the behaviour of laminated glass. Topics like principle design rules, static calculation of glass (linear and point fixed glass, effects of nonlinear calculation) are presented.

Keywords: glass constructions, point-fixing system, safety aspects, façade, overhead glazing, Finite-Element-Analysis, residual resistance.

Introduction

The application of glass in architecture and structural engineering is still growing. To fulfil the wishes of architects and, of course, to provide save and secure building elements, glass is used in a different way compared to the old application as classical window element.

Basics

Annealed or float glass shows linear elastic behaviour and is an excellent example of a brittle material. The tensile strength is not an intrinsic property like the density but influenced by several factors like load history, size of the surface and distribution of tensile stress, environmental condition and surrounding medium, surface quality. In case of heat-strengthened glass and thermally toughened glass (safety glass) the panes cut to their final shape are heated beyond the weakening temperature and cooled with cold air. By this process the inner glass stays longer warm and still contracts at a time the outer parts of the glass pane is already solidified; by this compressive stress on the surface and tension in the inner part of the glass ply is produced. Depending on the procedure the frozen-in compressive stress can become -200 MPa and more. The size of the fragments of broken glass is proportional to the level of frozen-in stress.

Laminated glass consists of two or more plies bonded together with an elastic interlayer, usually polyvinyl-butyral (PVB). The interlayer fixes the glass so in case of damage the broken fragments stick on the foil. Using thermally toughened glass the behaviour of a complete broken laminated glass unit acts like a wet towel: large deflections. A broken unit made of heat strengthened glass remains in most cases more or less in its position because of the larger fragments which are usually

https://doi.org/10.2749/222137809796067939
Distributed by structurae

held together. This post-breakage characteristic makes laminated glass an excellent glazing material for architectural applications.

Different Applications, Bearings and Requirements

The different applications of architectural glass can be divided according to their way of installation (geometrically) and – depending on the situation – eventually with respect to additional tasks the glazing has to fulfil. The bearing for all above mentioned possible applications of glass elements can be linear or at points. As all buildings or structural elements used in buildings also structures made of glass have to fulfil the common requirements like sufficient load carrying capacity and – in some cases – not too large deflections (SLS and ULS). In case of point fixed glazing the static calculation is difficult: To get a correct solution of the Finite-element analysis, a verification or calibration is necessary.

Figure 1 point fixings

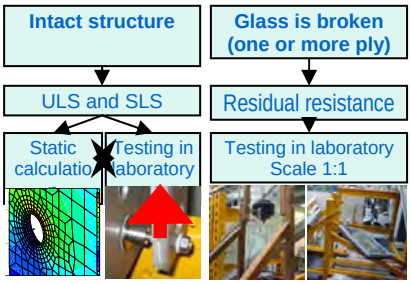

Figure 2: Requirements

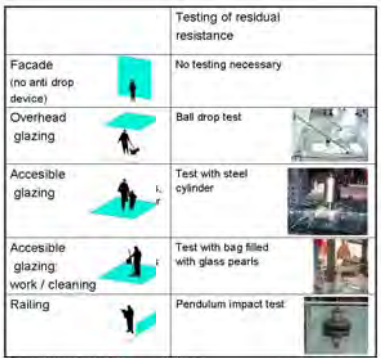

Figure 3 Testing

Testing of glass elements

It must be sure that a glass construction cannot collapse in case of breakage of glass, so that the safety of people, e.g. standing under a glass canopy is secured.

Depending on the kind of application there are different demands to the residual resistance, Fig. 3. To show the different testing results a canopy was built with different types of glass. As figure 4 shows, the broken pieces of fully tempered glass elements stick together, small pieces of harmless size are obeyed not before they hit the bottom.

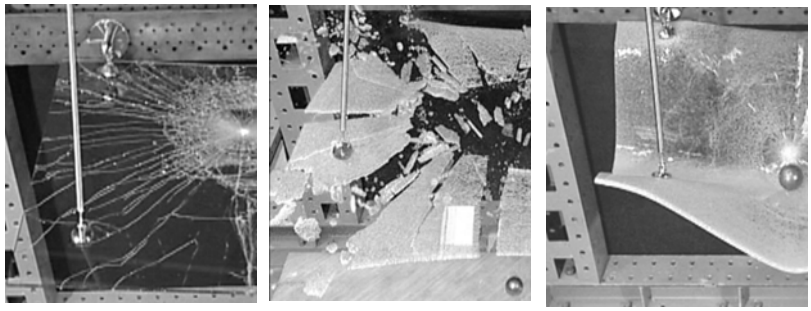

Figure 3 results after ball drop test for different glass types

Development of German and European Code

The development of design rules and regulations does in no way cope with the executed applications, especially as the ideas of architects and engineers seem to have no limits. The few, present regulations are presented in this paper.

Conclusions

Different applications require different levels of safety. These can be fulfilled by choosing the appropriate combination of glass, product and bearing. Static calculation is necessary most times. Often also testing has to be done to guarantee safety against impact or in case of broken glass. Obeying these points interesting objects can be realised.

References

See full paper