Glass meets new high-strength materials

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Summary

We all know how to build with concrete, steel or other traditional building materials. But now the world calls for load-bearing building elements made of glass. These elements shall transcend the field of facades where glass normally is used. Until now only a few projects in this field could have been realised.

In this contribution advisements to optimise glass constructions and experiences from experimental studies shall be presented. It can be determined that an efficient, readjusted geometry in combination with high-strength materials and prestressing is an elegant method to come closer to the aim of creating load-bearing glass structures. Thereby, redundancy, stability problems and the conditions of manufacturing have to be considered, too. First priority is to harness the high compression strength durability of glass which is ten times higher than the compression strength durability of normal concrete.

Keywords: glass; girder; high-strength materials; CFRP, prestress; load capacity; redundancy

1. Glass – really a modern material?

After a look in the history it can be found out glass in buildings is used for the Middle Ages, and it was always an exclusive material. But first since the insertion of the PILKINGTON method to produce large-sized glass panes in 1959 glass became a mass product. But it has not lost its exclusiveness. Now glass girders or columns as primary load-bearing structural elements promise more exclusiveness. Up to the present was mostly used only as secondary load-bearing elements.

One objective was to find more possibilities to give these constructions more redundancy and to get higher load capacity as well as to think about safety aspects in general. The aim should be to develop design concepts and construction rules to facilitate the use of glass for primary load-bearing structural elements like girders in roof constructions for instance. The first steps on that way shall be described here.

2. Increasing the load-bearing capacity of glass girders

2.1 Point of origin

If excluding a failure because of stability problems (for instance lateral torsional buckling) by appropriate actions, the reason for failure under bending stresses is the material's low tensile strength durability which is not a conventional material property, because it depends on the cuts and cracks on the glass surface. Already, cuts with the depth of some nanometers reduce the tensile strength durability exceedingly. The outstanding material property of glass is its compression strength durability which is more than ten times higher than the compression strength durability of normal concrete. But in general it can not be used to full capacity, not even rudimentary.

The objective was to find solutions to take more advantage of this outstanding material property. To increase the load capacity of glass girders associated with a redundant behaviour, the influence of

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different criterions shall be regarded, like the use of tempered and chemically prestressed glass, the optimisation of girder geometry, the combination with high-strength materials and prestressing of girders.

To give an example for the consequences to the load capacity and redundancy the possibilities for optimisation shall be demonstrated with prestressed single-span glass girders.

2.2 Experimental tests on prestressed single-span glass girders

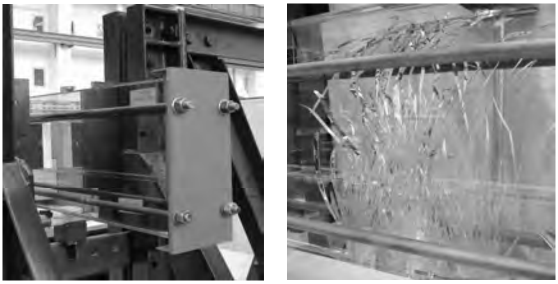

Fig. 1: Prestressed glass girders [1]

The girders were prestressed centrically or eccentrically by reinforcement inside or outside the glass girders with high-strength materials like high-strength steel for instance.

In the tests different pretensioning forces were simulated. Afterwards the vertical concentrated load was increased. As to be seen in the tensile stress-displacement-curves (Fig. 2) girders with higher pretensioning forces reacted with more stiffness, the rise of the curve is steeper. Glass failure started in the middle of the girder. The first cracks appeared as expected in the area of maximum bending moments with maximum tensile stresses at bottom side of the girder. From there they grew in direction of stress neutral axis. The failure started always at one pane; the other panes had to absorb the stresses supplementary and failed following, too. For glass it was used float glass to get large fragments. It could be observed that all fragments clung to the interlayer. For increasing load capacity the girders were reinforced additionally with Carbon Fibre Reinforced Plastic cloth in areas of high loading.

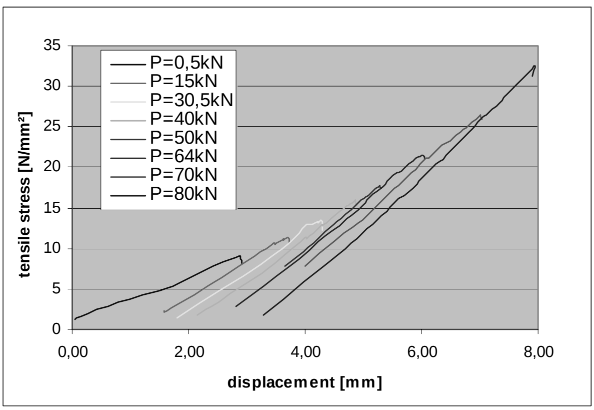

Fig. 2: Stiffness effects with different pretensioning forces

3. Conclusion

The material glass reacts similar to concrete: In combination with other materials which can absorb tensile stresses and bypass cracks efficient composite constructions can be created. These constructions can be developed redundant and with a failure behaviour with notice in advance.

With an adjusted geometry a better utilisation of the high compression strength of glass is possible and meaningful. Glued constructions extend the range of possibilities. Until now long-term experiences with adhesives in primary structural elements do not exist why reliable construction rules can not be given. In this field more research is needed.

4. Literature

[1] PIEPLOW K, ″Entwicklungen im Konstruktiven Glasbau - Tragende Bauelemente“, Research report F2008-21, Dep. for Concept. and Struct. Design – Steel Construction, TU Berlin, 2008.