Glass Covering of long span Roofs

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Summary

Glass is getting more and more popular in many fields of structural engineering. In case of covering of roof constructions it is possible to design very transparent and of the architectural side very attractive constructions. A combination with photovoltaic enables energy output. It is very important to consider some points: Glass is a brittle material, so it is important to do the static analysis very carefully. Sometimes tests are necessary for the remaining load carrying capacity in the case the glass breaks. In case of large roof constructions the deflection of the substructure must considered in the analysis of the glass. Unfortunately there exist presently only very few regulations.

Keywords: Glass, Roof construction, Photovoltaics.

1 Introduction

There are some principle design concepts for these roofs made of glass: Glass acting only as "filling" element in a main structure made of steel or timber, All-Glass structures with girders made of glass, roofs with cable-net constructions and glass acting as stiffening element.

2 Static analysis

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 nonlinear effects. Because the deflection of the glass-pane is in most times very large the nonlinear "membrane" - theory" must be used. Because of the brittle behaviour of glass the static analysis has to be done very carefully, especially in case of point fixed constructions. The point-bearing itself and the surrounding area has to be modelled accurately in a Finite Element Analysis to get close-to-reality results. In case of roof-constructions with very large deflections, it is of course very important to consider the interaction between glass and steel components. Often here a very complex finite-element analysis of the complete structure is necessary. In case of All-Glass-Constructions often partial failure of the structure must be considered. For In-plane loaded Glass-steel elements or glass acting as bracing element meanwhile some scientific work was done (see references).

3 Design-Rules and regulations

At present a new design code is nearly finished on German level (E-DIN 18008); this is taking into account the actual state of science and research, design is based on the modern system of partial safety factors like used in the European codes ("eurocodes").

4 Testing of Glass: "Remaining Load Carrying Capacity" (Fig. 1)

For long span roof constructions an often demand is the accessibility for maintenance reasons. In case the person, who is e.g. cleaning the glass, is e.g. getting unconscious, it is important to know that the glass construction stays in position also in the case that one or more layer of the glass is broken. Also the case that something is falling on the roof has to be taken in account.

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5 Example 1: GVZ Ingolstadt, “Rail Hall” (Fig. 2)

The “GVZ” is a cargo transportation center nearby the company site of the car manufacturer Audi in Ingolstadt with a total area of 830.000m². In 2012 a new building, the so called “rail hall” was erected. The length of this building is about 500 m, the span is about 20m. The main construction consists of suspended girders made of timber. The roof, with a total area of about 11.600 m², is covered with special photovoltaic elements. The size of one of these elements is 2.2m x 2.6m. Because of the translucent effect of the photovoltaic elements, natural light comes into the building. A static analysis for substructure and for the glass was done. The glass panes are supported on 4 sides for pressure, only on two sides for suction. The glass consists of: 3,2mm Float / 0,76mm PVB-Foil / PV Cells / 0,76mm PVB-Foil / 3,2mm Float / 0,76mm PVB-Foil / 10mm TVG / 1,52mm PVB Foil /10mm TVG. The glass is accessible for maintenance reasons, so an experts report was necessary.

6 Example 2: Castle Hotel in Westerburg

For a Castle Hotel in Westerburg, Germany a case study was done for a transparent covering of the inner court of the castle. For this project many aspects were important: Principle construction (cable-net constructions or glass acting only as filling element), the boundary conditions: possible connections to the old building, the Building physics (g- and u-value of the glass, light transmission, shading,…) and design aspects (transparent solution).For the case study several solutions were considered and for all solutions static analysis were done.

7 Example 3: Doberaner Weg Hamburg (Fig. 3)

Construction of large canopies or roofs can be realized also very easy. For the project “Doberaner Weg” in Hamburg, Germany there was planned an roof for a railway station with the dimensions of 88,3m x 6,85 m and an additional part of 10 x 11,5 m². The roof is divided in several glass-elements, held by 4 or 6 point fixings. Divergent to the bidding procedure it was realized using the presented system with a national general approval, so there was no loss of time and money because due to no static analysis and no expensive tests were necessary.

Fig. 1: Testing of a glass pane

Fig. 2: Rail hall from inside

Fig.3: Doberaner Weg

8 Conclusions

For the glass covering of long span roofs many points are important: choosing the right kind of glass, doing the static analysis– especially in case of point fixed glazings – very carefully, looking to the interaction between substructure and glass and looking to the remaining load carrying capacity. So the design and structural analysis of these transparent roofs may be very sophisticated. On the other hand side very easy to use systems for standard applications are existing.

9 References: See full paper