Earthquake Tests of Glass Structures

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Summary

Worldwide investigations to protect people in case of earthquakes in seismic active regions like e.g. Japan or part of the United States are done. Earthquake engineering develops different methods for design of building or bridges with minimised risk of collapse due to earthquake. But there is an – often underestimated – risk for the health of people outside the buildings (e.g. on pavements) in case of an earthquake caused by falling parts of facades or canopies.

In this paper basics of glass structures (different applications and bearing situations, different kinds of glass) and an overview about their design is given briefly. The main part is testing of glass elements with a special focus on earthquake tests which are done in laboratory of the Universität der Bundeswehr München at present. Research work will be continued with different bearing situations and other common applications like facades.

Keywords: earthquake, design, testing, glass structure, facade, canopy, railing.

1. Introduction

Buildings and their parts have to be built in a way that sufficient safety is guaranteed. Therefore before erecting or construction of buildings design (structural design as well as static calculation) is done; here one has to divide into ultimate limit state (ULS) and serviceability limit state (SLS). The first grants that the probability of collapse of building is small enough in case assumed loads appear, the latter ensures that buildings can be used like designed. This of course has to be applied to the building as well as to each single part of it.

In case a structure is planned in an area with seismic activity, special load cases in respect to this have to be taken into consideration. As result a structure with – in comparison to design without considering earthquakes – higher load bearing capacity elements is planned. Alternative or additionally so called earthquake protection systems can be used: here one can divide to special isolation, dissipation or damping elements. For more details see e.g. [1] and there mentioned – also English – references.

Structures made of glass of course also have to fulfil the mentioned requirements. Starting from applications of the craftsmen with predominately use of glass as window, glass was increasingly used as structural element. Parallel to this of course also design methods had to change from simple, mainly on experience based rules of thump to more complex methods. The latest, actual step is the application of up to date concept of partial safety factors also for glass used as structural element. As the development of the regulations for "normal applications" are still not finished until now no special requirements for earthquake are formulated.

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2. Design of glass structures

The static analysis for glass structures can be simple or more complex, depending on its function and related loads as well as on the static system and type of bearing. Here in some cases also the glass elements carrying structure has to be taken into consideration, e.g. different behaviour of flexible steel structure or stiff concrete structure.

Because of the brittle behaviour of glass special attention has to be paid to the details, especially in case point-bearings are used: no “intelligent behaviour of material” (like yielding of steel) in case of punctually high stress is possible. So one of the most important rule is to avoid any direct contact between glass and steel or other hard material.

It is not possible to cut or adjust thermally treated glass elements – and in most cases heat strengthened glass or thermally toughened glass is used. So problems due to tolerances in production (of glass elements as well as the load carrying structure) and the impossibility of treatment of tempered or heat strengthened glass of fabrication need special consideration.

Another important point is the “residual resistance”, residual load carrying capacity (RLCC) to ensure that also in case a single glass ply or complete laminated glass element breaks, no collapse will occur. At present the only way to guarantee a positive behaviour also in case of breakage of glass is by executing tests in scale 1:1 – unless a more expensive solution like planning laminated glass with additional glass plies is chosen. Testing of glass elements – static (non earthquake) loads

Testing often is needed to prove resistance against impact loads. Another important point is the residual strength to be sure that also in case a single glass ply or complete laminated glass element breaks no collapse will occur. At present the only way to guarantee a positive behaviour also in case of breakage of glass is by executing tests in scale 1:1 – unless a more expensive solution like planning laminated glass with additional glass plies is chosen.

3. Earthquake tests

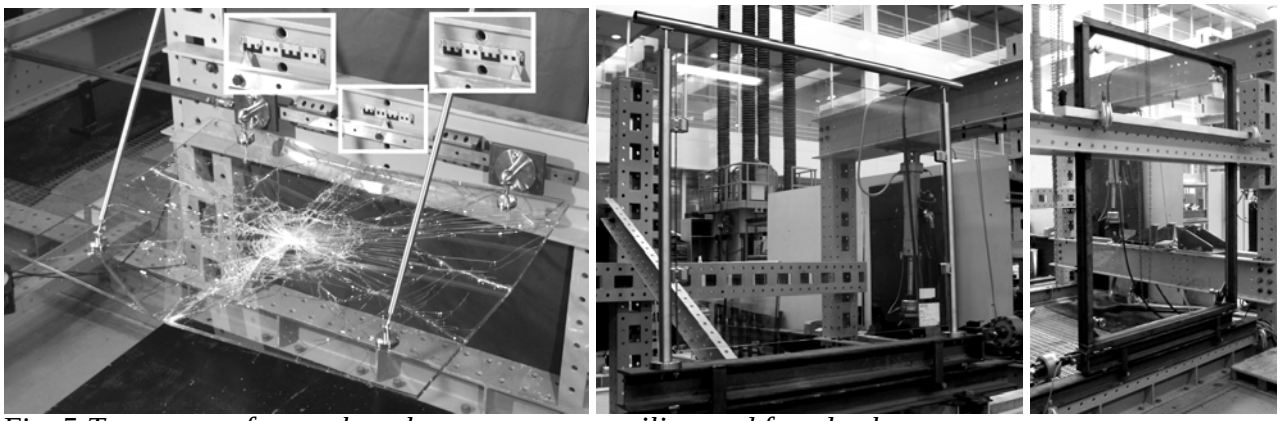

Fig. 5 *Test set-ups for earthquake test: canopy, railing and facade element*

To get an impression about behaviour in case of earthquake testing with horizontal movement were carried out with different combinations of horizontal deflection (amplitude, + and - relative to starting position) and frequency. One test run consists of a programme for the hydraulic jack running the frequency-amplitude-combinations of table 1, each step for some minute.

4. Discussion, Conclusions and Acknowledgements

The presented first testing shows that well designed structural elements made of glass can also resist loads they are intentionally not made for like horizontal movement of canopy. The canopy, the railing as well as the point supported façade element showed a high resistance to dynamic loads. The tests with the canopy proved that this is not only true for intact structures, but that even broken glass elements can have a safe behaviour and a high residual load carrying capacity if the appropriate type of glass is chosen.