EXPERIMENTAL AND NUMERICAL EXAMINATION OF LATERALLY LOADED LAMINATED GLASS

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1. Introduction
Several experimental and numerical examinations were done aiming the analysis of the laminated glass plates [1] - [4], but their common problem is, that their recommendations are only used in case of one direction bending. I consider it does worth further investigation regarding the topic because the architectural practice usually employs glass plates bent in two directions.

The study deals basically with the mechanical behaviour of laterally loaded laminated structural glass. To develop design guidelines there are two major factors to examine; the elastic mechanical properties of the laminated structures, and the breaking mechanism of the glass plates. In the present article I discuss the elastic mechanical behaviour of laminated structures, but I remark that I dealt with the analysis of design methods currently used as well.

2. Experimental Results

Fig. 1: Method of test in four point bending (EN 1288-3:2000 [5] where, 1. specimen (1000 × 360 mm), 2. bending frame, 3. steel rollers, 4. rubber stripes (3 mm thick, 40 ± 10 IRHD according to ISO 48:1994), 5. transducer (MOM LOAD CELL 7924 A), 6. hydraulic press (LUKAS HP 10/150), 7. supporting frame, 8. inductive transducer (HBN WA 100 TK), 9. bracing for the hydraulic press, 10. counterweight

For testing the elastic mechanical behaviour of structural glass plates, I built a finite element model in ANSYS 12.0. To verify the numerical model I used literature [4] and own experimental results, completed by the standard EN 1288-3:2000 [5].

The glass planes were loaded with four-point bending. In each case the specimens had the same ichnographical size (1100 mm x 360 mm), however, the thickness of the glass plates and the laminating film was different. The laminates had different layer structure too. The fundamental aim of the experiment was to verify the material model of the PVB (polyvinyl butyral) laminating film. Fig. 2. and Fig. 3. show the schematic figure of a glass plate breaking mechanism.

Fig. 2: Schematic load displacement curve of a 2 layered glass plate (1. end of linear phase, 2. bottom plate breaks, 3. only the top layer bears the load, 4. top plate breaks, 5. the PVB foil bears the tension the fractured top layer bears the compression, 6. the interlayer tears)

Fig. 3: Schematic breaking stages (I. two layers bear the load, II. only the top layer bears the load, III. the top layer breaks, the PVB foil bears the tension the fractured top layer bears the compression)

For further verification I used an analytic solution based on the theory of thick sandwich panels using small displacement theory.

In the numerical model I have assumed that the glass is linear elastic. The PVB film was considered to be nonlinear elastic, progressive
I used multi-linear material model in ANSYS. I have developed two types of boundary conditions, the first used for the experiments (one direction bending), the second is used for the parametrical study (two directions bending). So I used the [4] literature to verify the model of the composite panels (two direction bending), then I built in the PVB material model validated by the experimental results.

The final section of the study is a parametric examination of a two layered glass plate bent in two directions, as a function of plate dimensions, PVB and glass thickness, and the boundary conditions.

As result I can declare that the use of linear methods for the examination of laminated glass of slenderness more than 60 are only optimal at low load intensity.

By reducing the thickness of laminating film, the structure becomes more rigid, so that the deflection gets reduced. During the parametric studies I have examined asymmetrically build-up plates. The result showed that the maximum value of tensile stress – on the lower layers bottom surface – is reduced by 15-20 % (Fig. 4.), if the lower layer is selected thinner and the upper layer is selected thicker.

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4. References