23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

INFLUENCE OF AN INTIAL IMPERFECTION ON THE LATERAL AND TORSIONAL BUCKLING OF A HYBRID BEAM

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Abstract: *Glass has grown in importance in modern architecture because of its transparency. Various types of hybrid structures, consisting of glass and another material (e.g. timber, concrete, steel), are analyzed to ensure optimal structural interaction between the two materials. Hybrid steel–glass beams can also be used as vertical elements – as supporting fins for glass facades. Wind suction then becomes a source of instability of the beams because the compressed side is unsupported. Initial geometric imperfections can significantly influence the stability response of hybrid beams. This paper deals with measurements of the imperfections of hybrid steel-glass beams, and reports on a numerical investigation into the effect of imperfections on the behavior of simply supported hybrid beams subjected to four-point bending.*

Keywords: Imperfection, Hybrid beam, Glass, Lateral and torsional buckling, Critical moment.

1. Introduction

In practice, real beams are not perfectly straight. Geometric imperfections have a significant effect on their behavior and strength. Lateral and torsional buckling is a crucial problem of glass beams, particularly in the case of vertical glass structural elements that support facades, (Luible, 2005), (Belis, 2007), (Kasper, 2007). Geometric imperfections can be divided into two categories: global imperfections and local imperfections.

Global geometric imperfections vary according to the type of glass. It is known that annealed glass has very low initial deformation (< L / 2500, where L is the length of the beam). However, tempered glass has higher initial deformation up to L / 300. This is caused by the production process for tempered glass, which is warmed up 650 °C and then rapidly cooled. During this process the glass panes are placed on rollers, which cause a sinusoidal initial deformation.

Local imperfections occur when the cross-section deviates from its ideal shape.

This paper describes measurements of the initial imperfections of a steel-glass beam, and shows the effect of a geometric imperfection on the behavior of the beam in a numerical model.

2. Hybrid steel-glass beams

Research in progress at the Faculty of Civil Engineering, CTU in Prague, is focused on an experimental investigation of lateral and torsional buckling of hybrid steel-glass beams. The beams were 4.75 m in length and consisted of a 10 mm thick glass web and steel grade S235 flanges with dimensions of 40 x 8 mm. Direct connections between steel and glass were realized by a 3 mm thick layer of 2-component SikaFast-5215 NT acrylate adhesive (Pravdová, 2016).

Three hybrid beam experiments were performed in 2016. The beams were simply supported with a 4500 mm span, and were subjected to a four-point bending test. The load introducing points were 2900 mm apart. Lateral supports were arranged at the load introducing points. The beams were loaded by controlling the force value until total collapse. Horizontal displacements were measured in the mid-span

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and close to the supports. Buckling of the hybrid beam before collapse is shown in Fig. 1. The image was taken by a high-frequency camera that recorded the experiments.

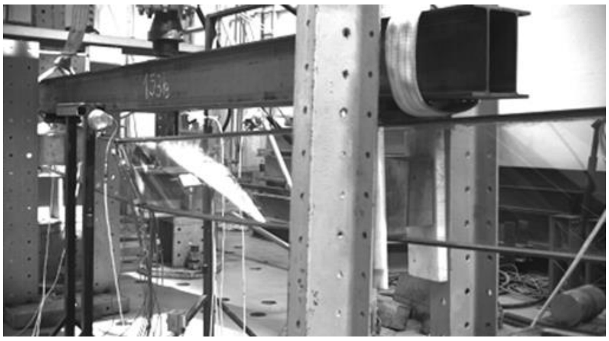

Fig. 1: Buckling of the hybrid steel-glass beam.

3. Measurements of initial imperfections

Geometrical imperfections (both local and global) of the steel-glass beams were measured using a laser scanning method. To enable the laser scanning method to be used on a hybrid steel-glass beam, it was first necessary to apply white paint to the glass web.

The Surphaser 25HSX accurate laser scanning system was used on two standpoints in order to scan both the upper flange and the lower flange of the beams, see Fig. 2 and Fig. 3. Subsequently, the scans were transformed to the unique coordinate system using identical points, which were formed by white spheres 145 mm in diameter. The spheres were fixed on the steel flanges by a magnetic pad.

Fig. 2: Laser scanning, first standpoint.

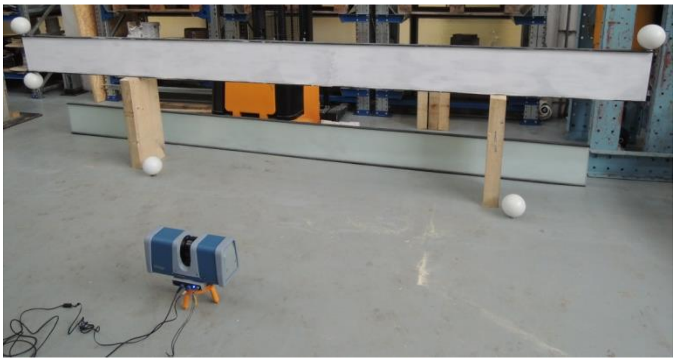

Fig. 3: Laser scanning, second standpoint.

The laser scanning system creates a model of the point cloud, and finally the horizontal and vertical sections are obtained. Fig. 4 shows the horizontal and vertical sections of the beams. The first horizontal line is placed in the middle of the cross-section, while the second horizontal line is from the top part of the glass web.

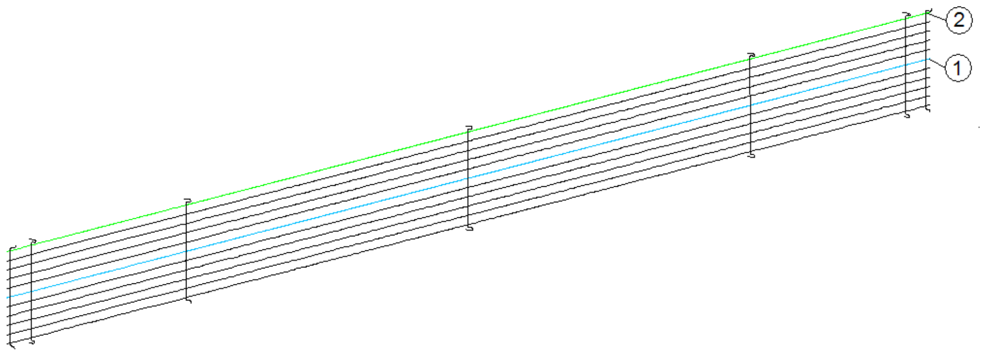

Fig. 4: Horizontal and vertical sections of the hybrid beam.

Fig. 5 and Fig. 6 illustrate the first and second horizontal sections of three beams. It is worth mentioning that the maximum imperfection of the glass web was very small (< L / 1500), although thermally toughened glass was used.

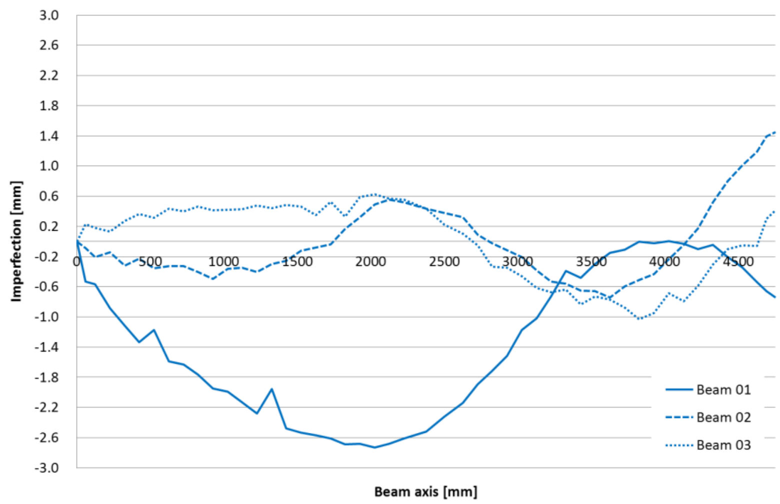

Fig. 5: Imperfections from the first horizontal section.

Fig. 6: Imperfections from the second horizontal section.

4. Numerical models of a hybrid steel-glass beam

Numerical models were created in RFEM 5.05 software using surface elements. Material models of glass, steel and adhesive were defined as isotropic linear elastic. Large deformation analysis was applied.

The initial imperfection has a significant influence on the lateral and torsional stability of hybrid beams. This imperfection was taken into account to obtain conformity between the numerical model and the experimental results. A geometrical imperfection was introduced into the model in a sinusoidal waveform of the beam with different amplitudes.

A comparison of the FE calculation with experimental results is shown in Fig. 7. Both numerical models, without imperfections and with imperfections with an amplitude of geometrical imperfections L / 3600 (a = 1.25 mm), L / 1800 (a = 2.5 mm), L / 400 (a = 11.25 mm), were analyzed by FEM. It can be observed that the numerical model with amplitude of geometrical imperfection L / 1800 corresponds to hybrid beam 03.

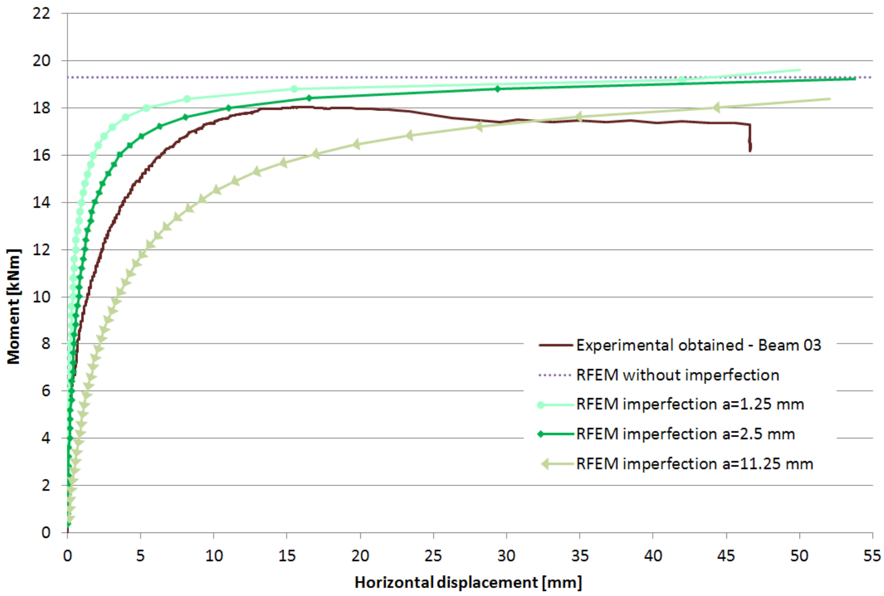

Fig. 7: Dependence of moment and horizontal displacement in the middle of the beam.

5. Conclusions

The lateral and torsional stability of steel-glass beams were investigated by a set of experiments. Beams were simply supported and subjected to a four-point bending test. Before the experiments, geometrical imperfections were measured by the Surphaser 25HSX laser scanning system on two standpoints. Horizontal and vertical sections of the beams were created, and the imperfections of all beams were read.

A numerical model of the beam was verified by the experimental results. Significant influence of the initial imperfection on the buckling of the beam was demonstrated by the numerical model. The results of a numerical analysis that fails to introduce the initial imperfection could be on the unsafe side.

Acknowledgement

This paper was written with support from GAČR project No. 16-17461S. We gratefully acknowledge Dlubal Software, which provided the RFEM 5.05 software that was used for the calculations.

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