BRITTLE FAILURE IN HYBRID STEEL-GLASS BEAM-COLUMN JOINT PROTOTYPE. EXPERIMENTAL INVESTIGATION AND NUMERICAL MODELLING.

Mirko Pejatovic[1]*, Robby Caspeele[1] and Jan Belis[1]

[1]*Ghent University, Department of Structural Engineering and Building Materials, Ghent, Belgium*
** Presenting Author email: mirko.pejatovic@ugent.be*

Abstract

A small-scale hybrid glass beam-column connection prototype is tested to assess its rotational characteristics and post-fracture performance. To replace the experimental testing by a numerical simulation, the possibility of using two numerical Finite Element (FE) approaches is explored and the results are compared to the experimental findings focusing on the connections failing in a brittle manner.

Introduction

A hybrid combination of structural glass and bonded stainless steel reinforcement enables to achieve architectural transparency while also satisfying post-fracture safety requirements [1]. The performance of joints and their rotational characteristics are of crucial importance in a context of safety of structural systems. For that reason, continuity of reinforcement needs to be ensured in the joint regions in these systems (see e.g. [2]). Depending on sectional design, joints might fail in a brittle manner due to glass fracture at the core. Brittle failure of a joint is undesirable and it could be considered as a limit situation in design. In this work, the connection specimen is made of welded stainless steel and soda-lime silica glass. The two materials are laminated together by using ionomer (SentryGlas®) interlayer. The assembly with the cross-section is depicted in Fig.1 as well as boundary conditions and loading conditions.

To replace the experimental testing by a numerical simulation, two FE approaches are considered: a 'brittle cracking' and a 'reducing element' approach.

The brittle cracking approach is used within dynamic analysis in Abaqus. In this approach, fracture in glass is modelled in such a way that when the cracking criteria are fulfilled, the finite element is deleted from the mesh.

The reducing element approach is implemented within Abaqus implicit analysis by defining an user-defined material. Regarding the computation time, it reaches the moment of failure relatively quickly. In this approach, fracture in glass is modelled by reducing E_{glass} to E_{res}=0.05MPa of a cracked finite element when the principle tensile strain exceeds f_t/E_{glass}.

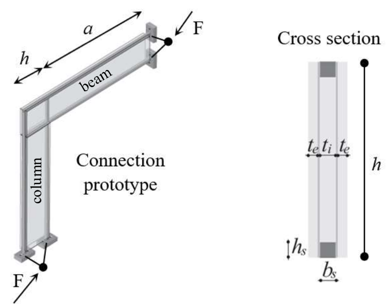

Fig.1 – Assembly of the connection (a=550m, h=125mm, t_e=6mm, t_i=10mm, b_s=h_s=10mm) with a load arrangement in the test (left) and the cross-section (right).

Results

A summary of the experimental and numerical results is given below:

- The connection specimen fails in a brittle manner due to comspression in the core (see Fig.2(a)).
- Both numerical approaches considered predict the failure moment on the safe side. However, crack patterns in both numerical approaches differ from the experimental one. The reason for this could be found in a lack of the random field definition in the glass. Currently, a characteristic value of the tensile strength of 45MPa was considered to be distributed uniformly.
- Both numerical ultimate rotations match very well with the one found in the experiment.
- From a practical point of view, it could be concluded that a sufficiently refined REA model provides a good and safe estimation of the rotational behavior of such joints at a minimized computational effort.

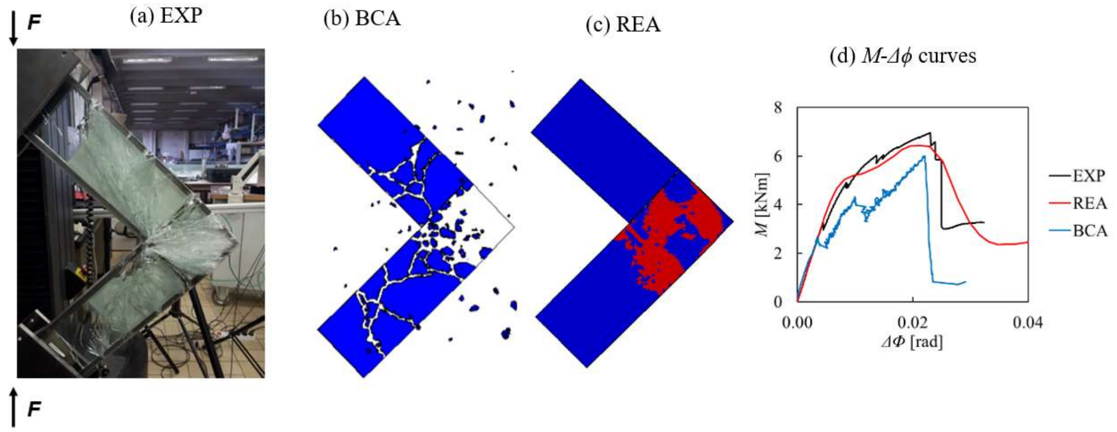

Fig.2 – Crack patterns of (a) experimentally tested joint [3] , numerical simulation by using (b) brittle cracking (white color represents deleted elements) and (c) reducing element approach (red color) represent cracked element. (d) M-$\Delta\phi$ curves.

Conclusions

The focus of this work is to develop an appropriate numerical approach for the simulation of the post-fracture performance of a hybrid steel-glass beam-column connection prototype focusing on brittle joint core failure. Two numerical approaches have been considered: brittle cracking and the reducing element approach. Both models predict a safe behavior in comparison with the experiment. The latter numerical approach has the potential to be used in practice since it yields a safe and reliable prediction with minimized computation time.

References

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[3] M. Pejatovic, R. Caspeele, and J. Belis, "Rotational stiffness and strength of a two-sided reinforced laminated glass beam-column joint prototype: Experimental investigation," in *Current Perspectives and New Directions in Mechanics, Modelling and Design of Structural Systems*, London: CRC Press, 2022, pp. 825–827. doi: 10.1201/9781003348443-135.