Behavior of polyhedral built-up glass compression members

Dr. Joseph Robert Yost, Professor, Villanova University, USA
Dr. Masoud Akbarzadeh, Assistant Professor, University of Pennsylvania, USA
Dr. Mohammad Bolhassani, Assistant Professor, City College of New York, USA
Liam Ryan, Graduate Student, Villanova University, USA
Dr. Jens Schneider, Professor, Professor, Technische Universität Darmstadt, Germany
Philipp Amir Chhadeh, Research Assistant, Technische Universität Darmstadt, Germany

This research presents an experimental program executed to understand the strength and stiffness properties of hollow built-up glass compression members that are intended for use in modular construction of all-glass, compression-dominant, shell type structures. The proposed compression-dominant geometric form has been developed using the methods of form finding and three-dimensional graphical statics (Bolhassani, et al. 2018, Akbarzahdeh et al. 2015a and 2015b). This research takes the first steps towards a new construction methodology for glass structures where individual hollow glass units (HGU) are assembled using an interlocking system to form large, compression-dominant, shell type structures thereby exploiting the high compression strength of glass (Akbarzahdeh et al 2019). In this study, an individual HGU has an elongated hexagonal prism shape and consists of two deck plates, two long side plates, and four short side plates, as is shown in Figure 1. Connections between glass plates are made using a two-sided transparent structural adhesive tape.

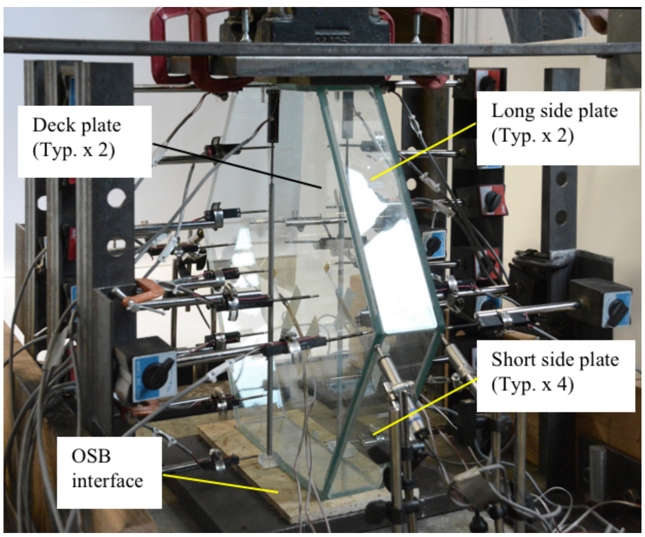

Figure 1 – Typical HGU in the test setup

The test matrix includes four HGUs, two each fabricated with 1 mm and 2 mm thick adhesive tape. All samples are dimensioned 64 cm on the long axis of symmetry, 51 cm on the short axis of symmetry, and are 10 cm in width. Glass plates are all 10 mm thick annealed float glass with geometric fabrication done using 5-axis abrasive water jet cutting. HGU assembly is accomplished using 3D printed truing clips and results in a rigid three-dimensional glass frame. Testing was done with the HGU oriented such that load was introduced on the short side edges of the two deck plates, resulting in an asymmetric load-support condition (Figure 1). A soft interface material was used between the HGU and steel plates of the hydraulic actuator and support, for the purpose of avoiding premature cracking from local stress concentrations on the glass edges at the load and support locations. Force was applied in displacement control at 0.25 mm/minute with a full array of displacement and strain sensors.

Test results for load vs. center deck plate transverse deflection are shown in Figure 2. All samples failed explosively by flexural buckling with no premature cracking on the load and support edges of the deck plates. Strain and deformation data clearly show the presence of second order behavior resulting from bending deformation perpendicular to the plane of the deck plates. In general, linear axial behavior transitions to nonlinear second order behavior, with increasing rates in deflection and strain growth ultimately ending in glass fracture on the tension surfaces of the buckled deck plates. Failure resulted in near complete disintegration of the deck plates, but with no observable cracking in any of the side plates and a secure connection on all adhesive tape. Results of the experimental program clearly demonstrate the feasibility of using HGUs for modular construction of compression dominant all-glass shell type structures. This method of construction can significantly reduce the self-weight of the structure and it will inspire the use of sustainable materials in the construction of efficient structures.

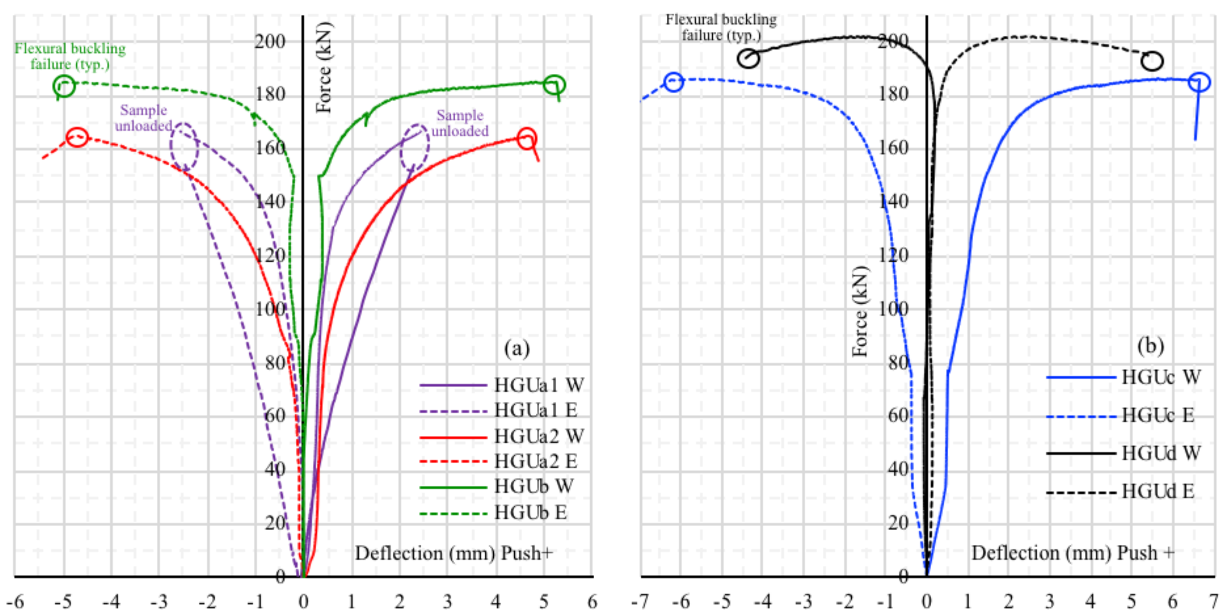

Figure 2 – Test results for axial load vs. center deck plate transverse deflection

References

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