Novel Approach for Strengthening Glass Joints Against Eccentric Loads and Dimensional Tolerances

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Introduction:

- Compared to other structural materials such as steel or timber, glass is a brittle material which means it cannot yield but its failure occurs suddenly and is hard to be predicted. It is for this reason that the most critical components of structural glass elements are the connections which can generate stress concentrations that could lead to premature failure of the glass.
- In order to meet the safety requirements, structural engineers are compelled to oversize the glass elements by 60 to 80% depending on the country, which implies higher production costs.
- Despite the generous allowance, glass is still susceptible to fail in extreme loading conditions such as blasts or earthquakes. Besides the material losses and the high costs of replacing the broken panes, the fallen glass possesses great hazard to the occupants and pedestrians around the building (Figure 1).

Figure 1: Damage of bolted connected façade elements in 2011 Christchurch earthquake New Zealand (Baird et al., 2012)

Aim and objectives:

- ➢ This research is aiming to investigate experimentally the effect of the Glass Fibre Reinforced Polymer (GFRP) reinforcement on the strength of **bolted glass joints**. To show that the method could **enhance the load capacity** of the reinforced samples and provide a more **ductile failure** compared to the reference samples.

- ✓ Effectively design an experiment setup to replicate glazing systems from current practice;
- ✓ Manufacture double-layered glass specimens with GFRP bonded between the glass panes in the joints areas;
- ✓ Perform tensile tests on both reference and reinforced specimens made of various types of glass (basic annealed, toughened, heat-strengthened and laminated), and collect data in order to quantify the method.

Methodology:

- The glass panes are 100 x 250 x 6 mm and have two 11 mm holes at both ends;
- Epoxy adhesive Araldite 2020 is used to bond the GFRP reinforcement around the holes in the area of influence of stress concentrations assumed two hole diameters (Figure 2);
- The tin side of the glass is identified and placed at the exterior of the specimen for reasons of consistency. Also, a scattered light polariscope is used to determine the residual stress of the glass function of depth (Table 1);

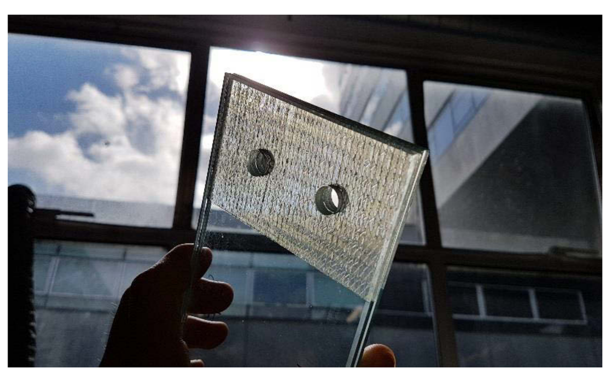


Figure 2: The reinforced specimen

Table 1: SCALP-05 stress values

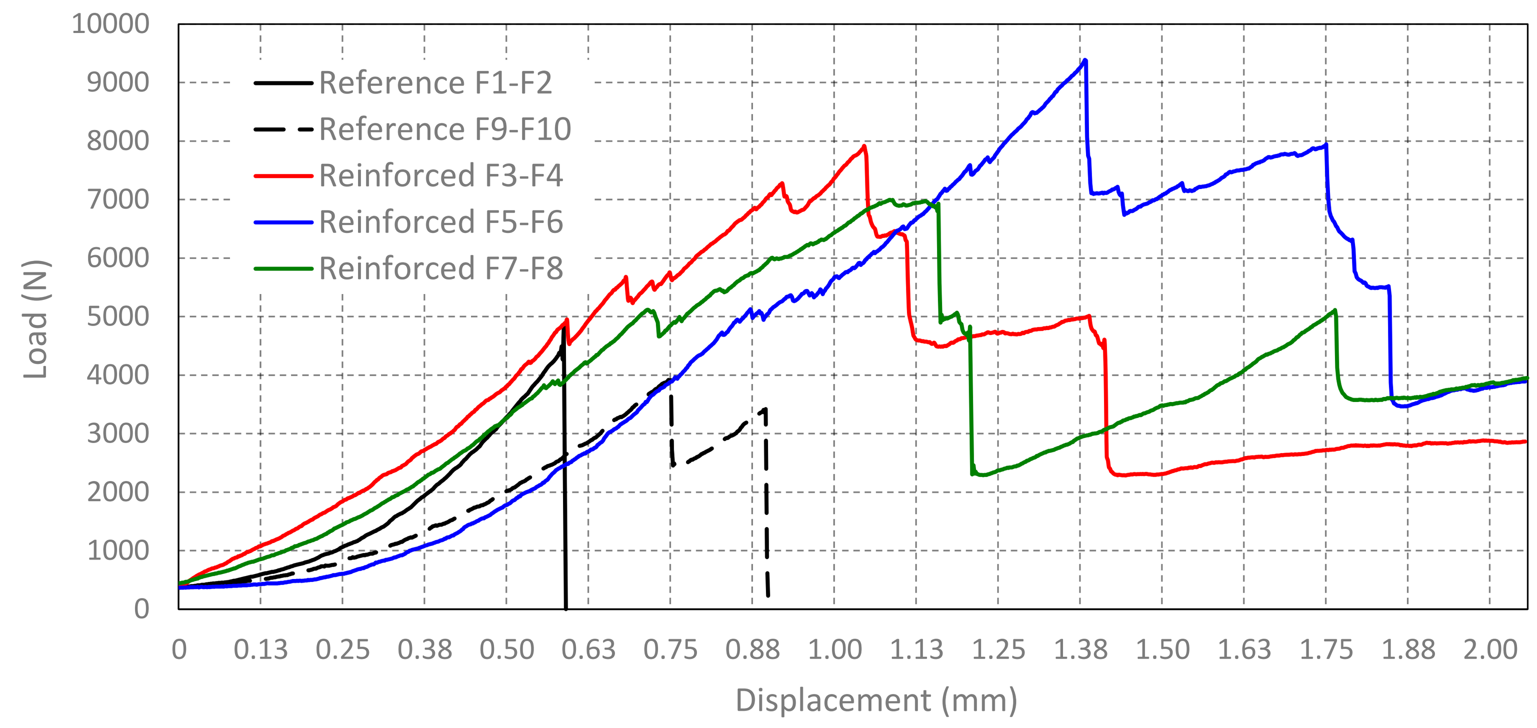
Glass type	Surface precompression
Float	~ 5 MPa
Toughened	85 ÷ 90 MPa
Heat-strengthened	30 ÷ 35 MPa

- EPDM rubber is used as bushing material between the glass and the M10 steel bolts;
- Aluminium pinned connections facilitate uniform distribution of tensile forces through the glass;
- A total of 13 specimens are tested using a servo-hydraulic machine applying a quasi-static load at a rate of 1 mm/min (Figure 3).

Figure 3: Experiment setup

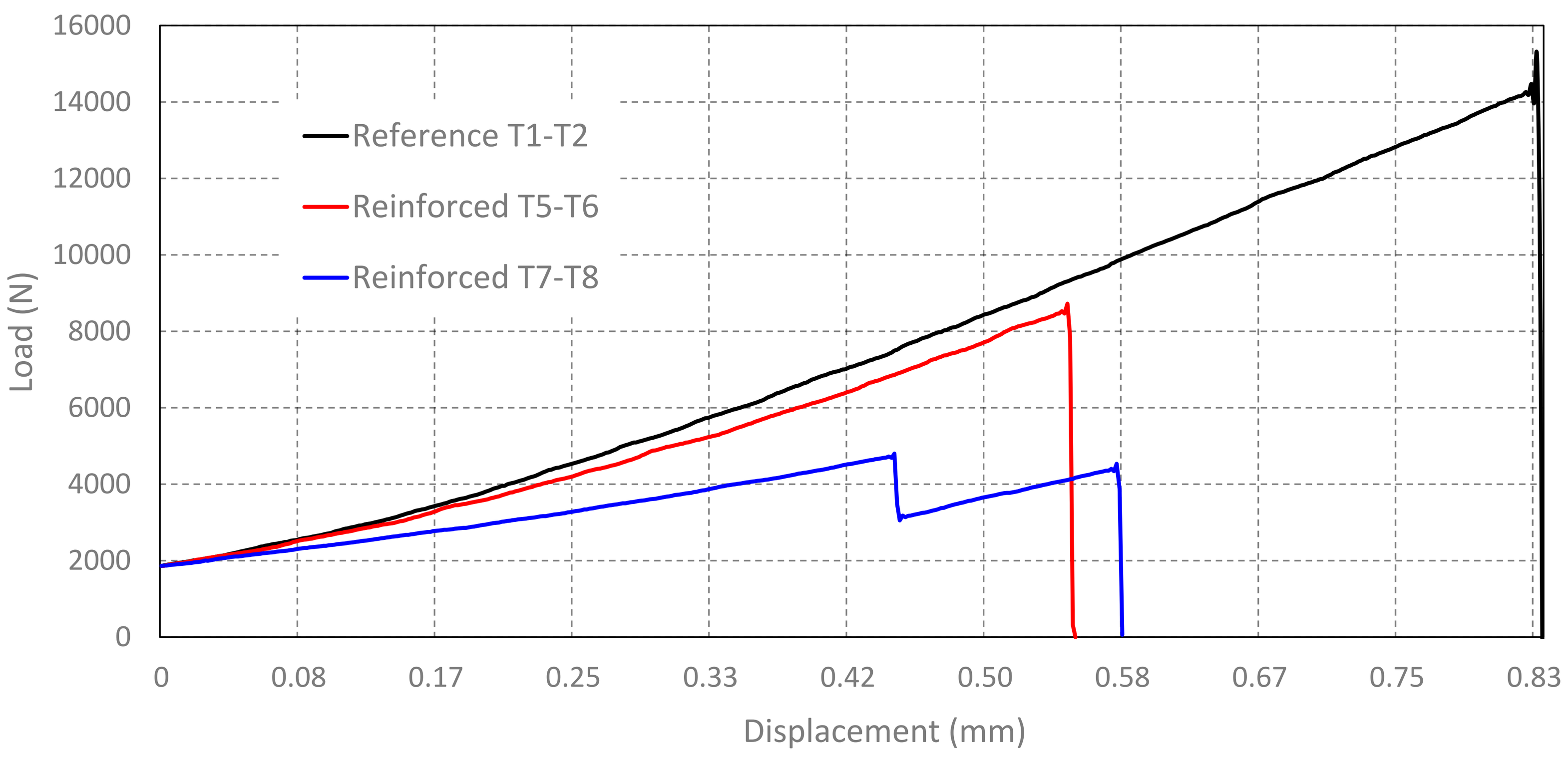
Results and discussion:

Basic annealed (float) glass specimens



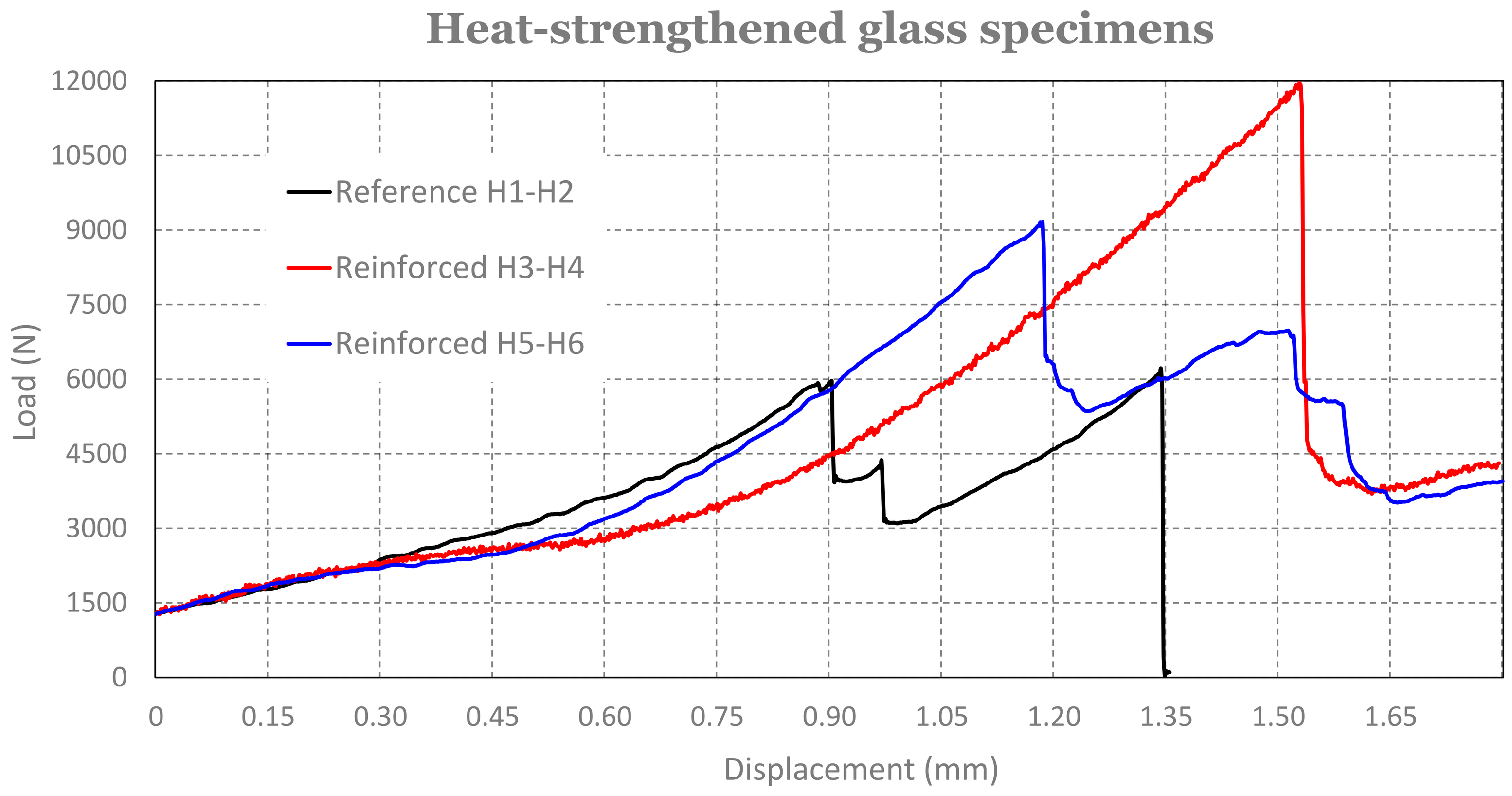
- The reinforced specimen F5-F6 has reached an ultimate breaking force two times higher than the reference specimen F1-F2;
- All reinforced samples presented post failure ductility;
- There was a residual strength of ~4 kN provided by the GFRP.

Toughened glass specimens



- The GFRP solution has decreased the ultimate strength of the reinforced specimen T5-T6 by 40 % compared to the reference sample;
- Due to the misalignment of the holes, sample T7-T8 was loaded eccentrically and failed one pane at a time at a lower load.

Heat-strengthened glass specimens



- The heat-strengthened glass was the most expensive and hard to find;
- Due to the change of the supplier, the precision of drilling the holes was less accurate, therefore H1-H2 and H5-H6 failed in two stages;
- The ultimate strength of H3-H4 was two times higher than H1-H2.

Conclusions and future work:

- ✓ The GFRP had enhanced the strength and provided a post-cracking ductility;
- ✓ The reinforcing method works better with basic annealed glass than with more expensive toughened glass, and provides ~4 kN residual strength;
- ➢ Perform cyclic tests to evaluate the fatigue of the connections, and bending tests to simulate extreme loading conditions (e.g. explosions);
- ➢ Employ finite element analysis tools to analyse the influence of stress concentrations around the joints, and to optimise the designs

Acknowledgements:

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References:

Baird, A., Palermo, A. and Pampanin, S. (2012) Facade damage assessment of concrete buildings in the 2011 Christchurch earthquake. Structural Concrete, 13 (1), 3-13.