GFRP-glass composite structures

A project to investigate the feasibility of composite components made of glass and glass fibre-reinforced polymer has recently been completed by the Glass & Façade Technology Research Group at the University of Cambridge, with the financial support of an Institution of Structural Engineers Research Award.

The combination of glass fibre-reinforced polymer (GFRP) pultrusions, toughened glass plates and high-stiffness adhesives provide structurally and thermally efficient building enclosures that outperform current curtain walling systems. The benefits in structural performance arise from the composite action between the GFRP and the glass plates via the stiff and strong adhesive, which produces a much stiffer cross-section and therefore a more-efficient use of materials.

The significant improvement in thermal performance is achieved by the relatively low thermal conductivity of the GFRP pultrusion that minimises thermal bridging across the glass plates. The durability and resistance to thermal cycling of the GFRP-glass composite components is also aided by the similar coefficients of thermal expansion of glass and GFRP. Such a system would be particularly useful in glazed façades, which have to meet increasingly stringent building regulations whilst meeting the architectural intent of lightness and transparency.

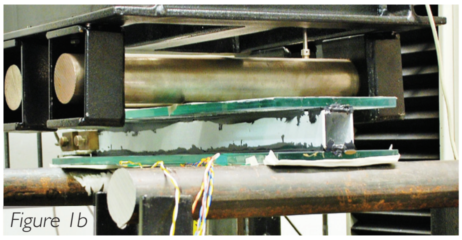
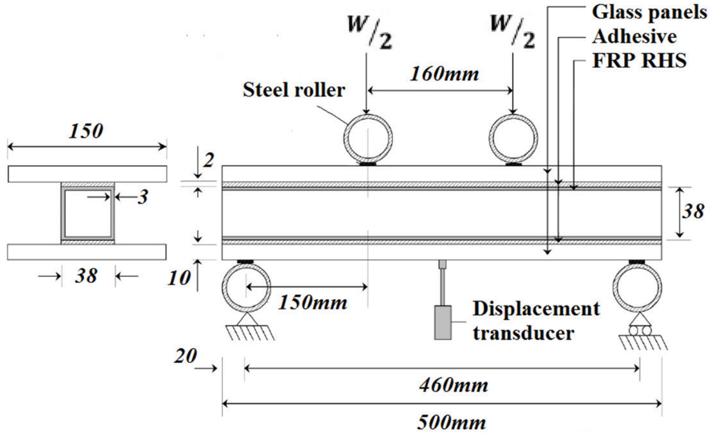


Figure 1b

The aim of the project at Cambridge was to assemble prototype GFRP-glass composite units and to evaluate their structural performance. Two rounds of experimental investigations were undertaken and were supported by analytical work.

In the first round of experimental investigations, candidate adhesives were identified and tested in single-lap-shear. The adhesives included epoxies, acrylates and silicones. By far the strongest and stiffest of the adhesives tested was a 2-part epoxy, to the extent that the fully toughened glass adherends consistently failed prior to the adhesive joint with a mean shear strength of 10.7MPa (mega-pascals). A more successful outcome was achieved by modifying the hardener-to-resin ratios of this 2-part epoxy. The best modifications produced a marginally more compliant joint, but a significantly improved shear strength at failure of 13.5MPa. A second candidate adhesive was also identified. This was a 2-part acrylate adhesive that produced a more compliant but weaker joint, with a mean shear strength of 1.69MPa.

Figure 1a



For the second round of experimental tests, a series of 500mm-long GFRP-glass composite beams were constructed using three options: the 2-part epoxy with modified hardener to resin ratio; the 2-part acrylic; and a layered beam, where a Polytetrafluoroethylene (PTFE) sliding joint was used in lieu of the adhesive (see Figure 1a). These beams were tested in 4-point bending (Figure 1b). In parallel, an analytical model was developed to predict the load-deflection response of the GFRP-glass composite beams. This model was set up to predict the full range of responses including monolithic behaviour (full composite action), layered behaviour (no composite action) and partially composite action as a function of the shear modulus of the adhesive used.

The test results showed that, as expected, both adhesively bonded beams had a higher stiffness and strength than the layered beam (Figure 2a). The beam with the 2-part modified epoxy adhesive out-performed the others, and exhibited more than twice the strength and more than 4 times the stiffness of the layered beam. The load bearing capacity of GFRP-glass composite beam could have been significantly higher as failure was governed by the longitudinal shear strength of the GFRP profile.

This analytical model showed very good agreement with the test results as it successfully predicted the stiffness of the GFRP-glass composite beams on the basis of the shear modulus of the adhesive. It was also found that unlike the layered beams (Figure 2b), the GFRP-glass composite beams showed a significant stiffness and strength (and were able to dissipate large amounts of strain energy) even after the glass plates had failed, indicating a high level of robustness.

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Figure 2a

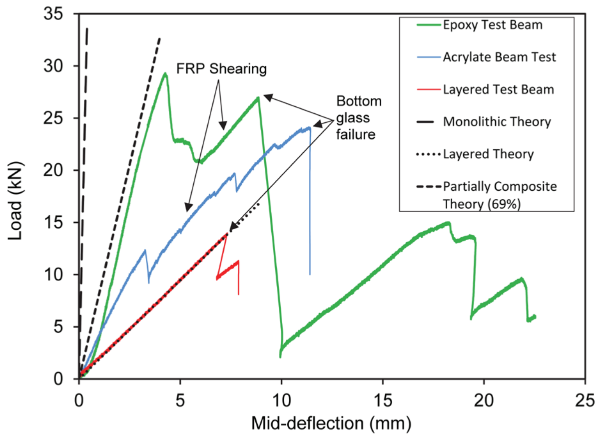

Figure 2b