gFT glass & façade technology research group

www.gft.eng.cam.ac.uk

UNIVERSITY OF CAMBRIDGE
Department of Engineering

The Glass and Façade Technology (gFT) Research Group provides solutions to real world challenges in the field of structural glass and façade engineering through fundamental and application-driven research.

Bi-annual Newsletter

Autumn/Winter 2014 Issue

Recent news

1 gFT and other European partners have secured EU funding for a new research network on Adaptive Façades. The aim of the network is to bring together academia and industry in order to share research and expertise on adaptive, dynamic and responsive façades. Dr Overend was appointed as vice-chair of the network. The first technical meeting will be held in March 2015 in Prague.

2 gFT welcomes two new members: PhD student Jacobo Montali and MPhil student Hanxiao Cui. Jacobo's research will focus on the environmental performance of novel facades whereas Hanxiao's MPhil is based on whole-life value analysis and its application to active vacuum - insulated facades.

3 gFT has secured funding from the EPSRC Bright Ideas call for a 2 – year research project on FRP - Glass composites. Funding has also been secured in collaboration with façade design consultancy Newtechnic from Innovate UK for research and development on composite free form facades.

4 The new gFT website was launched a few days ago. Please visit www.gft.eng.cam.ac.uk for further information on the group's news, research updates, publications and online resources.

5 The fourth Engineered Skins symposium was successfully organised by gFT on the 11th of September 2014 in Cambridge. gFT members presented their latest work alongside two keynote presentations by Lothar Wondraczek of the University of Jena and Ed Forwood of ARUP.

Cold bending distortion in monolithic glass

Cold bending is an effective and relatively inexpensive way of creating double curved glass surfaces that are required in modern architectural applications. Recent investigations at the gFT group, supported by EPSRC and Eckersley o' Callaghan, showed that a change in the deformation mode occurs during the shaping process of rectangular glass plates.

The cold bending method used, comprises the application of an out of plane load on one corner of the plate in order to create the desired curved shape (Fig. 1). To analyse this phenomenon, finite element analysis validated by experimental testing was undertaken. Alternative support conditions at the three corners of the glass plate were investigated.

Experimental and numerical results showed that by preventing in-plane translation at two opposite corners of the plate, a change in the deformation mode occurs comprising two phenomena under increasing applied displacement (Fig 2). Initially, the centre of the plate snaps in the opposite direction as the supported diagonal becomes stiffer confining significant vertical deflection to the loaded diagonal. This phenomenon is followed by the appearance of rippling along the length of the supported diagonal.

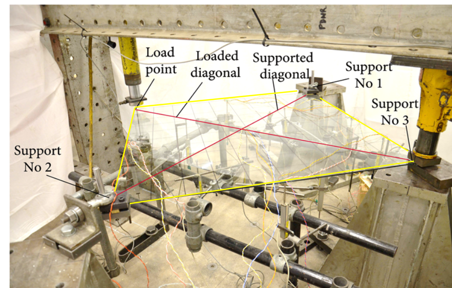


Fig. 1: Test set up.

The occurrence of the ripple is attributed to local buckling and can be referred to as "cold bending distortion". The amplitude of the ripple may exceed 0.5 mm which exceeds the maximum allowable roller wave distortion of thermally toughened glass set in EN 12150-1:2000. The occurrence of the "cold bending distortion" does not indicate fracture of the panel but can be interpreted as a serviceability limit which if exceeded would have a negative effect on the optical quality of the cold bent panel and cause unwanted visual distortions.

In addition to translational restraints, the influence of different rotational restraints on the ripple amplitude were also investigated (Fig 3). This shows that allowing rotation at the corners of the plate the amplitude of the ripple reduces.

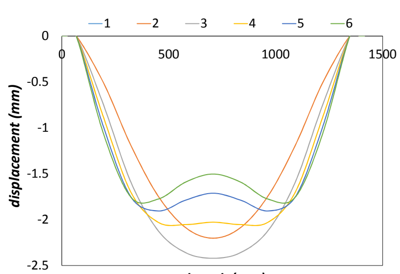


Fig. 2: Shape of the supported diagonal in consecutive steps during the

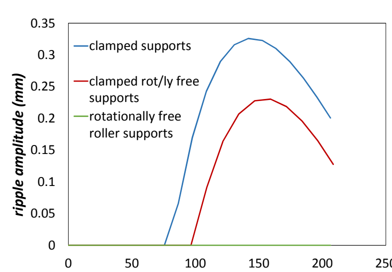


Fig. 3: Effect of the boundary conditions on the ripple amplitude.

Promising results from GFRP – Glass tests

A project to investigate the feasibility of GFRP-glass composite components has recently been completed by gFT with the financial support of an IStructE Research Award.

The combination of glass fibre-reinforced polymer (GFRP) pultrusions, toughened glass plates and high-stiffness adhesives could provide structurally and thermally efficient building envelopes that outperform current curtain walling systems. The aim of this project was to assess the benefits in structural performance arising from the composite action between the GFRP and the glass plates via the stiff and strong adhesive. Two phases of experimental investigations were undertaken and were supported by analytical work.

In the first phase the performance of candidate GFRP-Glass adhesives was assessed by single-lap shear tests. A 2-part epoxy was found to be the most promising and further improvements were achieved by modifying the hardener-to-resin ratios of the epoxy leading to a lap-shear strength of 13.50 MPa. A weaker but more compliant 2-part acrylic adhesive was also identified. The second phase consisted of experimental tests on 3 versions of 500mm long GRRP-glass beams using: the modified 2-part epoxy; the 2-part acrylic; or a layered beam with no composite action. All beams were tested in 4-point bending (Fig. 4). In parallel an analytical model was developed to predict the load - deflection responses.

The test results (Fig. 5) showed that the beam with the 2-part modified epoxy adhesive exhibited more than twice the strength and more than 4 times the stiffness of the layered beam. The analytical model showed very good agreement with the test results as it successfully predicted the stiffness of the GFRP-glass composite beams (Fig. 5), the GFRP-glass composite beams showed a significant level of robustness after glass fracture.

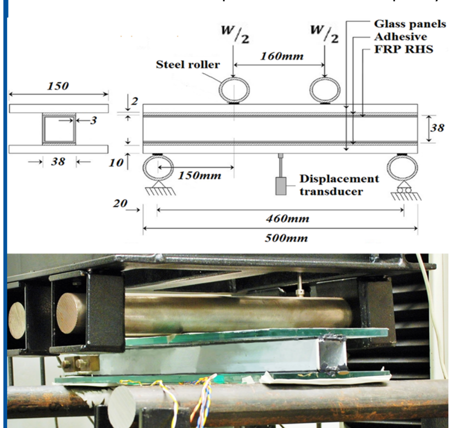


Fig. 4 : Four-point bending set up.

gFT have recently secured EPSRC funding to continue this research on FRP-Glass composite structures, starting in early 2015.

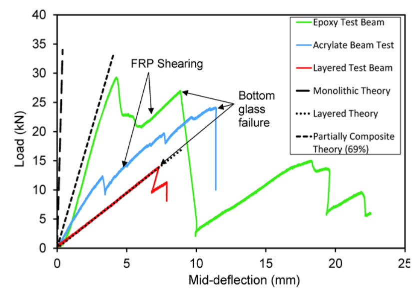


Fig. 5: Test results.

The effect of ground and polished edges on CTG strength

The effect of different edge treatments and in particular grinding and polishing on chemically toughened glass (CTG) specimens was investigated experimentally at gFT by visiting student Isabelle Paparo supported by the Friedrich – Elbert Foudnation and Trend Marine. Specimens of different thickness (6, 12, 19 mm) featuring the two different edge treatments were tested to failure on a 4-point bending set-up. Prior to testing, the stress profile in the CTG was obtained with a scattered light polariscope and the flaw density and severity were evaluated using an optical microscope.

Testing was performed in inert conditions using a perspex box filled with dry nitrogen gas to prevent subcritical crack growth (Fig. 6).

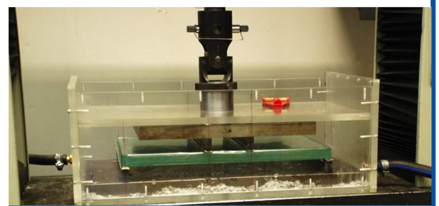


Fig. 6: Four point bending test performed in inert conditions

Test results showed that edge polishing leads to higher failure stress. However, the beneficial effect of polishing is diminished with increasing glass thickness. (Fig. 7).

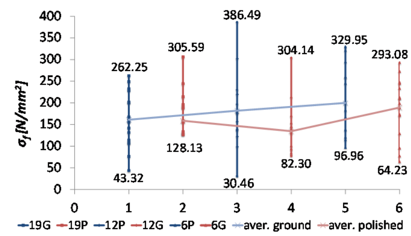
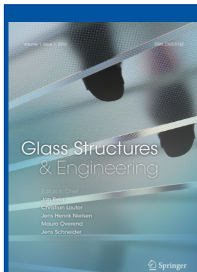


Fig. 7: Stress at failure for each series of 6, 12 and 19 mm for polished and ground edges.

Most of the specimens failed unexpectedly at lower stress values than those of the surface residual stress measured with the SCALP. This implies that the flaw size is in the order of or larger than the depth of pre-compression.

Furthermore, a general relationship could not be established between the observed density and severity of flaws and the stress at failure, suggesting that an optical microscope cannot be deemed accurate enough for flaw detection.

Further post-failure investigation is needed to verify this premature failure and to identify possible ways to improve the performance of CTG edges.



New Journal

The new Springer journal ***Glass Structures & Engineering*** has been launched. This high-level scientific journal addresses all aspects of structural glass research and applications. The journal is now open for submissions and contributions are welcomed from researchers as well as practicing experts.

More information is available at the journal website: www.springer.com/engineering/civil+engineering/journal/40940