gFT glass & façade technology research group
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UNIVERSITY OF CAMBRIDGE
Department of Engineering

The Glass & 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

Spring / Summer 2012 Issue

Recent News

1 On 18th April the IStructE Study Group on Façades and Structural Use of Glass held its biannual meeting. The members discussed the update of the 2nd ed. of *Structural Use of Glass in Buildings* and the implementation of an online research database.

2 gFT is hosting Belarmino Cordero who is on a six month academic visit. Belarmino, an Architect interested in construction technology and environmental design, is studying for his PhD on a High Performance Integrated Frame Unitised Curtain Wall System while working part-time at Buro Happold. During his stay at gFT he will develop system options through iterative numerical and sensitivity analysis.

3 On 9th and 10th February the gFT successfully hosted an Integrated Task group meeting for Working Group 4 of the European research network on structural glass. The meeting was attended by 22 delegates from across Europe and the focus was to finalise the Education Pack.

4 gFT member James Watson won a prize for his oral presentation entitled ‘Novel glass-metal and glass-glass structural joints for architectural applications’ at this year’s IStructE Young Researcher’s Conference held in March 2012. The prize was presented by IStructE Chief Executive Martin Powell.

(a) (b) (c) (d)

Figure 1: 100x and 25x magnified microscopy images showing: (a) sc specimen after indentation (b) sc specimen after grinding (c) sc specimen (cross section) after failure (d) vb specimen (cross section) after failure

Glass for outer space

A study aimed at developing the capability and know-how in Europe for appraising manned spacecraft windows is currently being undertaken by the gFT research group. Several candidate materials, including Aluminosilicate, Borosilicate, Fused Silica, Gorilla Glass, Magnesium Fluoride, Sapphire and Zerodur were identified from which Fused Silica and Aluminosilicate have been chosen for testing. This work has been commissioned by Magna Parva and The European Space Agency.
The program involves experimental investigation for static strength, inert strength, equibiaxial static strength, sub-critical crack growth and fracture toughness. The latter conforms to the ASTM C1421-01b standard, which suggests three different methods: (i) The pre-cracked beam method (pb) which involves creating a pre-crack through a bridge compression fixture followed by a Vicker’s indentation. Some procedural adjustments have been made to this method. (ii) The surface crack method (sc) is also a twofold process: a Knoop indentation is created (fig 1a) followed by grinding (fig 1b) to remove residual stress caused by the indentation and (iii) The chevron notch (vb) which is an indentation performed with a 0,2 mm thick diamond blade. The sc and vb preparation has been made with the assistance of IPM in Brno, Czech Republic. Once prepared, the specimens were subjected to 4PB tests. Fractography was used to analyse crack propagation (Fig 1c, d). The data obtained varied considerably with the test method and differed slightly from the 0.75 MPa $m^{0.5}$ generally used for soda lime glass. Detailed analysis of the test results is currently underway in order to identify the most suitable material. There are plans to undertake further investigations at the gFT including the testing of large glass specimens.

The strength of broken glass

Glass is inherently brittle, consequently failure occurs without warning and is difficult to predict. Monolithic glass provides no redundancy; therefore failure can result in complete loss of load bearing capacity.
Redundancy can be provided by laminating glass layers with a polymer interlayer. Upon fracture, glass fragments are held together by the interlayer, which provides residual tensile capacity. Under applied bending, glass shards interlock and are able to transmit compressive strains across fractures. To date, this post-fracture performance has been quantified by destructive testing on a project-by-project basis.

A method of calculating the post-fracture performance is required. The post-fracture behaviour is predominantly influenced by two phenomena: deformation of the interlayer, and glass-polymer adhesion. Through-crack tension (TCT) tests have been performed (fig 2) to investigate both properties under a tensile load.

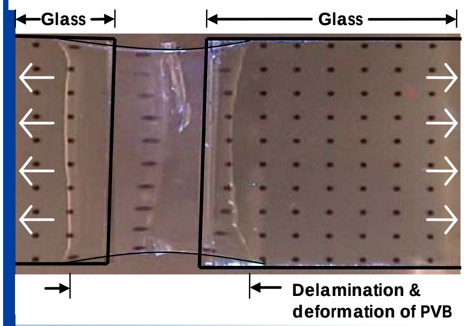

Figure 2: Deformed TCT sample with dotted interlayer grid

The samples were constructed of two 6mm layers of glass laminated with a Polyvinyl Butyral (PVB) interlayer. TCT tests simulate a single crack within a fractured laminated plate.

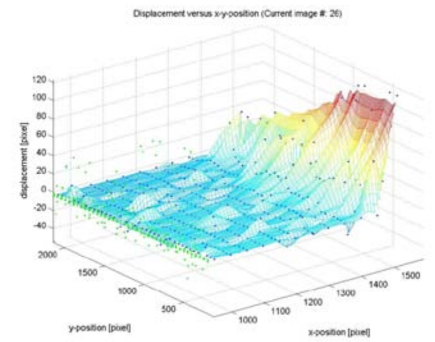

Figure 3: Digital Image Correlation: displacement of interlayer grid points

A pre-defined fracture was produced in each glass layer.Increasing applied displacement causes delamination and viscoelastic deformation of the interlayer.

During the TCT tests, images were captured and analysed using Digital Image Correlation (DIC). DIC tracks the movement of grid points on the interlayer in order to determine strain profile (fig 3).

The work done in extending the TCT sample can be equated to the sum of energies dissipated during delamination, and through deformation of the interlayer. The viscoelastic properties of PVB, and the strain profile determined using DIC were used to determine the strain energy in the interlayer and accordingly the glass-PVB interfacial adhesion. This knowledge of interlayer deformation properties and interfacial adhesion is essential for predicting post-fracture behaviour of more complex fracture patterns. This project is funded by EPSRC and supported by Interpane Glas Industrie AG.

Which façade?

The computational system developed at gFT for the multi-objective optimisation of façades was recently deployed on a real-world refacing project and has successfully identified optimal façade configurations. The system was used during the initial design phase of the renovation of the Inglis building in the Department of Engineering, University of Cambridge. The Inglis Building was constructed in 1945. It is a five-story steel-framed building with reinforced concrete floors. The façade earmarked for refurbishment is facing north and west (fig 4) and encompasses the mezzanine floor, the first and the second floor. It was constructed in 1964. The objective of this project was to identify an optimal façade solution that (i) reduces the carbon emission of the building; (ii) is economically viable; (iii) improves occupant comfort.

In-situ measurements were carried out to provide the basis for validating the building energy simulation model. A preliminary computational simulation of several renovation strategies was performed to identify generic façade options with the largest improvement potential.

Finally, a whole-life value based multi-objective optimisation approach was deployed to devise the optimal façade in terms of the three design objectives.

The optimal façade solution for the north façade (fig 5) has a window-to-wall (WWR) ratio of 50% with double glazing units (g-value = 62%, U-value =1.1 W/m^{2}K, visible transmittance = 80%) and thermally broken aluminium framing systems (U-value=2.8W/m^{2}K). Whereas the optimal façade solution for the west façade has a WWR of 50% with double glazing units (g-value = 30%, U-value =0.7 W/m^{2}K, visible transmittance = 54%) and thermally broken aluminium framing systems (U-value =2.8W/m^{2}K). Insulation on the opaque walls and the floors which are exposed to the external environment are also required.

These optimal façades result in a carbon payback period of 22 years and cash payback period of 27 years for the north orientation and a carbon payback period of 7.5 years and cash payback period of 13 years for the west orientation. Both façades significantly improve the indoor environment quality of the offices behind them.

The project was undertaken by Qian Jin, supervised by Dr Mauro Overend. A more detailed summary is included in a report which is available upon request.

Figure 4: Photographs of the Inglis north façade

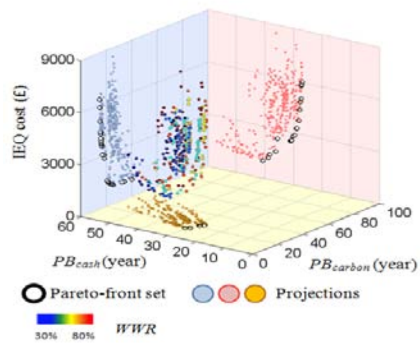

Figure 5: Optimasation result for the north façade

For further information on our research activities please visit www.gft.eu.com or contact: info@gft.eu.com.
The gFT research team has produced ten research publications since January 2011. These and previous publications may be accessed at www.gft.eu.com/04_our_publications