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

Autumn/Winter 2013 Issue

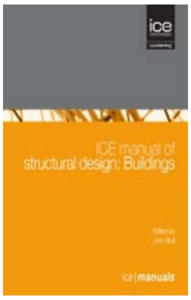
Recent News

1 This year, gFT welcomes a new PhD student Fabio Favoino. His research will focus on smart/responsive façades and is funded by EPSRC and Wintech Ltd. Meanwhile, last year the group hosted two visiting PhD students. Daniel Honfi from Lund University, stayed for two weeks on a COST Action (TU0905) funded scientific mission to investigate robustness of glass structures. Benedetta Marradi from the University of Pisa, visited for three months and mapped the design and construction processes in façade renovations.

2 A PhD studentship is available at the Glass and Facade Technology Research Group to explore and develop multi-layered high performance glass units for buildings. For more information visit our website.

3 gFT successfully organised the 3rd Engineered Skins symposium on 6 September 2012, at the University of Cambridge. Members of the gFT group presented their latest work alongside two keynote presentations by Mikkel Kragh of Dow Corning and Jonathan Watts and Peter Winslow of Hopkins Architects and Expedition Engineering respectively.

4 The Institution of Civil Engineers has published a manual that covers a wide range of structural materials and addresses key structural design topics. The manual includes a chapter on structural glass authored by Dr Mauro Overend.



The chapter includes guidelines on performance requirements, prototype testing, mechanical properties and limit state design for glass components.

Hybrid laminated glass units

The exceptional durability of chemically strengthened glass makes it attractive for use in façade and structural glazing systems. Corning Incorporated has developed a chemically strengthened glass product, Corning® Gorilla® Glass, with a surface precompression in the order of 800MPa. At present, this glass is used in electronic display protection applications such as laptops, optical components and smart phones.
The potential use of Corning® Gorilla® Glass in façade and structural glazing systems is being explored by Eckersley O'Callaghan in collaboration with the gFT research group.
Four-point bending tests and co-axial double ring tests (Fig 1a) aimed at investigating the post- fracture performance of hybrid chemically strengthened glass have been undertaken at the University of Cambridge. Samples consisting of combinations of chemically strengthened (CT), annealed (AN), heat strengthened (HS) and fully strengthened (FT) glass laminated with different interlayers were tested. Fig 1b and Fig 1c show that laminated units of chemically strengthened glass-PVB-annealed glass combinations exhibit the highest proportion of post-fracture strength (residual strength after first fracture). Laminated units with chemically toughened glass-SGP-fully strengthened glass combinations show the highest magnitude of strength to first fracture, but exhibited a modest post-fracture reserve. The work also includes tests on units constructed from transparent polymer materials in lieu of glass. Further analytical and numerical work is underway to characterise the post-fracture behaviour of these laminated units. Detailed findings from this project will be reported in a forthcoming journal publication.

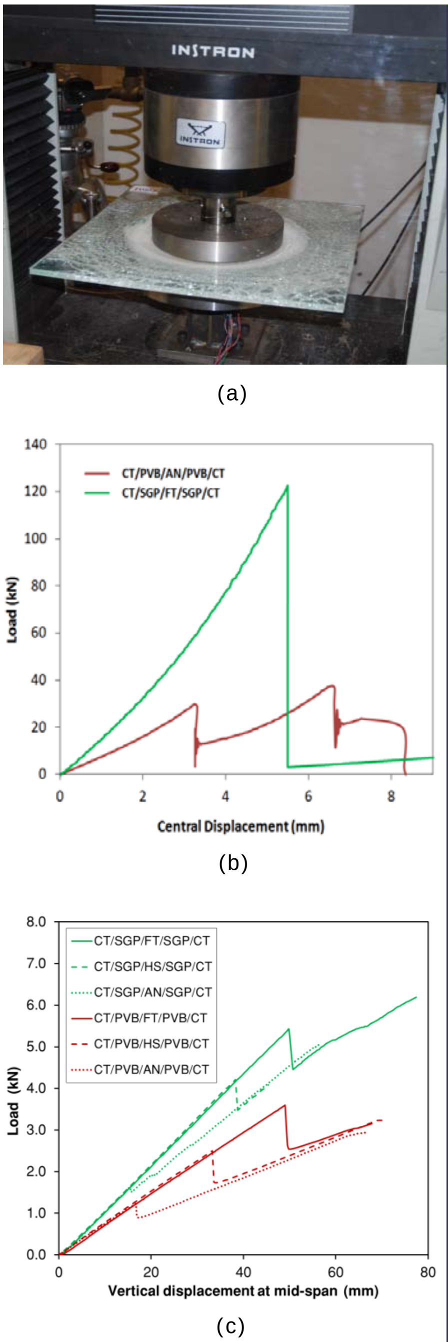


Figure 1: (a) Image of a coaxial double ring test, (b) Load versus central displacement plots for the coaxial double ring test and (c) Load vs. displacement plots for the four-point bending test

Façade renovation process mapping

A process map for the refurbishment of glazed façades has been developed at the gFT, extending the existing gFT process map for the design and construction of new façades.
The map uses BuildingSMART's adaptation of Business Process Map Notation and has been constructed using the information collected from interviews with selected architects, engineers, industry experts. The project was undertaken by Benedetta Marradi, a visiting PhD researcher and gFT PhD student Eleanor Voss.
Renovation of façades involves geometric, aesthetic, structural and thermal complexities that are often difficult to manage during the whole development of a project.
In other sectors, process mapping has been used successfully to manage complex processes by identifying roles, responsibilities, process constraints and requirements. The aim of the project was to identify possible weaknesses in the existing process and propose improvements.
The initial phase of the project has successfully identified the different renovation project classes. The classification system considers issues such as the historical importance of the envelope and the extent of the renovation. Following this, a review of significant renovation projects has been used to create a database of the main renovation approaches and the related technical options. Through interviews with industry experts, tasks specific to façade renovation projects have been incorporated into the façade and design construction process map. Two stages of the process have been included and analysed in more depth: (a) the assessment of the performance of the existing façade and (b) the design work to improve the performance.
The updated master map can be used to identify the façade related roles and responsibilities for both new-built and façade renovation projects.
The map can provide the basis for the development of support tools, to aid the efficient storage, access, transfer and use of design information.

Steel-glass connections

As part of the ongoing research into novel steel-glass connections an initial investigation was carried out into the feasibility of creating discrete bonds with a structural interlayer. Two products were selected based on industrial experience as well as using strength and maximum elongation at failure. The products selected were Dupont's SentryGlas Plus (ionomer) and Huntsman's Krystalflex PE399 (polyurethane).
The single-lap shear geometry previously used at the University of Cambridge for adhesives testing was used again to allow direct comparison with previously tested pot adhesives. Both products required cycles in an autoclave to achieve successful curing. A system was devised to constrain the flow of the adhesive whilst ensuring that the bond/adhesion with the interlayer was not compromised.
A typical bond can be seen in Fig 2a.
Tests were performed using an Instron 5500R electromechanical testing machine and the crosshead displacement rate was set as 0.2mm/minute. Five samples of each interlayer were tested. The Krystalflex samples all failed at comparatively low loads (mean 3.78MPa) through adhesion at the steel-interlayer interface despite demonstrating excellent adhesion to the glass. The SentryGlas specimens failed through glass failure (Figure 2b) at much higher loads (mean 16.47MPa) comparable to the best performing pot-adhesives.
The SentryGlas has been carried forward to the next phase of the testing where the long-term strength (under static and dynamic loads) is being investigated alongside the pot adhesives. However, the Krystalflex did not demonstrate sufficient adhesion to the steel, which could potentially be improved with a suitable primer, but will not be considered further in this project.

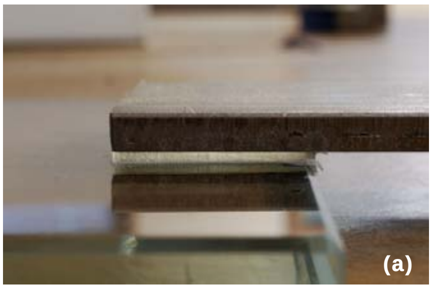


Fig 2: (a) steel-glass adhesive bond (b) glass failure on a SentryGlas specimen

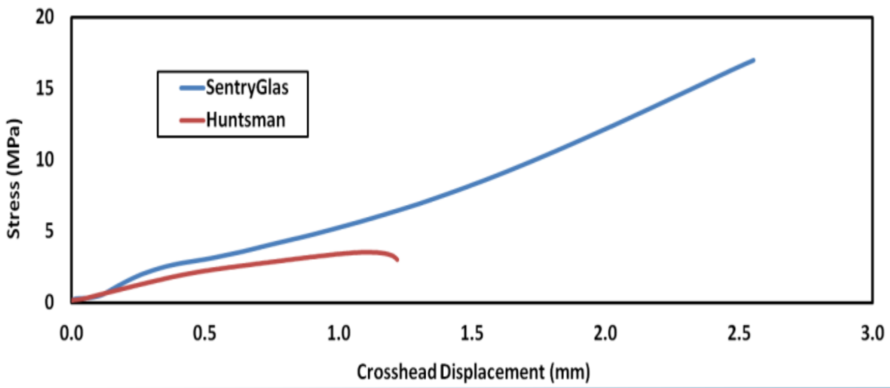


Figure 2: (c) Load vs. displacement plots for Dupont's SentryGlas and Huntsman's Krystalfex single-lap shear specimens

Publication Focus

- **What is the relative performance of bolted and adhesive connections in glass structures and are simplified sizing calculations accurate?** *gFT's latest paper in the ASCE Journal of Structural Engineering has some answers.*
- **Which design variables have the largest influence on façade performance?** *A numerical sensitivity analysis on open plan and cellular office buildings in different geographical locations has recently been completed by Qian Jin. The resulting sensitivity coefficient charts are due to be published shortly.*

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