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 2011 Issue***

Recent News

1 The research on the energy performance of retail units by means of wireless sensors has attracted extensive media coverage including The Telegraph, The Guardian and ITV. Further information about the research undertaken by Murat Basarir can be found on the gFT website (www.gft.eu.com).

2 The website of the European Research Network on Structural Glass was officially launched (www.glassnetwork.org). The website is designed and administered by gFT.

3 The Glass & Façade Technology Group hosted Michal Netusil a Ph.D student from the Czech Technical University of Prague. Michal is continuing his collaboration with gFT on steel-glass composite beams. A joint publication on this topic is scheduled for summer 2011.

4 The gFT group welcomes a new research student Caroline Butchart. Her work will focus on characterising the post-fracture performance of laminated glass, with the aim of reducing the need for costly project-specific testing during the design process.

5 gFT successfully organised the first Engineered Skins research symposium on 3 September 2010, at the University of Cambridge. It was the first conference hosted by the group since it was first established. 46 external industrial and academic partners from across Europe attended the event, and participated in lively discussions after every presentation.

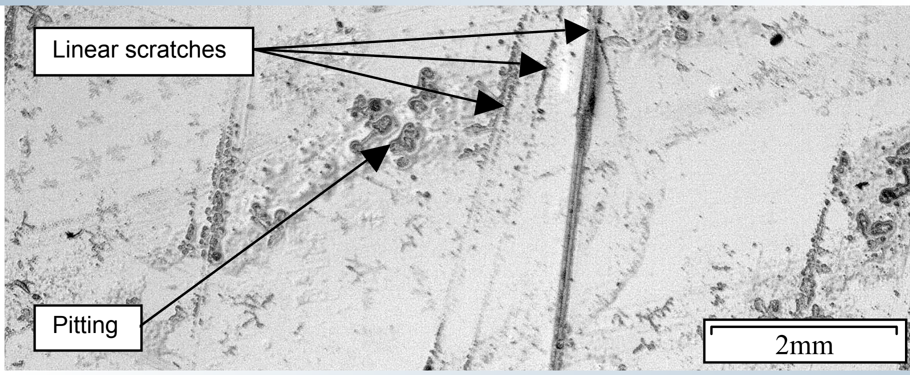

Figure 1: Micrograph of 20-year old window glass

An Algorithm for Predicting the Strength of Glass

Glass is often described as an 'unpredictable' material. There is some truth in this description which stems from the interaction of surface flaws and the molecular structure of glass. Like other materials, glass is prone to surface damage or flaws that result from manufacture and handling. These flaws accumulate from natural weathering or man-made scratching during service-life(Fig. 1). Unlike most other construction materials the amorphous molecular structure of glass lacks slip planes or dislocations that allow the material to redistribute stress concentrations. Glass therefore fractures when the stress peaks at the flaw tips exceed the molecular strength. This makes the strength of glass very sensitive to surface flaws, and since the severity and location of the flaws are unknown it is difficult to predict the strength of glass.

The recent generation of methods for determining the strength of glass design are therefore stochastic. They are accurate, but unattractive for manual computation.

A numerical algorithm and an improved glass strength model have been developed at gFT. The algorithm automatically computes the tensile strength of float glass by summating the contributions of all surface stresses to the probability of failure of the glass specimens.

The process is automated and involves a piecewise summation of the surface stresses obtained from conventional finite element analysis. Recent experimental validation and sensitivity analyses have shown that the proposed material model and computer algorithm provide an accurate and efficient means of determining the strength of glass specimens. The numerical algorithm is described in detail in a research paper by Mauro Overend and Kenneth Zammit due to be published in the journal Construction and Building Materials.

Multi-objective Design Optimization of Facades

During the whole life of a commercial building located in central London, the cost of operating the business in the building is 15 times the cost of construction, and 10 times the cost of maintaining and operating the building. A higher initial expenditure on facades could generate a more comfortable working environment for the occupants, and thereby improve the occupant productivity and the net economic gain. The lack of reliable systematic methods for determining the true whole life value of a given façade solution is a major barrier in this regard, and leads to sub-optimal façade solutions.

Qian Jin's research at gFT focuses on developing a whole-life value based multi-objective optimisation model for high-performance façade design by considering social values, economic value, and environmental value. She populated a comprehensive list of aspects that should be considered during the façade design process. All the aspects were grouped to form three main objectives, i.e., social value, economic value, and environmental value, which can be evaluated independently using 3rd party software and specially-developed MATLAB scripts. So far a multi-objective optimisation model has been constructed to optimise the design of a glazed façade, in terms of the three objectives.

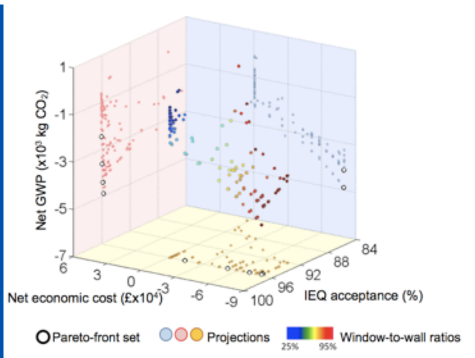

Figure 2: Optimisation result from NSGA-II

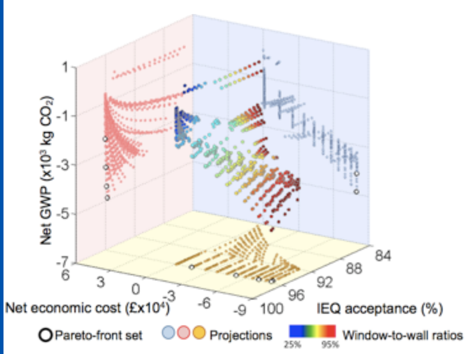

Figure 3: Optimisation result from exhaustive search

The principal outcome of this research is a whole-life value optimisation model for early-stage façade design. The multi-objective optimisation technique coupled with other 3rd party software provide façade designers with an integrated design tool for identifying optimal façade solutions. This is particularly useful in the early design stages, when design decisions have a large impact on the end result, but are difficult or too numerous to quantify. The project is funded by Cambridge Overseas Trust and

Altitude and Thermally Induced Stresses on Insulating Glazing Units (IGUs)

Bolted IGUs are increasingly being used in glazing systems because of their high thermal performance and their aesthetic appeal. It is however unclear how the combined actions of: (i) self-weight, (ii) indoor/outdoor temperature difference and (iii) altitude difference between production and installation of IGUs affect the critical stress concentrations around bolt holes.

To this end, the gFT Research Group undertook a parametric analysis of IGUs based on a real-world case study. The IGUs were numerically modelled and subjected to self-weight, pressure loads resulting from typical changes in altitude ($p_{H;0}$) and pressure due to differences in building interior/ exterior temperatures (ΔP_T) as shown in Figure 4.

The European Draft Standard prEN 13474-3:2007 was used to calculate the altitude isochore pressure and a MATLAB script was developed to determine the combined heat transfer (radiation, convection and conduction) through the IGUs. The script was validated with the WINDOW 6.3 software that calculates total thermal performance values.

It was found that the internal glass plates generally experienced

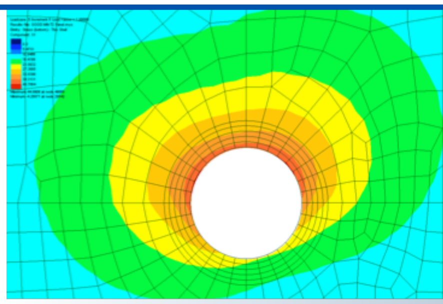
Figure 5: FE model showing principal stress contours around the bolt hole of the internal glass panel for an external/internal temp of -40/20 °C and altitude pressure of $5.2X10^{-4}$ MPa plus self-weight. σ_1 = 44.99 MPa

higher stress peaks when compared to the middle and external glass plates.

Geometric nonlinear 2D Finite Element models of the internal glass of the IGUs were therefore constructed and analysed. Results showed that the maximum principle stresses were always located on the upper quadrants of the bolt holes as shown in Figure 5.

The study showed that when IGUs are installed at an altitude higher than the point of production, pressure loads due to indoor/ outdoor temperature difference tend to oppose altitude pressure and therefore alleviate the net pressure on the internal glass of the units. As a consequence, the application of the worst pressure combination results in a stress peak of 58MPa which is significantly below the fracture strength of the toughened glass used in these applications. Currently, the models are being extended to incorporate the effects of wind loads.

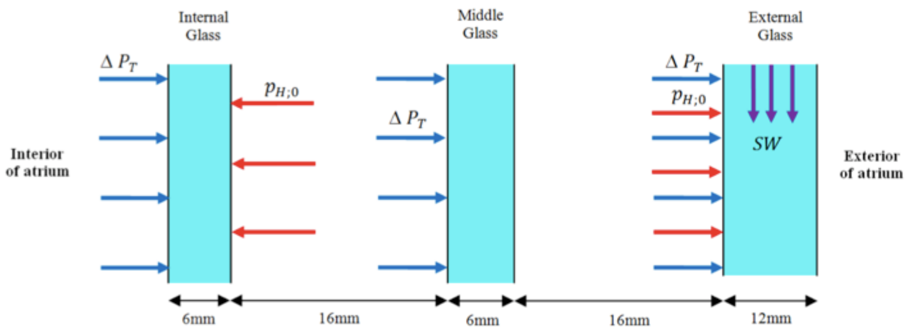

Figure 4: Schematic drawing of the studied triple glazing unit with arrows showing the distribution of pressure loads and self-weight on the IGU

For further information on research activities please contact: info@gft.eu.com

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