gFT glass & façade technology research group

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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 Research Newsletter Summer 2017

Recent news

1 Members of the gFT group led by Dr. Overend were invited to present their research at Ecobuild 2017 in London. The presentations included the cold bent glass research by Kyriaki Corinna Datsiou, the FRP facade panel samples by Isabelle Paparo and the GRC connections by Marco Donà.

2 Dr Mauro Overend was elected to the College of Fellows of the US-based Facade Tectonics Institute. His election was officially announced at the FTI World Congress in Los Angeles held on the 10-11th October. The fellowship is the highest award bestowed by the Institute and is a lifetime honour. Dr Overend will serve as a permanent member of the Institute.

3 The gFT research group recently hosted a two day workshop exploring common research interests with the Facade Research Group "FRG" of TU Delft. This workshop helped to identify areas of common interest and future collaboration

4 Mark Allen and Alessandra Luna Navarro have joined the gFT research group in Autumn 2016. Mark joins after completing an MRes in the CDT "Future and Infrastructure and Built environment" programme at Cambridge and Alessandra joins after completing an MPhil in Energy Technologies of Cambridge.

Artificial ageing of glass with sand abrasion

The strength of glass is governed by the condition of its surface which deteriorates progressively as surface flaws accumulate on exposure to weathering action during its service life. Therefore, knowledge of the strength of naturally aged glass is crucial in order to ensure its safe use in load-bearing applications. Artificial ageing tests (e.g. DIN 52348) can be very useful in this regard, but they have traditionally focused on degradation in light transmission properties rather than the strength of glass.

Experimental testing has been undertaken in the gFT group, to investigate the effectiveness of a falling abrasive method for the artificial ageing of glass (similar to DIN 52348). Abrasive medium is allowed to fall in a controlled manner on glass and induce a random surface flaw population. 390 annealed glass specimens grouped in 26 series were artificially aged using different combinations of ageing parameters (mass, *m*, and grain size range, GSR, drop height, H, rotation rate, *RR*, and curing time t_c). The specimens were subsequently subjected to destructive (Coaxial Double Ring tests) and pre- and post-fracture microscopy to determine the influence of each parameter. A Secondary aim was to identify a combination that produces strength characteristics similar to those of a 20-year-old naturally aged glass that was largely exposed to erosive action during its service life in the UK.

The naturally aged glass was found to be 90% weaker than as-received glass at for the lower probabilities of failure, commonly used in engineering design strength, in naturally aged glass (Fig. 1-2). Existing artificial ageing recommendations (DIN 52348) produced a less severe strength reduction, thereby overestimating design strengths by up to 484% for P_f=0.001, and are therefore, deemed unsafe (Fig. 1-2). However, adjustments to the parameters of the falling abrasive method using different parameters (H=3.0, m=3.0kg, 0.5 ≤ GSR ≤ 9.5mm, RR=250 rpm and t_c=7days) provides a far better correlation to the strength of naturally aged glass (Fig. 1-2). The study continues with artificial ageing of thermally and chemically strengthened glass. Full results will shortly be published in the Construction and Building Material Journal and in GPD 2017.

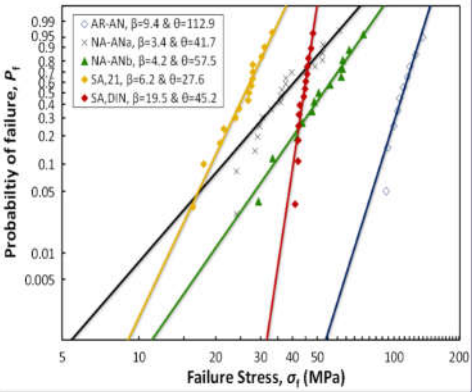

Figure 1: Cumulative distribution function for: as-received (AR-AN); naturally aged (NA-ANa-b); sand abraded with DIN 52348 (din 52348) and; best performing of sand abraded series (SA,21).

(a) (b) (c)

Figure 2: Micrographs of the surface of: (a) naturally aged; (b) sand abraded annealed glass and; (c) as-received.

Crack healing of annealed glass

Crack healing is a spontaneous process consisting of crack closure associated with strength recovery. The most relevant factors affecting crack healing in glass are humidity, stress history and temperature history. A study to quantify crack healing caused by thermal effects was conducted by the gFT research group. Crack healing was investigated for surface flaws and three different types of edge were considered: as-cut, ground and polished (Figure 4).

The study consisted of testing 4 series of soda-lime-silica glass, each consisting of: 16 as-received float glass and 16 as-received float glass subsequently annealed in the laboratory. The annealing cycle consisted of heating the glass up to 540°C, holding for two hours and cooling at 2°C/min. A carefully calibrated SCALP 5.0 was used to measure the surface residual stress before and after the annealing. Microscopy was performed before and after annealing in order to identify any change in the flaw size and morphology. The specimens were tested to failure: one series using a coaxial-double-ring (CDR) jig (to investigate crack healing on the glass surface (Figure 4)) whilst the remaining three using a four-point bending jig (to investigate crack healing of the edges). Crack healing for each series was assessed by comparing the extrinsic strength (fracture strength minus surface residual stress) of the annealed specimens with the as-received ones. Results showed that healing is correlated with the quality of the surface/edge finish, more precisely, the better the edge quality, the higher the relative strength gain. In particular, the surface and the polished edges experienced a strength gain as high as 35% at strength fractiles commonly used in design (i.e. 0.001). A possible healing mechanism was hypothesized and is summarised in Figure 3. Further details on this study are available in the scientific paper "Thermal healing of realistic flaws in glass", is accessible through the gFT website.

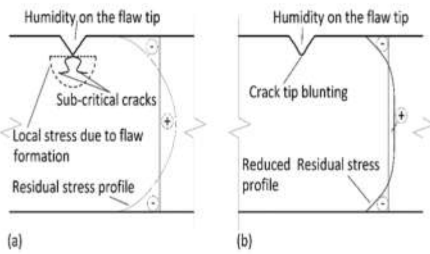

Fig. 3: schematic crack healing mechanisms

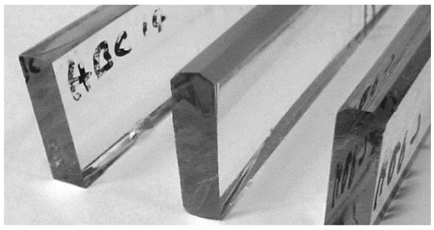

Fig. 4: different edges tested: from left to right, as-cut, ground and polished.

Buildings Inspired by Nature

Long has nature been an inspiration for architects and engineers alike. But it is only recently, with the realisation of climate change, and buildings large contribution to it, that we are again looking more seriously towards nature for ideas for our buildings. A case study of 6 buildings that are 'inspired by nature' found that although they appear to use less primary energy than their contemporaries, there is no quantitative in-use performance data to substantiate these claims. Further, the 'inspiration' taken from nature is often not developed to its full potential and it often appears to be an attractive label rather than anything more meaningful. The study proceeded to collate and classify natures mechanisms which is the first step in creating an inspired-by-nature building 'guidebook'. These are mechanisms relating to light, temperature and ventilation control both within natural organisms and on the structures that they build. The working principles of some of these natural mechanisms are not fully understood and there appears to be no direct comparisons between natural and human designed mechanisms. One of these 'unclear' mechanisms is that used by the termite species Odontotermes Obesus who's mounds can be found in South Asia (see figure 5). These intriguing 1m tall structures were explored further by means of a simple CFD model. The model showed how the internal layer of air isolates the inner mound, helping the flow to change direction diurnally and keeping the nest temperature reasonably stable. This could be developed further into a fully accurate 3D model of a termite mound for CFD analysis, something which has not been done before. Overall, this initial study gave a general insight and understanding of nature inspired buildings and its constituent topics. This research project is now focusing on how environments within buildings could improve occupant wellness by drawing lessons from natural environments. It is hoped that this research will lead to a novel façade technology or method that improves occupant wellness through the replication and imitation of natural stimuli found in environments such as forests and coastal areas.

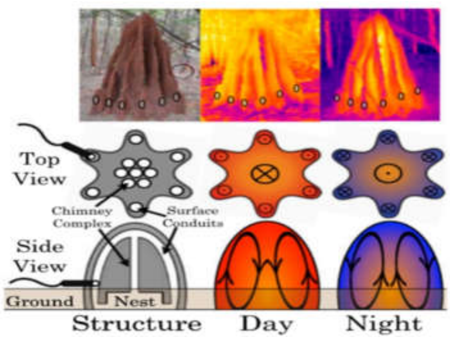

Fig. 5 : internal structure and convective flow within the mound (King et al 2015)

Recently published…

- ***How stiff is stiff enough? … use the new analytical models for FRP-Glass composites to determine the stiffness of the adhesive required for composite action as shown in paper # 84 on the gFT website.***
- ***How strong will my glass be after 20 years in-service? … read the realistic artificial ageing method for glass explained in paper #85 on the gFT website.***

Our recent papers are published in open access format and free to download.