High Strength, Thin and Flexible Glass Structural Members

University of Southampton

The Institution of StructuralEngineers

Undergraduate Research Grant

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Background

- Chemical strengthening is one way of strengthening glass. The conventional method of glass strengthening is thermal strengthening.
- Chemically strengthened (CS) glass are thin, strong & flexible compared to thermally strengthened glass.

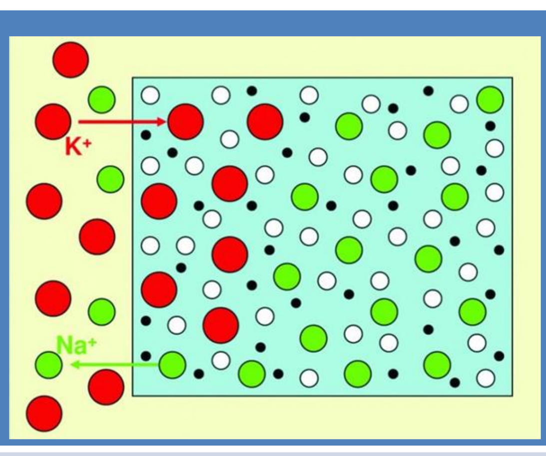

Fig. 1: Replacing smaller Na^+ with larger K^+, compressive residual stresses can be introduced in glass

Fig. 2: Chemically strengthened (CS) glass are thin, strong & flexible

- Despite the potential for practical applications, CS glass are not used in building construction industry.
- Low flexural/axial stiffness of thin glass & lack of understanding of the mechanical behaviour limit practical applications of CS glass.

Residual stresses

- The mechanical behaviour of CS glass depends on the residual stresses (RS) present in them.
- Replacement of smaller Na^+ particles in glass with bigger K^+ particles causes compressive RS in the surface regions of CS glass.
- Presence of a surface compressive mean CS glass is strong.
- Thermally strengthened (TS) glass is used in construction industry.
- RS distributions in TS glass are well known & the effects of RS are considered in structural design.
- Nothing is known about RS in CS glass & the mechanical behaviour.
- A Scattered-Light-Polariscope (SCALP) was used to measure RS in 2 mm & 3 mm thick CS glass purchased from a commercial supplier.

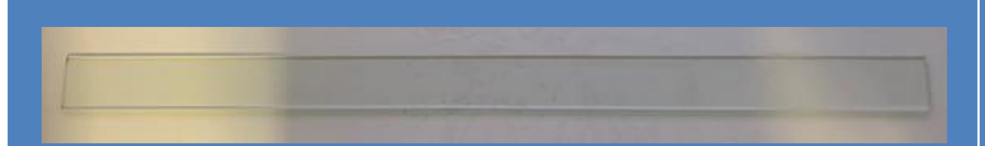

Fig. 3: Thin CS glass beam specimens purchased from a commercial supplier

Fig. 4: A SCALP was used to measure RS

- The surface RS measured using SCALP suggest that the RS distribution is largely uniform along the length & width directions of the beams.
- Surface compression RS in 3 mm thick CS glass beams was ~130 MPa, whereas that in 2 mm thick CS glass beams was ~70 MPa.
- The low RS measured in 2 mm thick glass may be attributed to the requirement of bulk material in order to introduce a high RS in a material.

Beam Tests

- Four-point bending tests of 2 mm & 3 mm thick CS glass beams

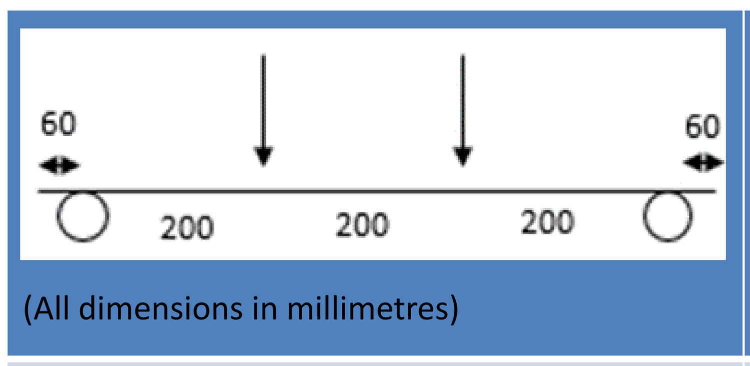

Fig. 5: Beam dimensions

Fig. 6: Actual testing arrangement

- Beams deformed (i.e. deflected) significantly (see Fig. 7)
- 3 mm beams shattered, whereas 2 mm beams failed due to a major crack

Fig. 7: Significant deflections

Fig. 8: Failure of 2 mm thick beams

- Average failure load of the 3 mm thick beams was 110 N & that of 2 mm beam was 34 N. High flexural stiffness & the high RS in 3 mm beams ensured higher load capacity compared to that of 2 mm thick beams.
- Results of the experiments show that the lack of a significant flexural stiffness in CS glass mean they cannot be used in construction industry.

CS Glass–GFRP Sandwich Beams

- As a mean of eliminating the low flexural stiffness of CS glass beams, sandwich beams made using two glass sheets as skins & a hollow pultruded GFRP profile as the core was proposed & tested (see Figs. 9 & 10).

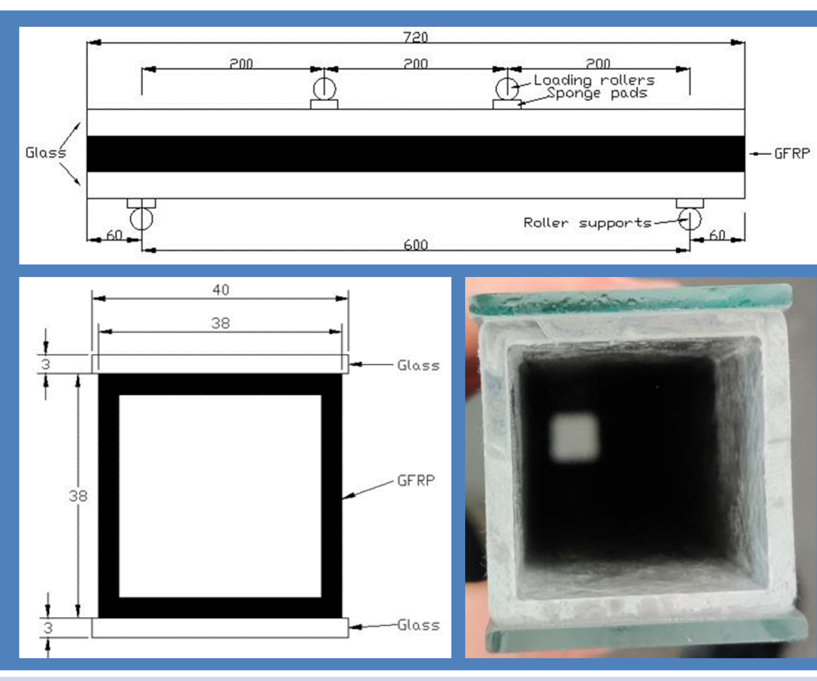

Fig. 9: Sandwich beam with two 3 mm thick CS glass skins on either side

Fig. 10: Four-point testing of CS glass–GFRP sandwich beams

- The GFRP pultruted profile used in the present proof of concept study was translucent. After the structural concept of CS glass–GFRP sandwich was validated, there is a scope for improving the visual aspects of the composite.
- Sandwich beams showed enhanced load capacity & flexural stiffness (see Figs. 11 & 12). Broken glass pieces attached to the GFRP without falling down(see Fig. 13).

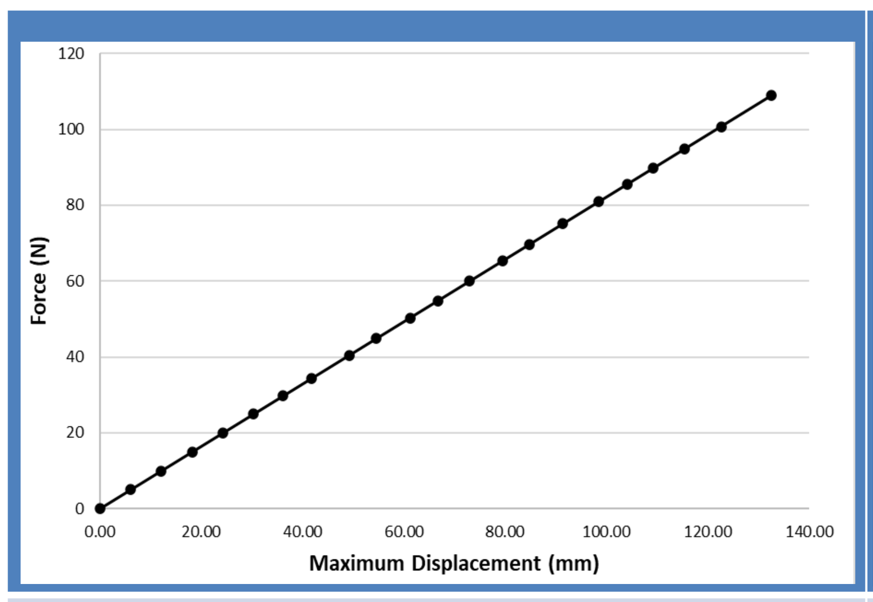

Fig. 11: Applied load vs midspan (i.e. maximum) deflection relationship for 3 mm thick single layer beam

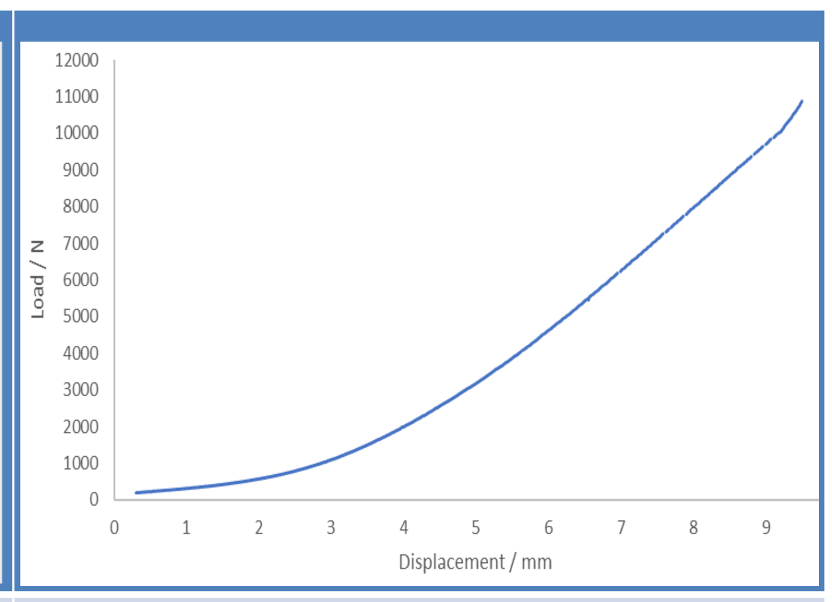

Fig. 12: Applied load vs midspan (i.e. maximum) deflection relationship for sandwich beam with 3 mm thick glass

Fig. 13: Broken glass pieces were attached to the GFRP without falling

Table 1: Failure loads of single layer & sandwich beams

Glass thickness (mm)	Failure load (N)	
	Single layer beam	Sandwich beam
2	34	3800
3	110	10900

Beams with Intermittent GFRP Segments

- As a mean of reducing the visual impact of the GFRP core, sandwich beams with a few intermittent rings of GFRP sections (see Fig. 14) were investigated as alternative to the full GFRP profile used in the previous test arrangement.

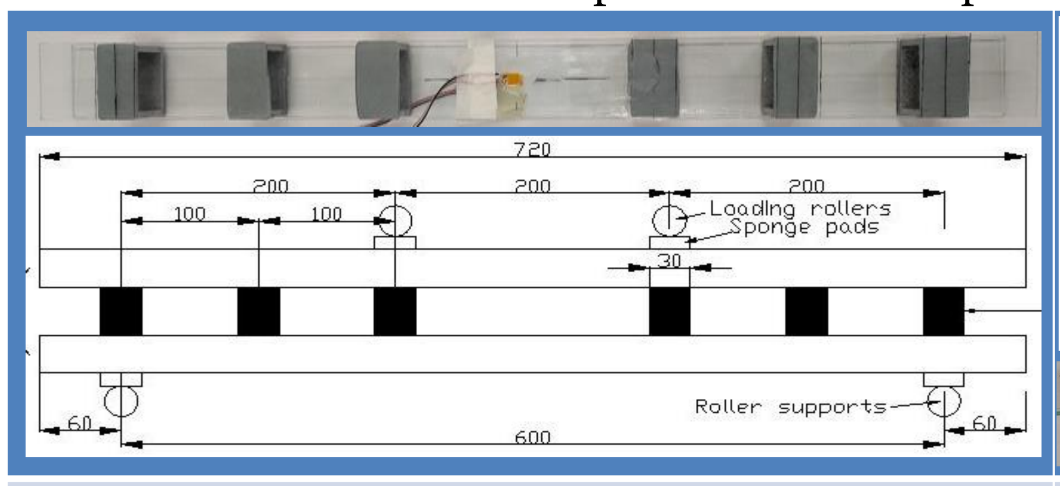

Fig. 14: Beam & testing arrangement of sandwich beams with intermittent GFRP rings

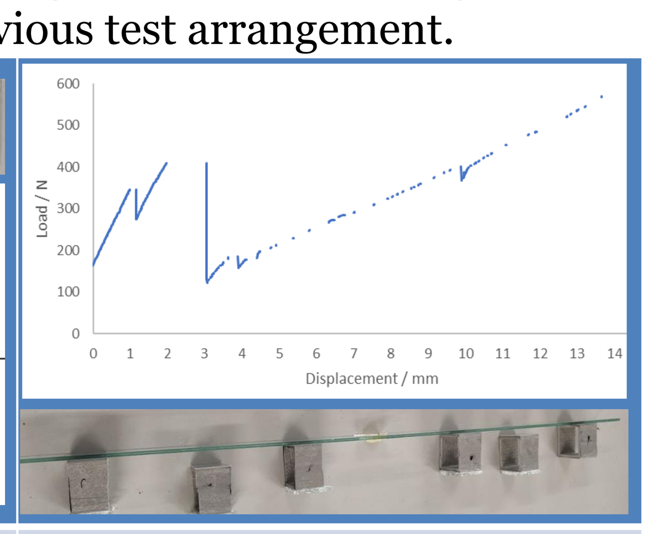

Fig. 15: Load-deflection relationship & failure mode

- Failure load of the sandwich beam with intermittent GFRP rings & 3 mm thick CS glass was 570 N compared to that of 110 N of single layer & 10900 N of the sandwich beam with the full profile of GFRP, respectively.
- The bottom (i.e. tension) glass skin failed but the top (i.e. compression) glass skin was remained undamaged (see the bottom of Fig. 15).

Conclusions

- It appears that the Residual Stress (RS) distributions in Chemically Strengthened (CS) glass of different thicknesses are different.
- Characetrisation of RS in CS glass is required in order to establish the mechanical behaviour, including the failure mode, of CS glass.
- CS glass alone cannot be used as structural members due to excessive deformation under applied loads.
- The use of CS glass in glass–GFRP sandwich has potential for ensuring adequate stiffness & strength in structural members.

Acknowledgements

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