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Artikel: A design method for glass-adhesive-glass composite structural elements

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A Design Method for Glass-Adhesive-Glass Composite Structural Elements

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Summary

The use of architectural glass in long span or high load applications is limited by the slenderness of glass plates which leads to excessive deflection. However, by using composite glass-adhesive-glass beam sections it is possible to carry greater loads, over longer spans with less deflection, Pye and Ledbetter (1997). This paper outlines current work at the University of Bath that will enable the quantitative design of T-beams fabricated from flat plates of toughened glass with a thin adhesive joint at the web-flange interface.

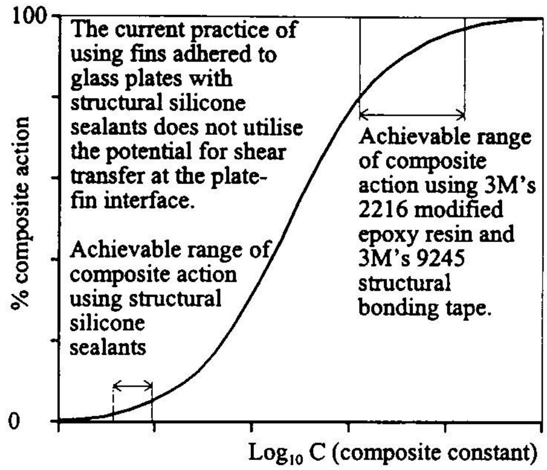
Composite Model

The authors have developed an expression which describes the behaviour of a thick-thin-thick composite with a flexible core, Equation (1). This demonstrates that the current practice of using fins to strengthen glass plates does not utilise the shear transfer at the plate-fin interface, Figure 1. It also demonstrates the increased degree of composite action which is possible using the adhesives that have been selected for this work. These are 3M 2216 B/A grey epoxy adhesive and 3M structural bonding tape 9245. The first is a flexible, two part, room temperature curing structural adhesive. The second is a new material that is applied as a tape and is heat cured to develop structural strength.

$$S_0 \frac{d^4y}{dx^4} - CS_1 \frac{d^2y}{dx^2} = \frac{d^2M}{dx^2} - CM \qquad (1)$$

S_0 is the stiffness of the equivalent layered section
S_1 is the stiffness of the equivalent monolithic section
x is the distance along the beam
y is the deflection perpendicular to the span
C is the composite constant
M is the moment

The degree of composite behaviour is controlled by the composite constant, C, which is a function of the adhesive shear modulus, glass Young's modulus and the cross section geometry. However, in most practical designs it is the choice of the core material and joint dimensions that offers the greatest scope for improving composite action.



$$\text{percentage composite action} = \frac{\delta_C - \delta_L}{\delta_M - \delta_L} \times 100$$

δ_C deflection of the composite section
δ_L deflection of the equivalent layered section
δ_M deflection of the equivalent monolithic section

Figure 1 Comparing the performance of a glass-adhesive-glass T-beam constructed using a structural silicone sealant and a modified epoxy resin. Based upon equation (1).

Failure Mechanisms

The failure of a glass T-beam may be by one of the five mechanisms listed in Table 1. After having determined and appropriately factored the necessary loads and material properties, the occurrence of each mechanism must be checked

In addition to the composite failure mechanisms the glass may also fail because of very localised high stresses such as those generated by a stone impacting upon the glass. Fortunately it is possible to design against these types of failures by either over-designing the glass plates or by introducing a sacrificial layer.

A potential problem in assessing the performance of wide-flanged beams is that the full width of the flange does not work compositely with the web because of shear lag effects. By strain gauging the flange during physical testing the authors have quantified this behaviour and shown that it would be possible to approach the problem by determining an effective width as is currently practised with steel and concrete structures.

Failure Mechanism	**Assessment**
Glass bending failure	- Equation (1) may be developed to yield the maximum tensile glass stress and while this is below the surface compression of the toughened glass failure will not occur.
Glass shear failure	- The maximum shear stress may be determined in the same manner as steel sections. This must be less than the shear capacity of the glass. However, initial results from a series of punching shear tests conducted to determine the shear capacity of glass indicate that a glass shear failure is unlikely in most realistic support conditions.
Lateral torsional buckling	- The distribution of compression stresses must be such that the section is stable. It is possible to design to a reduced moment capacity by considering the slenderness of the beam, position of restraints and distribution of load. Assessing the reduced capacity has been based upon a combination of physical testing and finite element modelling.
Adhesive shear failure	- This is dependent upon the ability of the adhesive to yield and redistribute stresses. It is also sensitive to the rate of loading. Difficulties arise in quantifying the complex elasto-plastic behaviour. Current work is based upon a combination of physical testing and finite element modelling.
Adhesive tensile failure/glass plucking failure	- There may be a cohesive failure which is a function of the adhesive, an adhesive failure which is a function of the adhesive and the primer or a plucking failure which is a function of the glass. All of these mechanisms may be easily prevented by suitable joint detailing and increasing the adhesive contact area..

Table 1 A summary of the failure mechanisms of glass-adhesive-glass T-beams.

Conclusion

It is possible to predict the performance of composite glass-adhesive-glass T-beams and by applying a similar methodology it would be possible to assess the performance of other sections such as I's,π's and boxes. However, the current process of determining critical stresses is complex and would need to presented in a simplified manner if it were to be used in practice.

References

Pye, A, and Ledbetter, S, (1997), 'The engineering of composite glass beams', ICBEST - 97, Bath.