Interfacial Bond Strength of Glass Fibre Reinforced Cement Composites

In the evaluation of the mechanical properties of fibre reinforced composite materials estimates of interfacial bond strengths are often required. In the case of reinforcement by discontinuous fibres, the bond strength largely determines the minimum length of the fibres which can be effectively used in composite fabrication. For glass fibre reinforced cements and plaster systems a method has already been described [1] for measuring the strength that develops between the fibre and the matrix, and the values obtained by this method have been used in the assessment of the experimental strength [2] given by these composite materials.

It has been shown recently [3, 4] that the strength of commercial glass fibres produced from either an aluminoborosilicate glass (E-glass) or soda-lime glass (A-glass) is severely affected by the Portland cement paste; composites prepared with such a cement and commercially available glass fibres lose strength rapidly with time. It has also been reported that zirconia-containing glasses are not so easily attacked by the cement paste.

In order to evaluate the influence of glass composition on the long-term strength properties of the composites it is necessary to have some idea about the effect of time and curing conditions on the strength of the interfacial bond formed between the glass fibre and the set cement matrix.

Bond strength determinations were carried out following the procedure described previously [1]. Uncoated filaments of E-, A- and zirconia-containing glasses measuring approximately 1 mm in diameter were produced in a glass drawing apparatus [5]. Suitable specimens were prepared using individual filaments of these glasses and a Portland cement paste having a water-to-cement ratio of 0.3. Specimens having zirconia, A and E glass filaments were stored under water and in air at 100% RH, both at 18° C. The glass filaments were "pulled out" of the specimens after definite periods of time using an Instron testing machine and bond strength values were computed. Ten specimens were tested in most cases.

Experimental values obtained at ages up to 270 days are given in fig. 1. All the samples were air-stored at 100% RH for 1 day before subsequent curing; thus the "one day figure" is for air-storage only. For all three glasses there appears to be a slight fall in the initial bond strength of the water-cured specimens followed by a subsequent rise. It is perhaps significant that the zirconia-containing glass maintains a low strength for the longest time, approximately 28 days, whereas A- and E-glass start rising at 14 days.

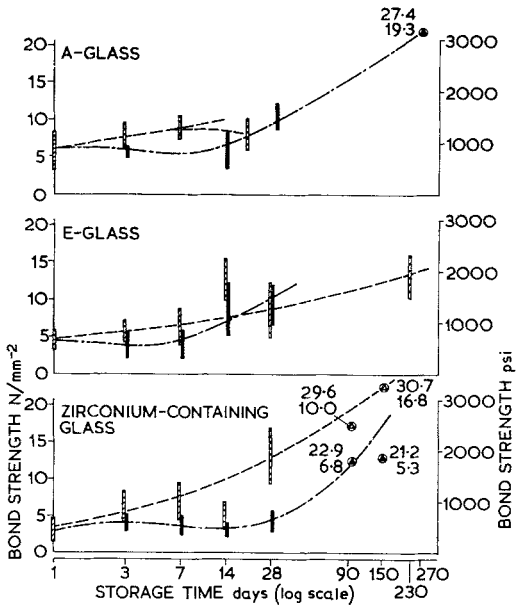

Figure 1 Bond strength versus time for three glasses in Portland cement paste. Bars represent mean value ± one standard deviation. Full bars, water-cured; hatched bars, air 100% RH-cured. For explanation of circles see text.

The bond strength of the air-cured specimens appears to rise steadily for both E- and zirconia-containing glass. The air-cured specimens for A-glass exhibit an early rise in strength followed by a possible fall. Further experiments to check this particular trend in the present results are in progress. In all cases except that of air-cured A-glass there is two to threefold increase in strength at 90 days compared to the value at 7 days. At values in excess of 10 N mm^{-2} some experimental difficulty was experienced as the filaments tended to fail before the bond. In these cases the value quoted is the mean bond stress at fibre failure and therefore represents a low estimate of the bond strength. Both maximum and minimum values are given, the spread being

much higher in this case, as is characteristic of tensile strength tests on glass filaments kept for a long period after drawing. It is thought, however, that interfacial bond strengths of the order of 20 N mm^{-2} are obtainable in glass fibre cement composites at ages in excess of one year. This value is close to the bond strength determined for glass fibre reinforced plastics [6] and is much higher than that quoted for asbestos cement.

Although the increase in the strength of the interfacial bond between glass fibre and cement paste reported here needs to be confirmed by other methods, it is interesting to note that in a comprehensive study on the cement-aggregate bond strength in concrete, Alexander [7] notes that the measured strength of the bond between the cement paste and several aggregates increased with time and was independent of the curing temperature. It is possible that at the very early stage the interfacial bond between cement paste and glass fibre is mainly physical (frictional) in nature. The gel-like material that forms when cement is hydrated and which surrounds the fibre becomes progressively more crystalline or less porous with age and the bond may become stronger as a result. With age it is also possible that the products of chemical reactions between the glass and the cement accumulate on the surface of the glass in large enough quantity and act as a cement between the fibre and the matrix phase.

The chemical reactions that may take place between the glass fibre and the cement paste at ambient temperatures must be limited to the surface only. The fibres "pulled out" from the matrix after 270 days curing have not given any positive indication of either severe etching or formation of compounds when examined by optical, electron-optical and X-ray methods. Direct carbon replicas of the glass fibre removed from the cement paste and subsequently washed in dilute acid (to remove adherent particles) did not show up any significant difference in the surface state of the glass region which was embedded in the cement and that adjacent to the bond-zone but exposed to air. A scanning electron micrograph of the bond zone is presented in fig. 2. This photograph was taken of a polished section which was subsequently etched, and it shows cracks in the cement paste and some unhydrated material. The cracking of the matrix may have taken place during sample preparation. The fibre appears to be virtually intact except for polishing scratches and pits. It stands slightly proud of the cement paste because the etchant attacked it at a lower rate.

In conclusion it is felt that at ambient temperatures there is no gross chemical attack of glass fibres in cement although some chemical bond forms at the surface. Since the bond strength rises to 20 N mm^{-2} (3000 psi) it is probable that any poor bonding in glass fibre cement produced from multi-filament strands may be the result of non-penetration of strands by the cement paste and not due to any limitation of the intrinsic glass/cement bond.

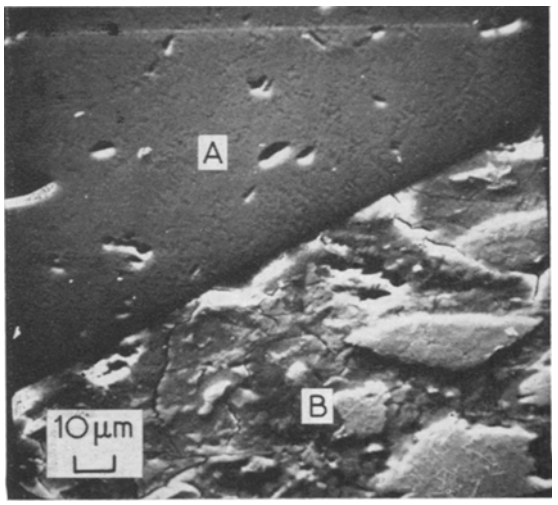

Figure 2 Stereoscan micrograph of glass fibre/cement interface (polished and etched section) Area A, glass fibre; area B, cement paste.

Acknowledgement

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