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Impact performance of the fibre-cement composites

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ABSTRACT: The transition zone of short filament fibres randomly dispersed in a paste of ordinary portland cement is analysed. Composites of vegetable fibres (malva, sisal and coir) are compared with those with chrysotile asbestos and polypropylene fibres. The series of composites are prepared to be tested at the ages of 7, 28, 90 and 180 days. The water-cement ratio is 0.38 and at the age of 28 days specimens with ratio of 0.30 and 0.46 are also tested. The backscattered electron image (BSEI) and energy dispersive spectroscopy (EDS) identify the major properties of the fibre-matrix interface. The microstructural characteristics are directly associated with the toughness of the composites, once the energy dissipation at transition zone is confirmed.

1 INTRODUCTION

The presence of steel re-bar, aggregates or impermeable fibres in cement paste produces the wall effect, that is, the formation of a water film in the interface, according to various researchers proposals (Mindess et al., 1986; Zhang & Gjorv, 1990). This hypothesis is used to explain the greater porosity and the concentration of portlandite (calcium hydroxide) and of ettringite (hydrated calcium trisulfoaluminate) crystals near the interface and that defines the zone or aureole of transition, with characteristics so different from the rest of the matrix..

Even so, the transition zone can also be originated in situations of different interfaces from those studied for impermeable fibres and that leads to the alteration of the porosity and of the concentration of hydrated products (Savastano Jr. & Agopyan, 1992). This research analyses the basic characteristics of the portland cement paste and vegetable fibres of malva, sisal and coir composites and compares them to those of mineral fibres from chrysotile asbestos and fibres of polypropylene.

The vegetable fibres present a few singular characteristics: (i) high water absorption (near 100% or even more); (ii) impurities such as powder and husk; and (iii) heterogeneous mechanical properties (Savastano Jr., 1990). Of course, these properties will affect the composites microstructural behaviour.

2 EXPERIMENTAL WORK

2.1 Materials

Ordinary portland cement without carbonate addition was used in order to avoid negative interference on the EDS results. The fibres used were malva (*Urena lobata* Linn.), sisal (*Agave sisalana* Perrine), coir (*Cocos nucifera* Linn.), chrysotile asbestos and polypropylene. No fibres received any chemical treatment.

The asbestos fibres are 4Z type (QUEBEC SCREEN TEST classification), commercially used by the asbestos-cement industries. The vegetable and polypropylene fibres are used at various lengths that vary, approximately, from 15 mm to 30 mm, for random distribution in the matrix. For the vegetable fibres, the variability of lengths is very large due to the crude cutting process used.

Table 1 shows the water absorption by vegetable fibres, during the first 24 hours of immersion. At the first 15 minutes, there are, at least, 52% of the total absorption and from 8 hours of immersion onwards, the stabilization process is evident. This aspect interferes with the water-cement ratio, used in the matrix, because part of the mixing water is used up by the fibres.

Table 1. Water absorption by vegetable fibreas at room temperature (ASTM C127/88).

	Water absorption (%)						
Fibre	5 min	15 min	30 min	1h	4h	8h	24h
malva	136.6	160.3	162.4	186.4	142.8	156.6	156.4
sisal	89.3	88.4	94.7	95.4	97.0	96.8	92.2
coir	43.2	52.9	53.0	58.3	67.9	72.2	80.4

2.2 Composite production

The matrix consists only of portland cement paste so that there is no interference of aggregates in the transition zone between fibres and matrix. Water-cement ratio of 0.38 and the ages of 7, 28, 90 and 180 days were chosen for the tests. At the age of 28 days specimens with the water-cement ratio of 0.30 and 0.46 were also tested.

From the characteristics observations of the five fibres studied, their specific gravity and tendencies to balling, fibre volume fraction varies from each other according to the composites: 4% for the vegetable fibres and 1% for the polypropylene and asbestos fibres.

2.3 Experimental methods

The analyses chosen for this study were the scanning electron microscopy with backscattered electron image (BSEI) and energy dispersive spectroscopy (EDS).

The BSEI is appropriate for specimens with a smooth and polished surface. This surface is better than the fractured surface which has the inconvenience of crossing, preferably, the composite elements of less strength. The BSEI has still the advantage of identifying the different surface regions analysed, by way of contrasting the atomic number: the higher the atomic number of chemical element, the clearer the image and vice-versa (Goodhew & Humphreys, 1988).

The technique for preparing the specimens for backscattered electron image analysis and by EDS was based on Kjellsen et al. (1991) recommendations.

3 RESULTS

It is evident for composite with asbestos fibres that the wall effect takes place. This is the main factor responsible for the formation of a transition ring as can be observed in Figure 1, showing a composite with water-cement ratio of 0.30.

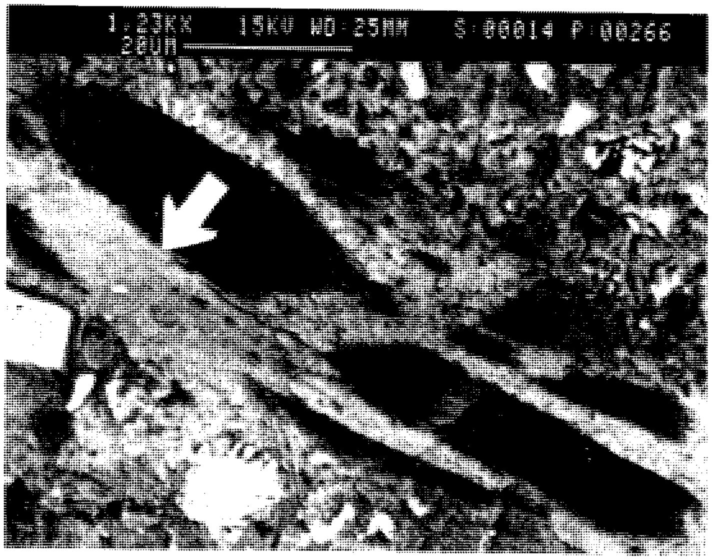

Figure 1. BSEI. Asbestos fibre-cement composite, w/c = 0.30, 28 days. Arrow: portlandite accumulation with thickness of up to 10 micrometers thick.

On the other hand, the vegetable fibres present a water absorption higher than 80% which inhibits the wall effect and induces a strong affluence of water to the fibre direction. This fact induces a local increase of the water-cement ratio which causes the calcium hydroxide accumulation and/or high porosity in the transition zone (Figures 2 and 3), which thickness varies between 50 and 100 micrometers.

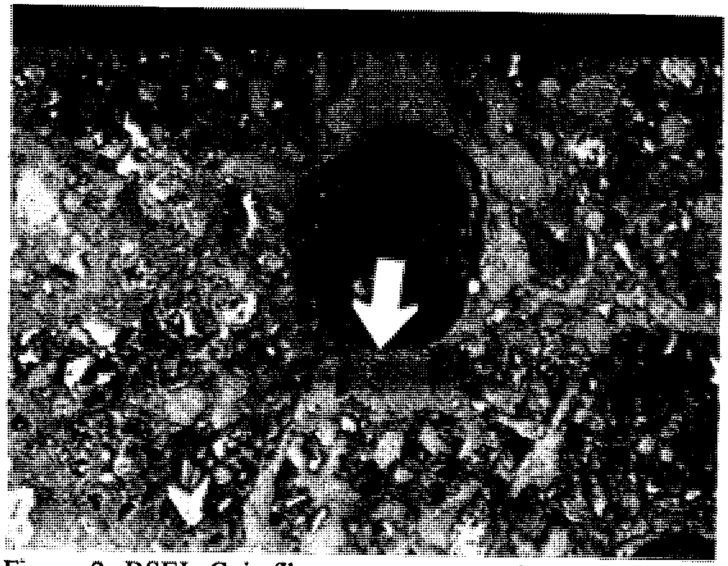

Figure 2. BSEI. Coir fibre-cement composite, w/c = 0.46, 28 days. Fibre debonding. Arrow: portlandite macrocrystals 50 micrometers thick.

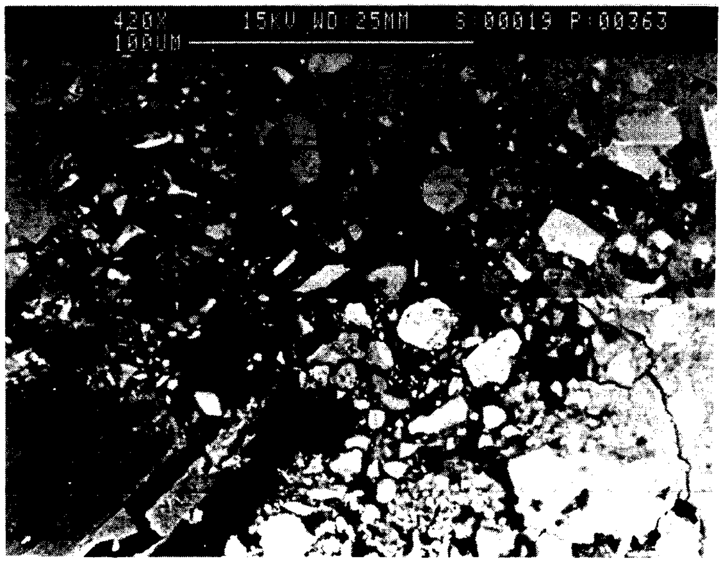

Figure 3. BSEI. Sisal fibre-cement composite, w/c = 0.38, 180 days. Fibre debonding and high porosity transition zone with thickness of up to 100 micrometers.

EDS analysis confirmed the presence of portlandite macrocrystals of which the growth is due to the higher mobility of calcium-ions in a water environment.

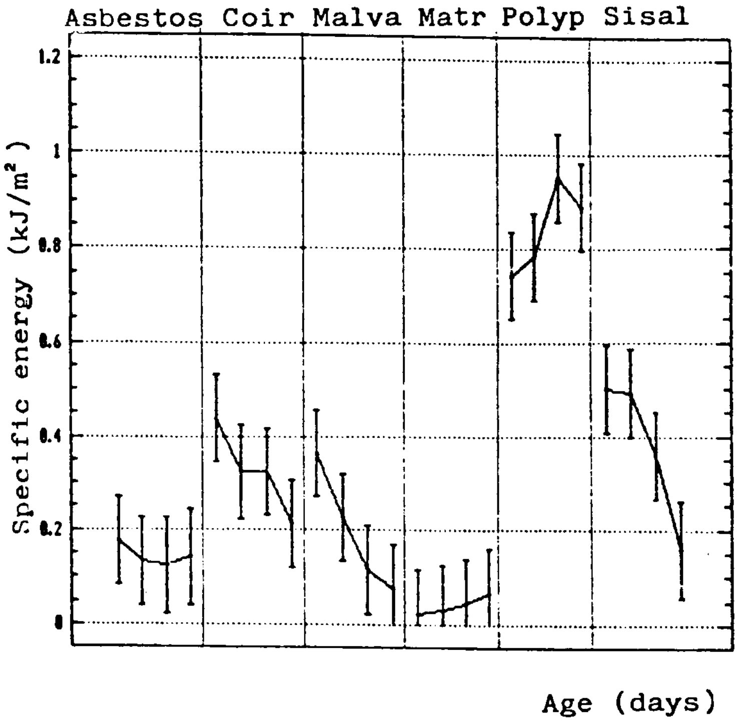

Figure 4. Bending test: effect of the age on specific energy with water-cement ratio of 0.38; for each fibre, the age sequence is 7, 28, 90 and 180 days.

Figure 4 presents the specific energy according to the age. Specific energy is the total energy absorbed by the fractured surface. As it was expected, the short asbestos fibres induce a small energy absorption of their composites; the best results are obtained from the polypropylene fibres. The vegetable fibre composites present a satisfactory performance when compared with asbestos ones and unreinforced matrix. The alkaline medium favours the fibre petrification and leads to loss of ductility. Certainly, this fact will contribute to the small energy absorption during the post-fissured stage at 180 days old, despite the large transition zone thickness and porosity.

4 FINAL REMARKS

The impact performance of fibre-cement composites is in fact evaluated by the energy absorption and not by the strength determination.

However the high composite toughness is not only a consequence of bond between fibres and cement matrix. A good example is the asbestos cement with a continuous fibre-matrix bond, but with impact performance near the unreinforced matrix. Otherwise, the vegetable fibre composites have a weak interface bond (Figures 2 and 3) associated with a high energy absorption in impact tests with coir fibres reinforced cement, as reported for example by Savastano Jr. (1987).

A quantitative conclusion is not possible because of the great variability of fibre and matrix conditions as well as of testing apparatus. Nevertheless, a qualitative remark verifies that the fibre-matrix transition zone contributes to energy dissipation by the possibility of fibre vibration.

This confirms the appropriate use of brittle matrixes reinforced with vegetable fibres in the Civil Construction to increase toughness of materials.

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