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FLEXURAL BEHAVIOR OF CEMENT SYSTEMS REINFORCED WITH HIGH ASPECT RATIO ARAGONITE MICRO-FIBRES

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Introduction

Micro-fibres in the context of cement science have been distinguished from larger macrofibres by an arbitrary limit in specific surface area (e.g. 200 cm^2/g) or fibre length (<6 mm) [1]. Cement composites with high volume fractions (>10%) of these fibres can be produced with significant increases in strength and toughness relative to the unreinforced matrix.

The use of micro-fibre reinforced cement systems for concrete repair has led to several improvements in these technologies that should have an impact on service-life of structures. Micro-fibres function by arresting and stabilizing matrix cracks before unstable growth occurs. There is evidence of pseudo-strain-hardening after the first matrix crack occurs [1].

Several types of micro-fibres have been investigated as candidates for reinforcing cement matrices. These include carbon, steel, polypropylene and wollastonite fibres. Recent work suggests that calcium carbonate micro-fibres with aspect ratios varying from 20-80 can be synthesized [2]. Solution-precipitation processes involving a variety of precursor salt solutions and blowing of CO_2 gas into suspensions are used. This paper describes the synthesis of high aspect ratio aragonite micro-fibres using $CaCl_2$ and Na_2CO_3 starting solutions and crystal growth using a seeding technique. The performance of these microfibres as reinforcement in portland cement paste matrices is verified.

Experimental

Micro-Fibre Synthesis. Reagent grade $CaCl_2$ and Na_2CO_3 powders were used. Solutions, 0.1M $CaCl_2$ and 0.1 M Na_2CO_3, were prepared at 23°C. A litre of the Na_2CO_3 solution was placed in a separation funnel. An equal amount of $CaCl_2$ solution was placed in a reaction vessel. The reaction vessel was placed in a temperature controlled water bath at 90°C. The Na_2CO_3 solution was allowed to flow slowly into the reaction vessel for a period of 3-4 hours. The solution was filtered, the filtrate was washed and the crystals were oven-dried for 8 hours.

The precipitate was identified as aragonite using XRD analysis. The aragonite needles were referred to as the first generation micro-fibres. The procedure was repeated using a small amount of precipitate as a 'seed' crystal source. The seed crystal amount was about 1 mol/100 mol $CaCl_2$. The micro-fibres produced were referred to as second generation. A third and fourth generation micro-fibre were also produced. The average length of the aragonite crystals was 30, 50 70 and 100 μm for the first to fourth generation products respectively. An SEM photomicrograph of fourth generation micro-fibres is shown in FIG. 1.

The following parameters were found to have some effect on the growth of the needle-like $CaCO_3$ crystals: reaction temperature, solution concentration, reaction time, mechanical stirring. For example reaction at 2°C produced no needle-like crystals. The needles produced at 90°C were more regular and longer than those at 80°C.

The conditions of formation at 90°C described above appeared to provide the most suitable fibres for inclusion in cement matrices. It was therefore decided to use aragonite micro-fibres synthesized at 90°C (0.1M solution concentration) as reinforcement for cement paste binders.

Micro-Fibre Reinforced Cement Paste

The performance of high aspect ratio aragonite fibres in a high performance cement-silica fume paste was evaluated in a few preliminary experiments. Silica fume (SF) pastes (water/cementitious solids = 0.35, 15% SF) containing 3, 6, 9 and 20 volume % aragonite fibres (synthesized at 90°C) were cast in the form of wafers and hydrated in lime saturated water. Beam specimens, 42 mm × 3.5 mm × 3.5 mm, cut from the wafer specimens, were tested in flexure at 14 days (3 point bending, MTS loading system) using displacement control. A classical reinforcing action was observed in many specimens at the 9% volume level. A typical load deflection curve is given in FIG. 2. Three regions are observed: region 1 where the load is carried by both fibres and matrix; region 2 where multiple fracture of the matrix occurs; region 3 where the load is carried by the fibres bridging cracks.

Not all results gave this idealized behavior due to non-uniform fibre dispersion in some instances. The presence of aragonite micro-fibres significantly increased the peak-load (by a factor of 2) in most cases.

FIG. 1.
SEM photomicrograph of high aspect-ratio aragonite microfibres aynthesized through reaction of 0.1M solutions of $CaCl_2$ and Na_2CO_3.

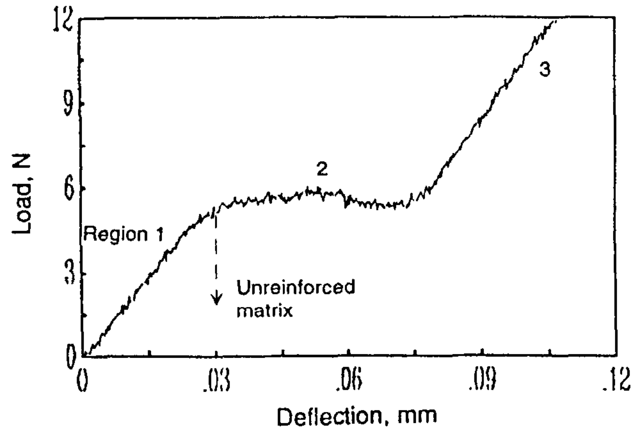

FIG. 2.
Typical load deflection curves for silica fume cement binders reinforced with aragonite micro-fibres and the unreinforced matrix. Fibre volume fraction, 9%.

Concluding Remarks

High aspect ratio aragonite micro-fibres can be easily synthesized through reaction of calcium chloride and sodium carbonate. These micro-fibres can function as reinforcement in hardened cement paste matrices.

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