論文 Durability Characteristics of Carbonated Cellulose Fiber Reinforced Cement Composites

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ABSTRACT: Durability characteristics of carbonated cellulose fiber reinforced cement composites are evaluated. The specimens were subjected to repeated cycles of freezing and thawing, wetting and drying, warm water immersion, and wetting-drying-carbonation. Under diverse accelerated weathering effects, carbonated cellulose fiber reinforced cement composites provide improved longevity and weathering resistance.
KEYWORDS: cellulose fiber reinforced cement composites, durability, strength

1. INTRODUCTION

Cellulose fiber reinforced cement composites manufactured by slurry-dewatering process which are subjected to a special carbonated curing prior to high-pressure steam curing. The cellulose fiber derived from softwood or hardwood present highly cost effective means of reinforcement for thin cement products. Cellulose fibers possess adequate stiffness, strength and bonding capacity to cement-based matrices for substantial enhancement of their flexural strength, toughness and impact resistance. These improvements are archived through the stopping and deflection of cracks propagating in brittle cement matrices by cellulose fibers. Desirable technical qualities and low cost of cellulose fibers have made them the reinforcing materials of choice to substitute asbestos fibers in the broadly utilized thin cement products. These composites have found commercial applications for the production of thin-sheet products, including roofing, siding, soffits, curtain walls, and backer boards. There is, however, concern about the long-term durability of cellulose fiber reinforced cement composites made by carbonated process.

The main thrust of this research was to assess the durability of cellulose fiber reinforced cement composites made by carbonated process, and contents under repeated wetting-drying, freezing-thawing, wetting-drying-carbonation and warm water cycles.

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2. EXPERIMENTAL PROGRAM

The effects of accelerated aging on the flexural performance and microstructural characteristics of the carbonated cellulose fiber reinforced cement composites and control composites (made with conventional process) were investigated. The cellulose fibers used in this investigation were bleached southern softwood Kraft pulp with average fiber length of 3 mm; they were refined to provide a Canadian Standard Freeness of 500. The fiber mass fraction was 8%, and the mix had a sand-binder ratio of 0.75 by weight, and a flocculent-binder ratio of 0.001; the binder comprised 92.5% by weight Type I Portland cement and 7.5% silica fume. Cellulose fiber reinforced cement sheets were manufactured by a laboratory version of the slurry-dewatering method. The sheets were slightly pressed at pressure of 0.24 MPa for 5 minutes, and then subjected to the carbonated pre-curing followed by autoclave curing steps. The target thickness of all boards was 10 mm. The autoclaved sheets were air dried for seven days.

Aging effects on the flexural performance (strength, toughness and stiffness) of composites were evaluated. Tests generally followed by ASTM C1185. Flexural tests were performed on specimens 10 mm thick by three-point loading on a span of 254 mm. The accelerated aging tests conducted in this investigation are reviewed below. One non-standard condition was used where wetting-drying cycles was accompanied with artificial carbonation. Aging effects of cellulose fiber reinforced cement composites were evaluated through the experimental program on table 1.

Table 1. Experimental Program

Type of Composite	Durability Tests
CO_2, (1-1-6)*	Repeated Wetting- Drying
Control 1, (1-1-6)**	Repeated Freezing-Thawing
Control 2, (1-1-8)**	Repeated Wetting-Drying-Carbonation
	Warm Water Immersion

*: 1-1-6 means 1 hour in oven at 50°C, 1 hour in CO_2 chamber and 6 hours in autoclave

**: 1-1-6 or 1-1-8 means 1 hour in oven at 50°C, 1 hour in CO_2 chamber but with 0% CO_2 and 6 or 8 hours in autoclave

2.1 REPEATED WETTING-DRYING

Repeated wetting and drying cycles simulating repeated rain-heat conditions in natural weather promote some key chemical and physical mechanisms of deterioration in cellulose fiber-cement composites. These conditions accelerate any potential attack by the alkaline pore water of cement-based matrices on certain cellulose fiber constituents; they also promote migration (through dissolution and reprecipitation) of some cement hydration products from the matrix into the fiber cores and their interface zones. These microstructural changes would affect the engineering qualities of aged composites. A total

of 25 cycles of wetting-drying were used. In each cycle, specimens were moistened by spraying water for 3 hours at 30°C, and then dried for 3 hours at 60°C.

2.2 REPEATED FREEZING-THAWING

This test investigates the possible degradation of cement-based materials exposed to repeated freeze-thaw cycles. Freezing of water in the cement-paste capillary pores, owing to the volume increase of water upon turning to ice, would cause internal pressures that lead to cracking and deterioration of concrete. A total of 50 cycles were applied as required by ASTM C1185. Each cycle lasts 4 hours and consists of cooling the specimen to -20°C over a period of 1 hour, holding it at -20°C for 1 hour, thawing it to 20°C over a further period of 1 hour, and maintaining it for 1 hour at 20°C before proceeding to freezing.

2.3 REPEATED WETTING-DRYING-CARBONATION

Carbonation plays key role in the natural aging of cellulose fiber cement composites. Dissolution of calcium hydroxide in pore water and its precipitation within cellulose fiber cores and at the interface zones would be accomplished by carbonation, which turns calcium hydroxide into calcium carbonate and causes the weathering effects. Each cycle in this accelerated aging test consists of 8 hours of saturation under water, heating in an oven for 1 hour at 80°C, carbonation for a period of 5 hours in carbon dioxide rich environments and heating for 9 hours in an oven, followed by cooling for 1 hour at room temperature.

2.4 WARM WATER IMMERSION

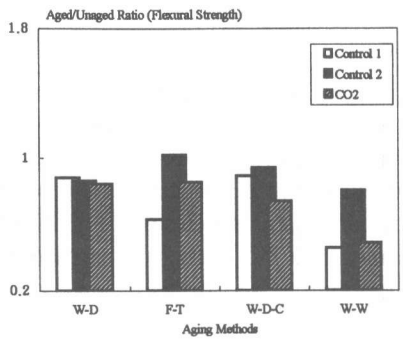
Any deleterious chemical reactions (e.g. alkali attack by pore water on some cellulose fiber constituents) taking place under natural aging would be accelerated upon immersion in warm water. ASTM C1185 specifications were followed; the temperature of water was 60°C, and the immersion period was 55 days.

3. TEST RESULTS

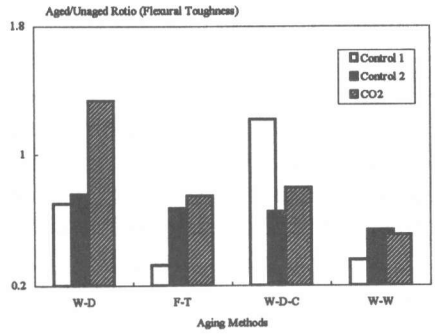
Figure 1 presents the effects of various accelerated aging conditions on the strength, toughness (defines as the area underneath the load-deflection curve) and stiffness of carbonated cellulose fiber reinforced cement composites.

The results presented in Figure 1 suggest the repeated wetting-drying cycles caused an increase in the flexural stiffness and a drop in the flexural toughness of composites, without significant affecting their flexural strength. The effects of freeze-thaw cycles on flexural strength were mixed, but flexural stiffness generally increased and toughness decreased after exposure to repeated freeze-thaw cycle. Warm water immersion had generally adverse effects on flexural strength, toughness and stiffness. There was a tendency in flexural

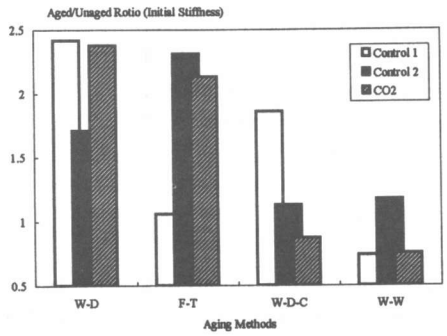
toughness and strength to drop and in flexural stiffness to generally increase after wetting-drying-carbonation aging process.



(a) Strength



(b) Toughness



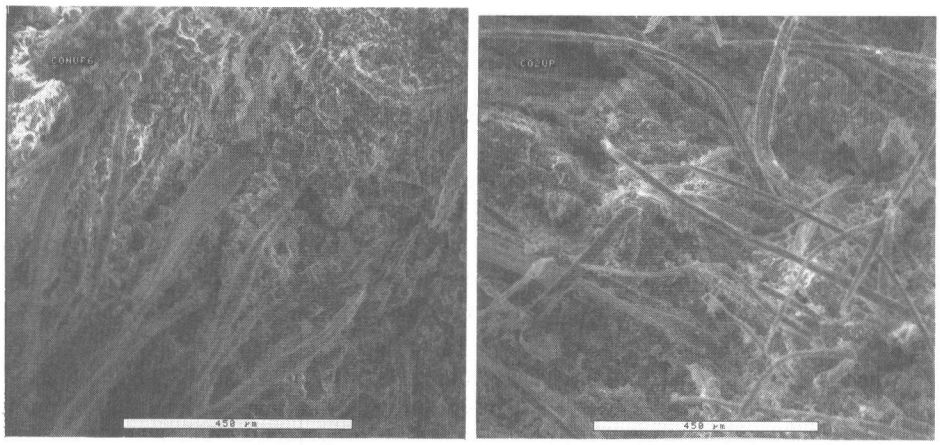
(c) Stiffness

Figure 1 Effects of Accelerated Aging on Flexural Performance

4. MICROSTRUCTURAL CHARACTERISTICS

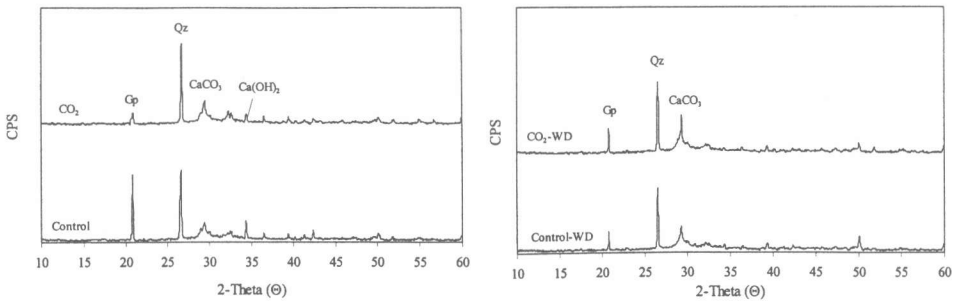
Typical Scanning Electron Microscope of the fracture surface of carbonated cellulose fiber reinforced cement sheets subjected to normal and carbonated curing are presented in Figure 2. The carbonated pre-curing seems to have reduced the extent of microcracking in autoclaved sheets

The mineralogy of composites, as indicated by the x-ray patterns shown in Figure 3, tends to be more stable under aging effects when they are subject to the carbonated processing in lieu of conventional process.



(a) Conventional Process (b) Carbonated Process

Figure 2. Scanning Electron Micrographs of Cellulose Fiber Reinforced Cement Composites



(a) Unaged (b) After Wetting-Drying

Figure 3. X-Ray Diffraction Patterns of Unaged and Aged Composites

5. SUMMARY AND CONCLUSIONS

The effects of accelerated aging on the microstructural characteristics and engineering properties of carbonated cellulose fiber-cement composites were investigated. Microstructural studies utilized the Scanning Election Microscope and X-ray diffraction pattern techniques. Test results shows carbonated process composites with important improvements in durability characteristics. The microstructure of carbonated composites showed less sign of microcracking, and their mineralogy was also more stable under aging

effects. The carbonated process provides opportunities for improving the durability characteristics under severe exposure conditions

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