INVESTIGATING SELF-HEALING CAPACITY OF MICRO-CRACKED ECC WITH DIFFERENT VOLUME OF FLY ASH

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ABSTRACT

Crack is called the intrinsic flaw of concrete that is inevitable for concrete infrastructures during their service life. The presence of crack offer aggressive agent access to pass through, which has a direct impact on durability, therefore resulting in shortened service life. Nevertheless, the influence of crack on the durability can be greatly minimized when crack width is controlled within certain limits. Engineered Cementitious Composite (ECC) is a new class of HPFRCC micro-mechanically designed to achieve high tensile strain capacity of 3-5%, while maintaining very tight crack width. In this paper, we attempt to investigate the self-healing capacity of micro-cracked ECC by capillary water sorption test. Three ECC mix proportions with different volume of fly ash are used in this research. Before water curing the specimens are pre-loaded at 28 days so as to produce micro-cracks. The micro-cracked specimens are then cured under water for another 30 and 60 days, respectively, before water sorption test is conducted. It is found that water absorbed by cracks of the pre-loaded specimens reduces with increasing curing age, which suggests that self-healing products accumulate within the cracks over time. Subsequent ESEM observations also confirm the above findings. Most pronounced self-healing behavior is revealed for the mixture with highest fly ash content, which also shows smallest crack width. The crack width reduces with increasing volume of fly ash, denoting better capacity of crack width control. With excellent crack width control and self-healing behavior, ECC can be an ideal material for durable concrete infrastructure.

1. INTRODUCTION

Concrete cracking is a result of the combined effects of mechanical loading conditions and environmental exposure, which is inevitable for concrete infrastructures during their service life. The presence of crack offer aggressive agent access to pass through, and has a direct impact on durability, thus decreases the service life. In this paper, we attempt to investigate the self-healing capacity of ECC with different fly ash content.

2. MATERIALS

Table 1 lists a set of ECC mixtures used for this study. The fly ash-to-cement ratios are 1.2, 2.2 and 4.0, while water-to-cementitious material ratio (w/cm) and silica sand-to-cementitious material ratio (s/cm) are fixed at 0.25 and 0.36, respectively.

Table 1: ECC mixture proportions

Mixture ID	Cement (c)	Fly ash (FA/c)	Silica sand (s/cm)	Water (w/cm)	Water reducer	PVA fiber(by volume)
M1	1.0	1.2	0.36	0.25	0.03	0.02
M2	1.0	2.2	0.36	0.25	0.03	0.02
M3	1.0	4.0	0.36	0.25	0.03	0.02

From each mixture beam specimens of 355 by 75 by 50 mm were prepared for water sorption test. All specimens were demolded at the age of 24 h, and cured under 95 ± 5% RH, 20°C for 27 days . At 28 days, except for the control specimens, all other ECC beams were loaded until final failure via four-point bending test. The cracked specimens were then cut for subsequent water curing and sorption test. For each mixture, a series of virgin specimens were left un-cracked as control.

3. METHODS

Self-healing capacity of the cracked specimens was evaluated by the normalized crack water absorption. The crack water absorption is defined as water sorption of cracked specimens minus that of the control specimen. The crack water absorption is then normalized by water absorbed by cracked specimens before water curing. A lower normalized crack water absorption denotes better self-healing capacity.

During the capillary water sorption test, specimens were dried and then side surfaces were coated with silicone. Afterwards, specimens were weighed and the cracked surface was brought into contact with water. At regular time intervals, the increase in mass, due to water sorption, was determined.

4. RESULTS

The crack number and width for the specimens of each mixture are shown in Table 2. As shown in Table 2, the crack width of specimens for M3 is much tighter; meanwhile, the crack number in the specimens of M3 is much more compared with that of the M1 and M2. This trend is similar to what Yang et al 2007 has observed in high volume fly ash ECC, which is a result of increased frictional bond due to high compactness of fly ash within the fiber interface zone [1].

Table 2: Crack information of specimens for capillary water sorption test

Specimens No.	M1.1/M2.1/ M3.1	M1.2/M2.2/ M3.2	M1.3/M2.3/ M3.3	M1.4/M2.4/ M3.4
Crack width (μm)	0 0 0	60 30 20	80 60 20	90 90 13
Crack number	0 0 0	1 2 2	1 2 7	2 3 7

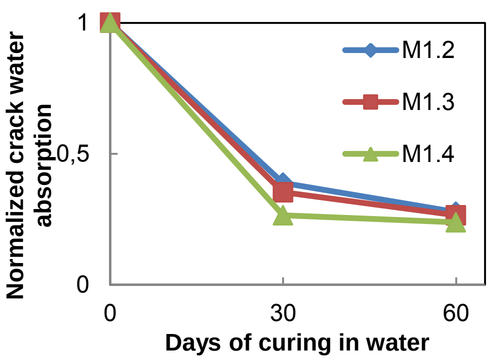
*M1.1-1.4, M2.1-2.4, M3.1-3.4 mean the specimens No. of M1, M2, M3, respectively.

Figure 1 shows normalized crack water absorption for each mixture undergoes self-healing process. After water-curing for 30days, the normalized crack water absorption for M2 scheme is larger than that of M1. There is no factor of crack width influence on self-healing effect, because the crack width for M1 and M2 scheme is so close that the crack width factor can be neglected. There it seems that increasing fly ash content is detrimental to self-healing capacity with the same crack width. The low cement content will influence the amount of hydration products which is necessary for the pozzolanic reaction of fly ash.
The comparison between M3 and M1, M2 shows the opposite trend. The normalized crack water absorption of specimens for M3 scheme reduces to 0.23， which is lower than M1 and M2. One possible explanation is that crack width of M3 is much tighter than that of M1 and M2 as shown in Table 2, and the tight crack is beneficial to self-healing behavior as demonstrated in previous studies. Compared with the benefits of tighter crack width for M3 scheme, the negative effect brought by increasing fly ash content is diminished.
Figure 2 shows the self-healing products in ECC crack under ESEM. In order to investigate the chemical nature of the self-healing products, specimens were examined using EDS. Table 3 suggests that the main healing product may consist of calcium carbonate and C-S-H. Therefore, the correct combination of cement and fly ash is critical for robust self-healing behavior.

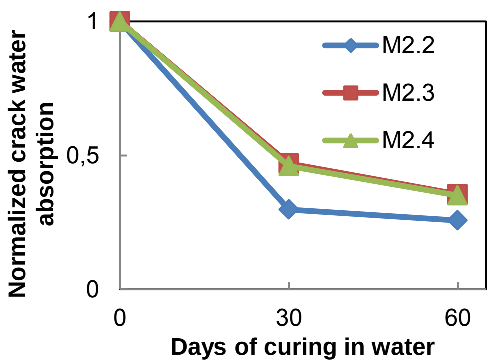
Table 3: EDS element analysis of self-healing product

Element	C	O	Al	Si	Ca	Fe
At %	15.96	56.17	4.06	9.13	12.55	1.16

*Elements with less than 1 atomic percent concentration not shown.



(a)



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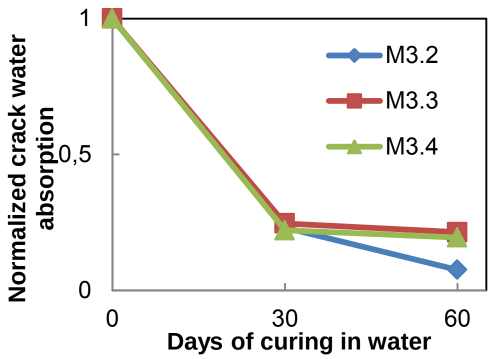

(c)

Figure 1: Normalized crack water absorption

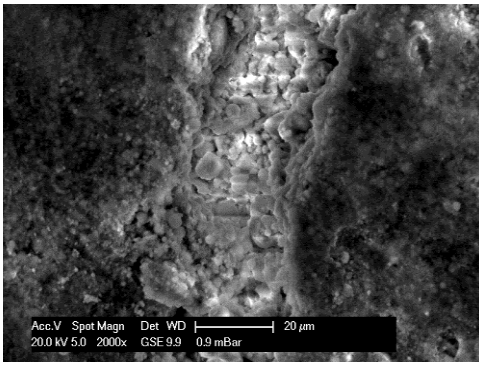

Figure 2: ESEM image of self-healing products in ECC crack

5. CONCLUSIONS

From this paper, it can be conclude that the self-healing capacity of ECC with the highest fly ash content is the best. The main self-healing product is calcium carbonate and C-S-H, denoting fly ash participate the self-healing process.

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