Trigger of self-healing process induced by EC encapsulated mineralization bacterium and healing efficiency in cement paste specimens

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ABSTRACT

A microbial self-healing system based on microcapsule technology for cementitous materials was established. Bacterial spores were encapsulated by using ethyl cellulose (EC). The evaluation of self-healing behavior of encapsulated mineralization bacterium in cement paste specimens was focused. The crack closure behavior of the specimens with/without bio-microcapsules was visually studied by light microscopy. A high resolution X-ray Computed Tomography (XCT) was used to visualize the self-healing process inside the specimens. The XCT results showed that formation of crack successfully triggered the breakage of embedded microcapsules. Compared with the specimens without embedded bacterium, the healed crack width of specimens embedded with bacterial microcapsules was bigger, suggesting effective self healing of concrete crack can be achieved by introducing encapsulated mineralization microorganisms into concrete structures.

1. INTRODUCTION

Bacteria induced calcium carbonate precipitation has been proven to be effective in concrete structure self-healing[1]. A microbial self-healing system based on microcapsule technology for cementitous materials is established in Guangdong Provincial Key Laboratory of Durability for Marine Civil Engineering, Shenzhen University. To confirmed the feasibility of the self-healing system, one important step is to verify the crack-healing process, mechanism and healing effectiveness. In this paper, we focused on the evaluation of self-healing behavior of encapsulated mineralization bacterium in cement paste specimens.

2. MATERIALS AND METHODS

Bacterial spores were encapsulated by using ethyl cellulose (EC), and then microcapsules were introduced into cement paste specimens during mixture period. After 14 days hydration period, the specimens were subjected to a splitting test to make crack. The crack closure behavior of the specimens with/without bio-microcapsules was studied quantitatively by light microscopy. To visualize the self-healing inside the specimens, a high resolution X-ray Computed Tomography (XCT) was used. Micro-morphology of healing material produced during the process was investigated by Environmental Scanning Electron Microscopy (ESEM) and X-ray energy dispersive spectroscopy (EDS). Furthermore, efficiency of self-healing performance was evaluated with healed crack width.

3. RESULTS AND DISCUSSION

In this study, self-healing behavior of encapsulated mineralization bacterium in cement paste specimens was investigated. The crack-introduced specimen with crack width from 20 to 50um was carefully studied to figure out the working mechanism of the trigger. It was shown in Figure 1 and Figure 2 that some microcapsules were fractured upon the formation of crack, indicating that the desired trigger system actually works. Subsequent production of calcium carbonate confirmed by EDS indicated activation of encapsulated mineralization bacterium.

The crack-healing process, mechanism and healing effectiveness were studied to evaluate the feasibility of self-healing system. Compared with the specimens without embedded bacterium, the healed crack width of specimens embedded with bacterial microcapsules was higher (Figure 3), suggesting effective self healing of concrete crack can be achieved by introducing encapsulated mineralization microorganisms into concrete structures.

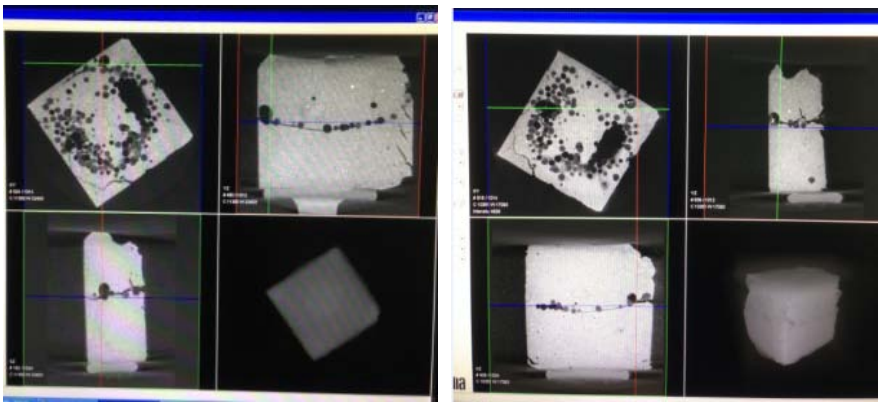

Figure1: Breakages of microcapsules upon cracking and subsequent healing procedure were visually monitored by XCT in three dimensions.

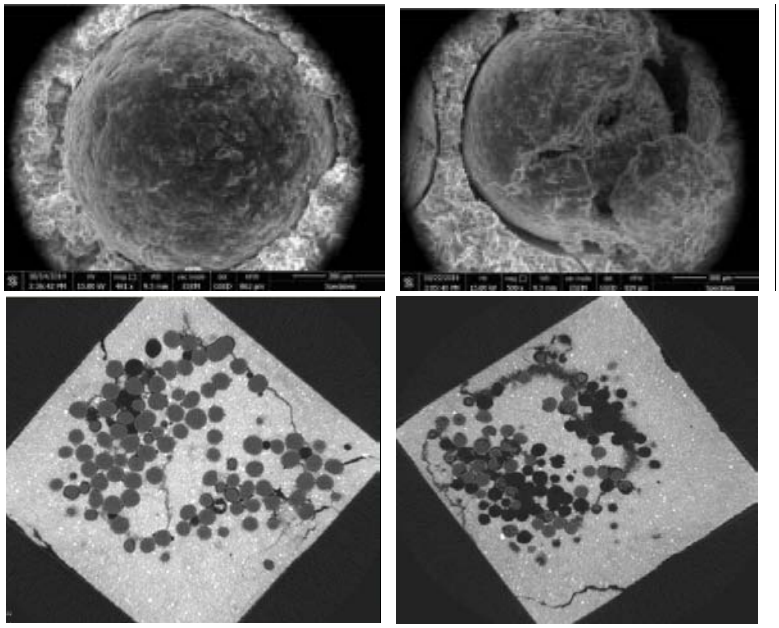

Figure 2: SEM images and XCT results of the microcapsule before and after triggered by formation of crack.

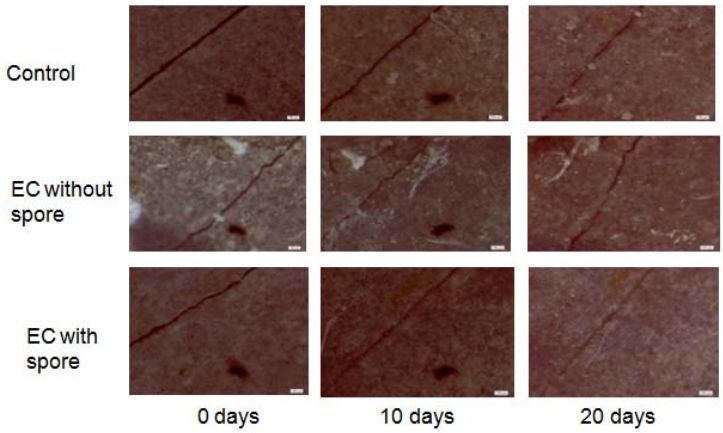

Figure 3: Breakage of crack and subsequent healing procedure was visually monitored by light microscope.

4. CONCLUSION

The healing concept of bio-microcapsules based self-healing system was demonstrated to be feasible. More specifically, the physical trigger system was proved to be viable. And the crack-healing process, healing mechanism and healing efficiency were investigated in the research. The experimental results manifest that the adopted bio-microcapsule based self-healing system is indeed suitable to fulfill the healing functionality in cementitious materials.

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