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Autogenous healing of engineered cementitious composites at early age

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ABSTRACT

Autogenous healing of early ages (3 days) ECC damaged by tensile preloading was investigated after exposure to different conditioning regimes: water/air cycles, water/high temperature air cycles, 90%RH/air cycles, and submersion in water. Resonant frequency measurements and uniaxial tensile tests were used to assess the rate and extent of self-healing. The test results show that ECC, tailored for high tensile ductility up to several percent and with self-controlled crack width below 60 µm, experiences autogenous healing under environmental exposures in the presence of water. However, the recovery for these early age specimens is not as efficient as the recovery for more mature specimen, for the same amount of pre-damage and exposure to the same environment. Even so, the self-healing for these early age specimens demonstrates high robustness when the preloading strain is limited to 0.3%. This conclusion is supported by the evidence of resonant frequency and stiffness recovery of the healed ECC materials.

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1. Introduction

High strength concrete with high cement content and a low water/ cement ratio has been developed with the availability of new generations of high-range water reducing admixtures in recent years. High strength concrete is expected to improve the structural performance and durability of reinforced concrete structures due to a dense microstructure that lowers water permeability and limits access of corrosives to steel reinforcement [1]. However, several investigations [2,3] revealed that high strength concrete structures experience early age cracking due to the increase of autogenous shrinkage and concrete brittleness. Early age cracks can have negative impacts on durability and the service life of reinforced concrete infrastructure. This has heightened concerns about early age cracking in high strength concrete in recent years and remains a technical challenge to the practice and research communities.

Several different strategies have been employed to control early age cracking of high strength concrete [4]. For structural engineers, efforts have been placed on detailing the rebar reinforcement, and increasing the reinforcing ratio and the arrangement of transverse or confinement reinforcement. For materials engineers various kinds of fibers, fiber mesh, shrinkage reducing agents, and curing admixtures have been adopted for crack control. These approaches are effective in certain situations but their efficacy and consistency remain to be proven in others. Therefore, it is highly desirable to develop concrete materials that automatically regain lost performance in mechanical and permeability properties after early age cracking. Such self-healing concrete should reduce repair needs and extend structural service life.

Self-healing of cracked concrete is an often-studied phenomenon. Two strategies for the promotion of self-healing have proven promising. One approach focuses on the embedment of capsules that contain self-healing compounds within the concrete material [5,6], while the other relies on a continuous dispersion of self-healing compounds (i.e., free calcium ions or unhydrated cement particles) intrinsic to the concrete matrix. The latter, often referred to as autogenous healing, has various advantages over encapsulation selfhealing [7], including economics, which is extremely important for the highly cost-sensitive construction industry. Autogenous healing is the research focus of the present study.

Previous researchers have studied the necessary conditions for autogenous healing in concrete materials. These studies have resulted in identifying three general criteria critical to robust self-healing: the presence of specific chemical species [8–14], exposure to various environmental conditions [12,14–20], and small crack width [8,9,15,21–23].

Autogenous healing can occur in a variety of environmental conditions ranging from underwater immersion to cyclic wet–dry exposures. These conditions are practical for many infrastructure types, particularly for transportation infrastructure. Hence this criterion for robust self-healing can be easily satisfied.

The second criteria – the need for adequate concentrations of certain critical chemical species, is also readily satisfied, at least for concrete mixes with high cement content, due to the presence of a large amount of unhydrated or partially hydrated cement grains. As well, the presence of CO_2 in air and NaCl in seawater and deicing salt are elements that support self-healing.

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