DEVELOPMENT OF BACTERIALLY-MEDIATED SELF-HEALING IN ENGINEERED CEMENTITIOUS COMPOSITES

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ABSTRACT

Cracks are unavoidable throughout the lifetime of a concrete structure. Many factors, including excessive loading and harsh environmental conditions, can lead to the initiation and propagation of cracks. Cracking not only negatively impacts the mechanical properties of a concrete structure, but it also lowers the durability by creating pathways for harmful agents to penetrate the surface of the structure. Therefore, the development of a concrete material that can regain this loss in durability and mechanical properties would both increase the safety of concrete structures and eliminate the need for costly and time-consuming repairs.

Engineered Cementitious Composites (ECC) are a class of fiber reinforced cementitious materials that have been optimized through the use of micromechanics to achieve high tensile ductility and tight crack widths. ECC has a tensile strain capacity of 3-5% and forms multiple microcracks, typically less than 60 mm, under tensile loading [1]. These tight crack widths are an intrinsic material property of ECC and promote robust self-healing behavior that is not easily attainable in brittle concrete.

Although self-healing in current ECC materials occurs to a reasonable extent, there is room for improvement. It has been found that complete self-healing does not always occur. This means that cracks larger than 20-30 mm are not entirely filled with healing products and there is not a complete regain in mechanical properties after healing is allowed to occur [2,3]. In order to improve the self-healing capacity of ECC, calcite-producing spore-forming bacteria are being used to investigate the potential to increase both the amount and rate at which the self-healing products form.

Bacterial spores and organic growth substrates have been incorporated separately into the ECC matrix to evaluate the impacts on the characteristic properties of ECC. Since ECC is known for its ductility, it is important that the biomass and growth substrates do not hinder the multiple cracking behavior and tensile strain capacity of the ECC material. In addition to these properties, the incorporation of biomass and substrate must not significantly reduce the compressive or tensile strength of the ECC.

Three *Bacillus* strains, *B. agaradhaerens, B. cohnii, and B. clarkii*, were selected based on previous research [4] and their ability to produce spores and tolerate highly alkaline environments. Optimal pH and temperature range for growth, as well as sodium chloride tolerance were also considered. In order to evaluate the effects of incorporating biomass into the ECC matrix, *B. agaradhaerens* spores were generated in liquid media, washed, and suspended in the ECC mix water prior to mixing and casting of the concrete specimens. Preliminary uniaxial tensile test data for 7-day specimens indicates that the incorporation of biomass does not negatively impact the mechanical properties of ECC. However, more extensive compression and tensile tests will need to be performed at 28-days in order to confirm these preliminary results.

Calcium lactate was chosen to study the effects of incorporating organic growth substrates into the ECC matrix. The amount of substrate added was equivalent to 0.08 and 0.8% of the weight of the ECC mix. It was found that 7 and 28-day specimens containing calcium lactate performed better than the

ECC control samples. While the incorporation of substrate did not seem to alter the compressive strength of the ECC, tensile specimens containing calcium lactate had higher first cracking strengths, ultimate strengths, and strain capacities than the controls (Figures 1 and 2). This increase in performance is attributed to the increased amount of calcium ions from the calcium lactate. These ions were most likely consumed during the pozzolanic reaction, leading to the production of additional C-S-H gel within the ECC matrix. In addition to improved mechanical properties, these mixes also had much tighter crack widths than the control samples, indicating a stronger bond between the fibers and surrounding matrix.

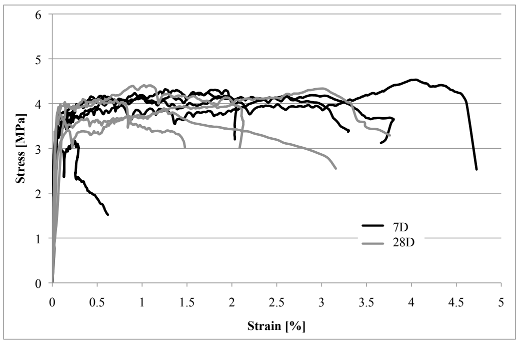
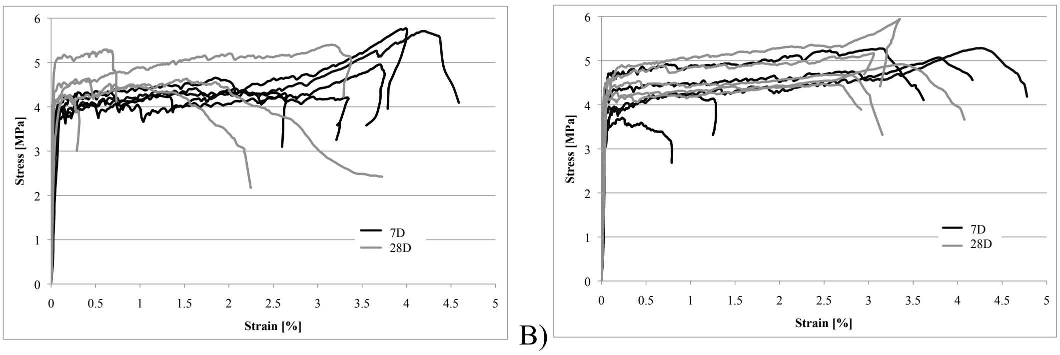


Figure 1: Uniaxial tensile data for ECC controls



A) B)

Figure 2: Uniaxial tensile data for ECC samples containing calcium lactate. A) 0.08% B) 0.8%

Cracks are unavoidable throughout the lifetime of a concrete structure, and these cracks lead to safety concerns and costly repairs. Therefore, the potential to use bacterially-mediated self-healing in ECC is being investigated. It has been found that the addition of bacterial spores and calcium lactate do not negatively impact the mechanical properties of current ECC materials, so they can be utilized for further investigation of bacterially-mediated self-healing.

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