Determination of the Optimal Parameters for Self-Healing Efficiency of Encapsulated Bacteria in Concrete in a Simulated Subtropical Climate

Determining the parameters for encapsulated bacteria in concrete to grow in a simulated environment

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Principal Investigator(s):

Momen Mousa

Louisiana State University

mragab@lsu.edu

Marwa Hassan

Louisiana State University

marwa@lsu.edu

Gabriel Arce

Louisiana State University

garcea1@lsu.edu

Lead Institution:

Louisiana State University

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$135,000

Concrete is one of the most used construction materials in the world. While strong in compression, its weak tension makes it susceptible to cracking and thus exposes steel reinforcement to harmful agents that can cause corrosion. The latest infrastructure report card from the American Society of Civil Engineers (ASCE) has determined that the US civil infrastructure is poorly maintained, with insufficient funds to improve roadways and bridges in the nation, thus earning a D+ grade. Poor funding has steadily increased the backlog of new construction, repair, and maintenance, up to $836 billion for highway and bridge infrastructure. There is a clear need to increase the durability of construction materials to reduce repair and maintenance. A promising solution proposed is the implementation of self-healing concrete technologies. Examples of this technology includes the implementation of expansive mineral admixtures, chemicals in glass tubing or microcapsules, bacteria, and self-controlled tight-crack width cementitious composites such as Engineered Cementitious Composites (ECC). These strategies are promising in sealing hairline cracks autonomously; yet the crack-healing effectiveness of these systems are very dependent on the crack size. Among the self-healing concrete technologies available, bacterial concrete has emerged as the most promising alternative because it can seal crack widths up to 1 mm wide without human intervention. This is done through a process known as Microbial Induced Calcite Precipitation (MICP), by embedding alkali-resistant bacterial spores in concrete that spur calcium carbonate to seal cracks. The success of the MICP reaction depends on water, a mineral precursor compound and nutrient for the bacteria (admixed in concrete), and a calcium source (readily available). In addition, these bacterial spores are not dangerous to humans, and can stay dormant for up to 200 years.

Problem Statement

Reinforced concrete's susceptibility to cracking can considerably reduce the durability of infrastructure through corrosion. Currently, patching materials and waterproofing membranes are commonly used for crack-sealing. Yet, due to funding limitations, it is difficult to afford the costly and labor-intensive evaluation, maintenance, and repair needed throughout the service life of structures. Therefore, to address this problem economically, researchers have proposed self-healing concrete materials. Bacterial concrete has become one of the most promising self-healing alternatives due to its capability to autonomously heal large cracks.

Objectives

This research study aims to optimize self-healing methods of encapsulated bacteria in concrete, and to assess whether a higher bacteria cell concentration, better nutrient selection, or an alternative encapsulation method is required. These parameters will be first tested in mortar beams with respect to self-healing efficiency, and depending on the results, further testing will be done in concrete specimens. The efficiency of the proposed bio-concrete will be tested to evaluate the bacteria's effect on concrete's inherent properties like compressive strength and static modulus of elasticity, and monitor the self-healing efficiency through crack repair through 28 wet-dry cycles (consisting of 8 hours of water immersion and 16 hours of drying). If successful, this project will move field-testing in Region 6, where it can help enhance the performance of the concrete transportation infrastructure.

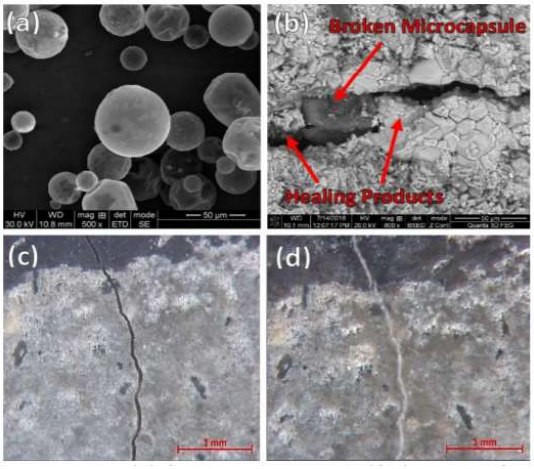

Figure 1: (a) Secondary Electron (SE) Image of Microcapsules (b) Backscattered Electron (BSE) Image of a Broken Microcapsule Intersecting a Crack in Cement Mortar (c) Cracked Cement Mortar (d) Autonomously Healed Crack in Cement Mortar with Microcapsules after 7 Wet/Dry Cycles

Intended Implementation of Research

Workforce Development and Education: This research project will fund one graduate student at Louisiana State University and will help prepare future leaders in transportation, including high school and undergraduate college students, through symposiums and demonstrations. Results of this work will also be disseminated in national conferences and journal publications. In addition, this project will demonstrate the use of an encapsulator (BUCHI Encapsulator B-390 for which a larger, industry-level device is also available) and associated technologies in future real-world concrete applications. In addition, educational material to be incorporated into LSU courses will be prepared.

Outreach: The research findings will be shared to the public in the form of seminars and YouTube videos. Furthermore, the technology used for this project will be showcased at related educational or workforce venues.

Impacts

The main deliverables from this study are: (1) a final report will be delivered with the details of the factors that would maximize the self-healing mechanism of encapsulated bacteria in concrete in a Simulated Subtropical Climate. The report will include a complete description of the problem, approach, methodology, findings, conclusions, and recommendations, (2) an implementation report will be delivered at the end of the implementation phase using the TranSET template for implementation reports. The Implementation Report will include a complete description of the developed products from the education, T2, and workforce development activities that were executed during the implementation phase of this project.

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.