Ohio Department of Transportation
ORIL Research Project Fact Sheet

Analysis of Mitigating Concrete Cracks with Bacteria

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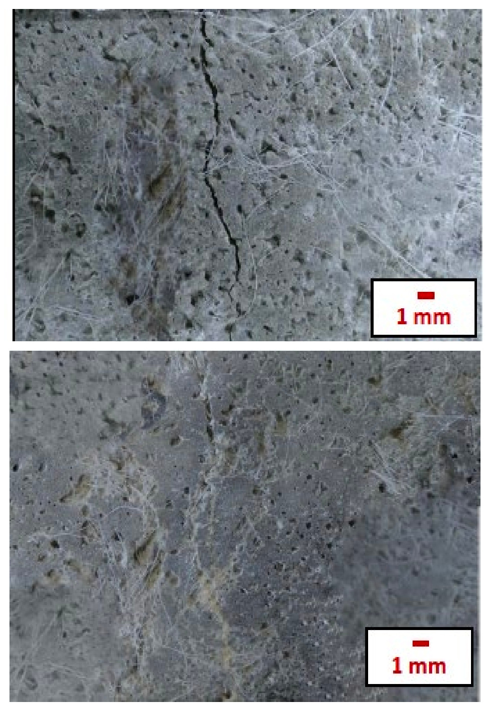
The Problem

Despite considerable improvements in concrete mixture design, production, placement, and curing cracking continues to be a significant issue in concrete construction. Incorporating bacteria capable of precipitating calcium carbonate into the concrete mixture may help mitigate the negative impacts of concrete cracking, while also leading to increased strength and durability through microstructure densification. If successful and cost-effective, this method could provide an opportunity to reduce maintenance and repair activities and the associated costs. However, many questions surround use of bacteria in concrete systems. This research attempted to answer the questions:

- Can we heal concrete cracks with bacteria?
- Can we produce “better” bacteria for crack healing from the local environment?
- Can we use existing concrete mixture designs successfully for bacterial concrete mixtures?
- How do we cure the concrete to induce crack healing?
- How do environmental stressors like heat, cold, and salt affect the bacterial system?
- How much does incorporating bacteria into concrete cost?

Research Approach

To address the limitations in knowledge associated with use of bacteria in concrete to prevent cracking, this project investigated the influence of a variety of bacterial systems, including ones produced using local Ohio cement and fly ash, mixture designs, curing, and exposure conditions, to determine bacterial system efficiency over time, and optimum growth conditions. To prove the ability of the systems to be upscaled to more realistic production sizes, and realistically examine many of the factors affecting in-situ placements, concrete pavement mixtures (in the form of a sidewalk) were cast using an ODOT QC1 mixture, exposed to the Ohio environment, and tracked over the second year of the project, to establish viability of the system when exposed to real-world environmental conditions.



Cracked *B. Subtilis* bacteria mortar before and after healing

Findings

Can bacteria heal concrete cracks?

Yes → Bacteria were able to heal cracks in mortar samples if samples were sprayed daily with additional nutrient solutions over 6-8 weeks.

Can we produce “better” bacteria from the local environment? Maybe → Bacteria produced from local soil samples did successfully heal cracks but was generally outperformed by the standard bacteria (*B.*

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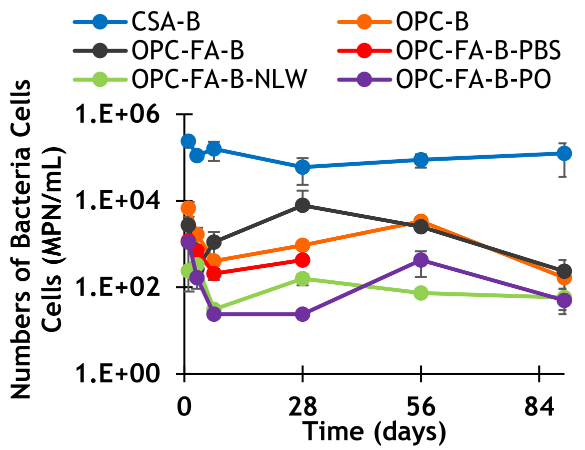
subtilis). The slight cost savings associated with the environmental sample doesn't appear worth the performance reductions and potential system variability. Still, it is possible that other starting materials or locations may provide better, more resilient strains of bacteria.

Can we use existing concrete mixture designs successfully for bacterial concrete mixtures?
Yes and No → Fly ash and tap water did not reduce bacteria numbers. However, non- or de-chlorinated water must be used. | Bacteria must be mixed in using a protective media. Here bacteria were sorbed into a small amount of lightweight sand. | CSA cement increased the numbers of bacteria surviving in samples by 100x that of OPC, and could lead to longer periods over which crack healing would be successful. | Bacteria had little effect on concrete compressive strengths, nor resistance to freezing and thawing. Some improvements in permeability in bacteria mixes were evidenced by reduced water absorption.

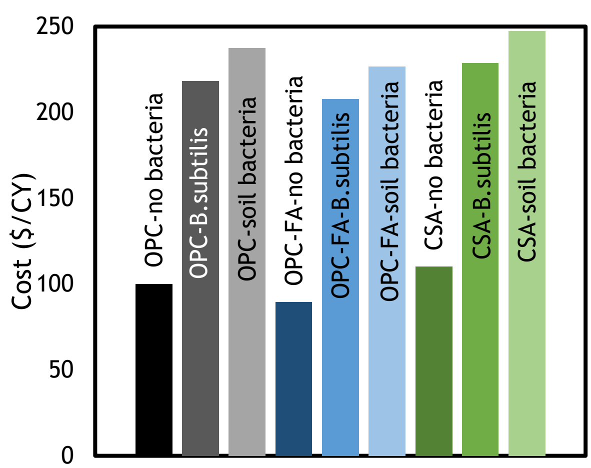


Viability of *B. subtilis* bacteria in mortar cubes. PO: cured by ponding in nutrient solution, PBS: saline solution use in lieu of mixing water, NLW: lightweight sand not used.

How do we cure the concrete to induce crack healing? Nutrients and hydration for the bacteria were applied by spraying in a manner similar to application of curing compound. Samples cured by ponding retained fewer living bacteria and did not demonstrate significant crack healing.

How do environmental stressors like heat, cold, and salt affect the bacterial system? All environmental stressors reduced bacteria numbers and prevented successful crack healing.

How much does incorporating bacteria into concrete cost? Initial concrete materials costs are approximately double that of non-bacterial mixes.



Cost of concrete with and without bacteria

Recommendations

Use of an axenic bacteria, in this case *B. subtilis*, is recommended over a local environmental culture.

Existing concrete mixtures utilizing OPC, CSA (more typical in rapid repairs) and fly ash will not harm bacteria, but lightweight aggregate, or another protective media MUST be used to protect bacteria from initial harsh mixing conditions.

Ideally bacterial mixes should be placed in spring or fall to avoid high or low temperatures which resulted in cell death and reduced crack healing potential.

Incorporation of bacteria in concrete may be a feasible approach to reducing early age plastic shrinkage cracking in concrete flatwork. Strong evidence of crack healing and reduction in water infiltration into cracks was provided in this study. However, additional work is needed to understand minimum cell concentrations required to ensure crack healing ability in in-situ installations and to refine and scale bacterial solution production.

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