# Experimental Investigation of the Self Healing Potential of Bacteria for Sustainable Concrete Structures

Project 2239
May 2023

Pitiporn Asvapathanagul, Simone Galano, Andrea Calabrese, Mehran Rahmani
Maggie Ly, Daniela Flores, Michael Hernandez, Nicholas Banuelos

## Introduction

Concrete is the most widely used building material in the world, but—due to its limited tensile strength—cracking is a common phenomenon in concrete elements. Cracks may affect the durability of concrete structures by allowing potentially harmful liquids or gasses to sink in. Additionally, the steel reinforcement within concrete elements may be affected by degradation phenomena, such as corrosion. Increasing the service life of concrete structures is a key task of civil engineering, and self-healing is an eco-friendly and low-cost method to increase the durability of concrete. This work aims to study an autonomous self-healing technique. The crack-healing potential of different types of high-alkaline-tolerant bacteria or calcite-precipitation microorganisms is investigated. The outcomes of experimental tests on concrete samples healed with biological processes demonstrate how this technique can be implemented when retrofitting durability-enhanced, eco-friendly concrete structures to improve the strength of durability of the material.

## Study Methods

High-alkaline-tolerant bacteria and calcite-precipitation microorganisms were used to retrofit lab-fractured concrete samples. The samples healed with each of these bacteria groups were cast and tested under compressive load up to failure to measure the compressive strength of the concrete samples.

For the manufacturing of the samples, the 90-lb (40.8 kg) QUIKRETE® ready-to-use concrete mix was used. This is a pre-blended mixture of cement and aggregates, requiring only the addition of water. The concrete was mixed in a Portable Concrete Mixer. As per the manufacturer's recommendations, 3.96 L of water were gradually added to the concrete mix, which was mixed for 5 minutes.

The concrete mixture was cast into 4" x 8"-cylinder molds (101.6 mm x 203.2 mm) to obtain samples of the required dimensions. The ASTM (American Society for Testing and Material) C31 – Making and Curing Concrete Test Specimens in the Field procedures was referenced.

Following ASTM C511 requirements, after an initial curing, all the concrete samples were positioned in curing tanks filled with water saturated with calcium hydroxide. All the tanks were located inside a curing room with a temperature of 73.5 degrees F. During initial curing, the cylinders were stored in a curing room and were not exposed to sunlight or heating for 48 hours. For all samples, curing in water lasted 28 days.

After curing, 77 samples of concrete were ready to be tested. Compression tests were performed at the College of Engineering of the California State University, Long Beach, using the Humboldt HCM-500-iHA Compression Testing machine.

## Findings

The research team measured the average compressive strength of each set. The strength of the samples subjected to the self-healing procedures were compared to the compressive strength of a control set. The team observed how self-healing procedures with Bacillus subtilis, Pseudomonas stutzeri, and Sporosarcina pasteurii increased the average compressive strength of the concrete samples, while in the remaining the self-healing procedure with Bacillus megaterium did not prove to be effective in increasing the mechanical properties of the material.

The standard deviation and the coefficient of variation of the compressive strengths were also reported for each tested set. These parameters showed how a slight dispersion resulted in computing the compressive strength of the single sample of the generic set because of the different failure modes observed during the experimental tests.

Finally, a discussion on the elastic and ultimate responses and the ductility of the concrete sets were also reported. All the self-healing treatments increased the ultimate compressive strain of the samples, reducing the elastic moduli at the same time. The ductility of the concrete appeared to be improved by self-healing with Bacillus megaterium and Sporosarcina pasteurii, while Bacillus subtilis and Sporosarcina pasteurii play a minor role in this parameter.

The results of this work can contribute to the diffusion of sustainable concrete structures with the ability to fix cracks autogenously or autonomously.

The *BacteriaL Bacillus subtilis, Pseudomonas stutzeri*, and *Sporosarcina pasteurii* increased the average compressive strength of concrete when given time to heal.

## Policy/Practice Recommendations

Practice recommendations include the implementation of methods to create consistent artificial cracks in concrete specimens. The method should be replicable on all specimens consistently to minimize crack and strength variations across samples. Another recommendation is maintaining a consistent time between all manufacturing and testing procedures. This ensures all samples are cured for the same amount of time under the same conditions and are tested after the same amount of time. Minimizing variations in manufacturing and testing procedures allows for consistent samples that produce representative data. These recommendations reduce variations in the data, which allows for more accurate analysis of the healing effects bacteria have on the concrete samples.

## About the Authors

**Dr. Pitiporn Asvapathanagul** is a faculty member in the Civil Engineering and Construction Engineering Management Department at California State University, Long Beach.

**Dr. Simone Galano** is a Visiting Scholar in the Civil Engineering and Construction Engineering Management Department at California State University, Long Beach.

**Dr. Mehran Rahmani** is a faculty member in the Civil Engineering and Construction Engineering Management Department at California State University, Long Beach where he focuses on structural system identification, structural health monitoring and earthquake damage detection of buildings using sensory data.

**Maggie Ly** is a post-graduate student in the Civil Engineering and Construction Management Department at California State University, Long Beach.

**Daniela Flores**, **Nicholas Banuelos**, and **Michael Hernandez** are all undergraduate research assistants at California State University, Long Beach.

**Dr. Andrea Calabrese** is a faculty member in the Civil Engineering and Construction Engineering Management Department at California State University, Long Beach whose current research interested include experimental testing, structural dynamics, base isolation, vibration engineering, and in the development of novel low-cost devices for the seismic protection of buildings.

## To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2239

MTI MINETA TRANSPORTATION INSTITUTE

MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.