Contribution ID: **198** Type: **Oral Presentation**

Assessing the strength of biomineral strategies for concrete repairs.

Tuesday, 23 May 2023 10:00 (15 minutes)

Worldwide production of concrete is estimated to be responsible for approximately 8.6% of all CO2 emissions originating from human activity [Miller et al., 2016]. Many countries, including the UK, now have ambitious targets to achieve net zero greenhouse gas emissions. To achieve these targets, the construction industry needs to transform its use of materials and approaches to asset management, with a shift towards extending the lifespan of existing structures, rather than constructing new ones.

Microbially Induced Carbonate Precipitation (MICP) is a novel engineered process in which ureolytically active bacteria trigger the catalysis of urea, resulting in the formation of calcium carbonate crystals. MICP shows promise for a wide range of engineering applications including rock fracture grouting, soil strengthening and for stone and concrete repair.

The aim of this research is to develop a mesoscale Finite Elements Model (FEM) to predict the mechanical behaviour of MICP-treated concrete. In order to calibrate the FEM model, MICP treatment and tensile strength tests were conducted on concrete cores.

Seven cylindrical concrete specimens were drilled from a caisson acquired from docks in Devonport, England. Subsequently, the cores were artificially cut along their vertical length creating a single fracture within each core. A variety of filling scenarios were investigated: (i) open fracture with glass bead spacers (500µm in diameter) only present at corners, (ii) patches of glass beads within the centre of the fracture, (iii) fully packed with glass beads, (iv) fully packed with silica sand grains, and (v) fully packed with carbonate sands.

Cores were subjected to multiple treatments of MICP. Each treatment included the injection of *Sporosarcina Pasteurii* (highly ureolytically active bacteria) followed by injection of a cementing solution consisting of calcium chloride and urea. Core permeability was monitored after each treatment cycle. Treatment was stopped once a 2-order of magnitude reduction in permeability was observed. After treatment, the cores were subjected to X-ray Computed Tomography (XCT) scanning and image analysis was conducted to evaluate the amount and spatial distribution of contact points created by calcium carbonate precipitation bridging across fracture surfaces. Following XCT imaging, the cores were loaded under Brazilian test conditions to evaluate tensile strength. After failure, the patterns of calcium carbonate precipitation on the surfaces of the fracture were inspected, validating the results derived from image analysis.

The experimental results show that the mechanical strength of the MICP-treated cores is governed by the amount of calcium carbonate precipitation which bridges across from one fracture surface to the other. A FE model simulating tensile loading has been developed which can be used to predict the mechanical behaviour of MICP-treated concrete as well as to better understand the influence of MICP treatment strategies on mechanical strength recovery.

Participation

In-Person

References

SabbieAMiller, Arpad Horvath, Paulo J M Monteiro. Readily implementable techniques can cut annual CO_2 emissions
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Session Classification: MS05

Track Classification: (MS05) Biochemical processes and biofilms in porous media