Effect of Biocementation on Shear Modulus

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Introduction

Enzyme Induced Calcite Precipitate (EICP) is a bio-inspired ground improvement method used to enhance the mechanical properties of undesirable subsurface materials, such as loose sands and silts. This method employs urease enzymes to catalyze a chemical reaction that induces supersaturation through the consumption of urea, leading to the precipitation of calcium carbonate (calcite cement/biocement) that bonds the grains at their contacts. This research aims to understand the effects of biocement on the dynamic mechanical behavior of EICP biocemented sands by determining their shear modulus (shear stiffness) and damping. The study will utilize a resonance column device, allowing the variation of cementation, confinement, and stiffness, and damping. The study will utilize a resonance column device, allowing the variation of cementation, confinement, and density in a laboratory testing environment.[1]

Objective: Our research objective was to determine the effects of Biocementation on Shear Modulus and Damping curve.

Background

The process of biocementation begins with the hydrolysis of urea to form carbonate and ammonia. This is shown in equation 1. The solution for cementation is determined by adding calcium chloride dihydrate. The presence of enzyme enzymes not only aids in hydrolysis, but also contributes to the formation of calcite crystals (CaCO3) that form between the sand particles.

\[ CO(NH_2)_2 + H_2O \rightarrow CO_2^- + 2NH_4^+ \]  
\[ CaCl_2 \rightarrow Ca^2+ + 2Cl^- \]  
\[ Ca^2+ + CO_2^- \rightarrow CaCO_3 \]

Methods & Results

(1) Resonant Column Device: A resonant column test is a geotechnical test that helps determine the dynamic properties of soil, i.e., Shear Modulus (G) and Damping, by applying torsional vibrations in which a laser detects the resonance frequencies and a linear variable differential transformer (LVDT) measures the displacement. It is composed of an enclosed soil column that is passively fixed on the bottom end (no torque) and an active end that applies a vibrational torque as shown below.

Figure 1. (a) Soil sample within confinement chamber. (b) Motor of RC device.

(2) Enzyme Crude Extract: Crude extract is the separation of compounds from a natural source. Jack beans, canavalia ensiformis, is used to extract the desired enzymes called urease which is needed for the cementation. Urease extract is attained by the following:

i. Jack beans are placed in deionized water overnight and then blended to disrupt the cells.[1]
ii. The aqueous solution is filtered using cheesecloth fabric to remove the coarse solids from enzyme solution.
iii. Centrifuged the enzyme solution to 11,000rpm for 21 minutes to extract the enzymes.

Figure 2. (a) Image of jack beans, used for EICP. (b) Crude extract of enzymes from the jack beans after centrifuge.

(3) Data Analysis: After gathering data in the lab, I analyzed and plotted the information using Excel and Python. I learned to filter specific data from large documents (over 100,000 rows) in Excel and used Python for plotting. Resources like Khan Academy were instrumental in understanding Python and generating code.

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Results Analysis

Cemented specimens exhibit greater stiffness compared to uncremented ones. As shown in Figure 3, biocemented specimen have almost 5 times greater strength after cementation as compared to uncemented sand. This increase is attributed to the lower void volume after cementation, and also the bonds of calcite which binds the soil particles together and make it behave like a sandstone.

Next Steps for You & Advice to Future SHINE participants

I plan to leverage my lab experience and skills to guide me as I determine my specific focus within the STEM field. I would encourage future SHINE students to build strong relationships and seek guidance from their professors, mentors, and lab peers.

Citations
