PhD Open Days

Design of soil biocementation strategies using biological activity monitored with biosensors

PhD PROGRAMME IN CIVIL ENGINEERING

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Objectives

Develop strategies to predict the hydro-mechanical properties of the treated material using data from in situ monitoring of biocementation treatment.

- optimize biosensors for urease detection as a monitoring tool for biocementation;
- define relationships between the amount of calcium carbonate and relevant soil engineering properties (stiffness, strength and permeability);
- relate the biosensors readings with the engineering properties of the treated soil, the bacterial activity and the amount of biocement.

Biocementation

Biocementation consists in using bacteria to produce calcium carbonate. The most stable form is calcite mineral (biocement). The biocement bonds the grains and clogs the soil pores, improving the hydro-mechanical properties of the soil (permeability, stiffness and strength).

Urea hydrolyzes:
$CO(NH_2)_2 + 2H_2O \rightarrow CO_3^{2-} + 2NH_4^+$

Calcium carbonate precipitation:
$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3 \downarrow$

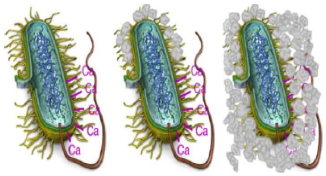

FIGURE 1: Chemical equation of the biocementation processes (left) and scheme of bacteria S. pasteurii producing biocement (right)

Biocement is more environmentally friendly than traditional techniques. C8/10 concrete releases 75.6 $kg\ CO_{2-eq}/ton$, even with a low content of Portland cement, on the other hand, biocement releases between 11.6 – 24.4 $kg\ CO_{2-eq}/ton$ of greenhouse gas emissions (Røyne, 2017).

Monitoring tests and measurements

Outflow liquid samples:
- pH measurment
- Indirect measurement of Urease Activity
- Urease concertation measured with a magnetoresistive biochip platform

Cylindric sand samples:
- Unconfined compression test
- Consolidated undrained triaxial compression test

Small sand samples:
- Scanning electron microscope (SEM)
- X-ray Diffraction (XRD)
- Mercury Intrusion Porosimetry (MIP)
- Calcium Carbonate Content (CCC%)
- Wax Immersion Test

FIGURE 2: Triaxial test

Experimental setups

Biocemented sand samples
An experimental setup was developed to produce several biocemented sand samples with different levels of treatment and allowing to visualize the precipitation of calcium carbonate.

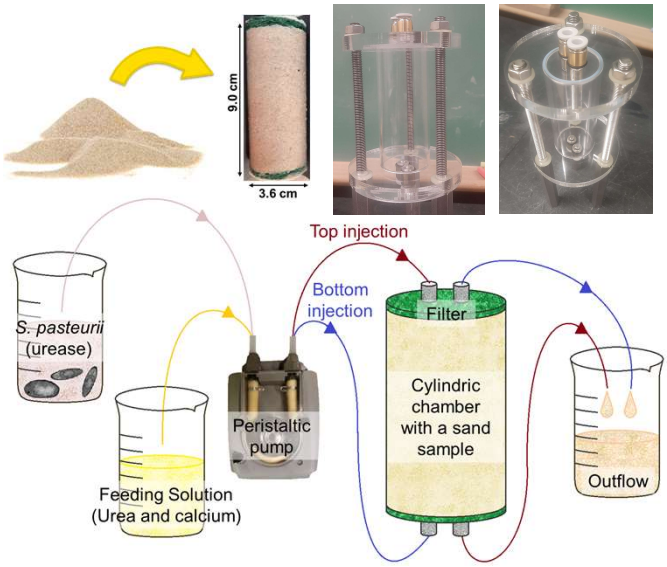

FIGURE 3: Cylindric biocemented sand sample (before and after treatment) (top, left); transparent cylindric chamber for biocementation (top, right) and scheme of the experimental setup

Magnetoresistive biochip platform
A biochip is being optimized to measure the concentration of enzyme urease in the fluid purged from the soil, in which the urease is not purified. The detection is based in a sandwich ELISA assay. The readings from the magnetoresistive biochip platform will allow monitoring the treatment in progress.

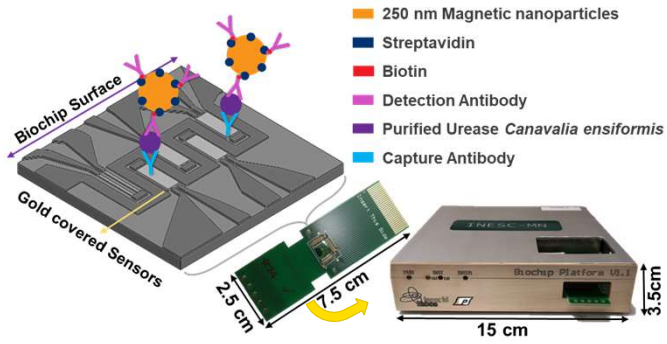

FIGURE 4: Scheme of sandwich ELISA detection method (left); biochip sensor mounted on a green printed circuit board (middle) and platform (right)

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