Stimulating In-Situ Soil Bacteria For Bio-Cementation

PEER Internship Program – Summer 2012

Soil Interactions Laboratory
UC DAVIS

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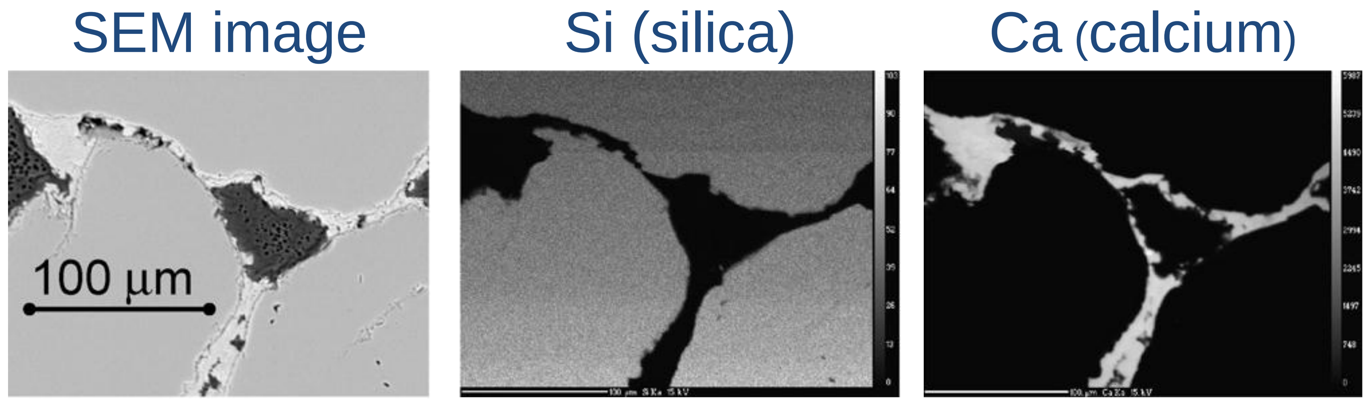
Overview

Microbial Induced Calcite Precipitation (MICP), or bio-cementation, has been shown to drastically reduce liquefaction potential in sands by reducing permeability, increasing shear strength, and increasing stiffness as evident in increased shear wave velocity. Currently, there is a field trial of MICP in Northern Canada to assess the feasibility of large scale testing using foreign calcite precipitating bacteria injected into the soil. This research project aims to answering the following question: Can the in-situ bacteria can be stimulated to precipitate calcite, while avoiding chemical crash out in the pore fluid?

SEM image | Si (silica) | Ca (calcium)



Background

MICP occurs through two primary reactions. The first reaction is hydrolysis of urea by bacteria containing urease enzymes.

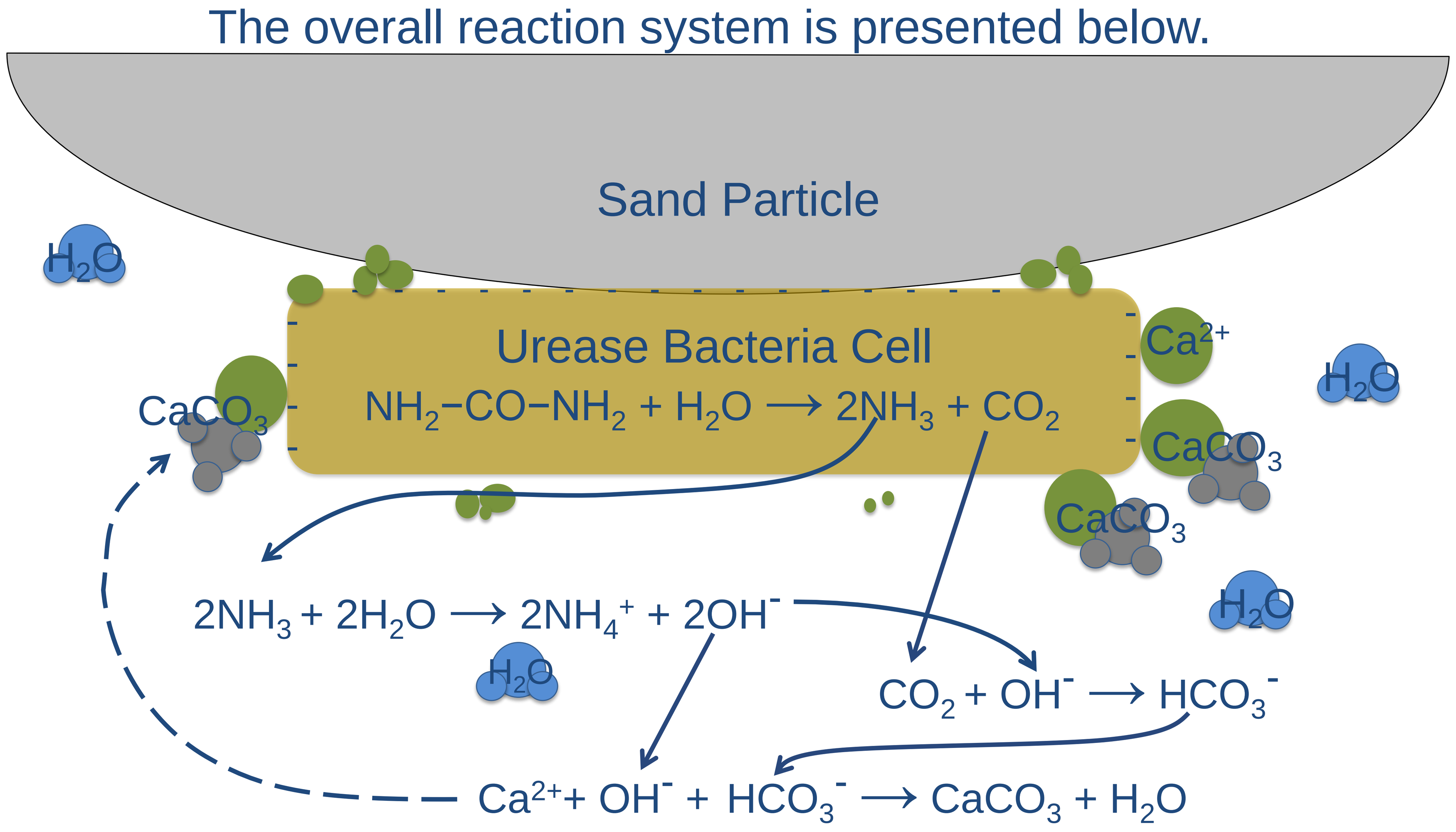
$$NH_2-CO-NH_2 + 2H_2O \rightarrow 2NH_3^+ + HCO_3^- + OH^- \quad (1)$$

When calcium is injected into the pore fluid, a second chemical reaction results in the precipitation of calcite ($CaCO_3$).

$$Ca^{2+} + HCO_3^- + OH^- \rightarrow CaCO_3 + H_2O \quad (2)$$

This precipitation of calcite at the grain boundaries of sand particles can be correlated to increases in shear wave velocity using piezoelectric transducers.

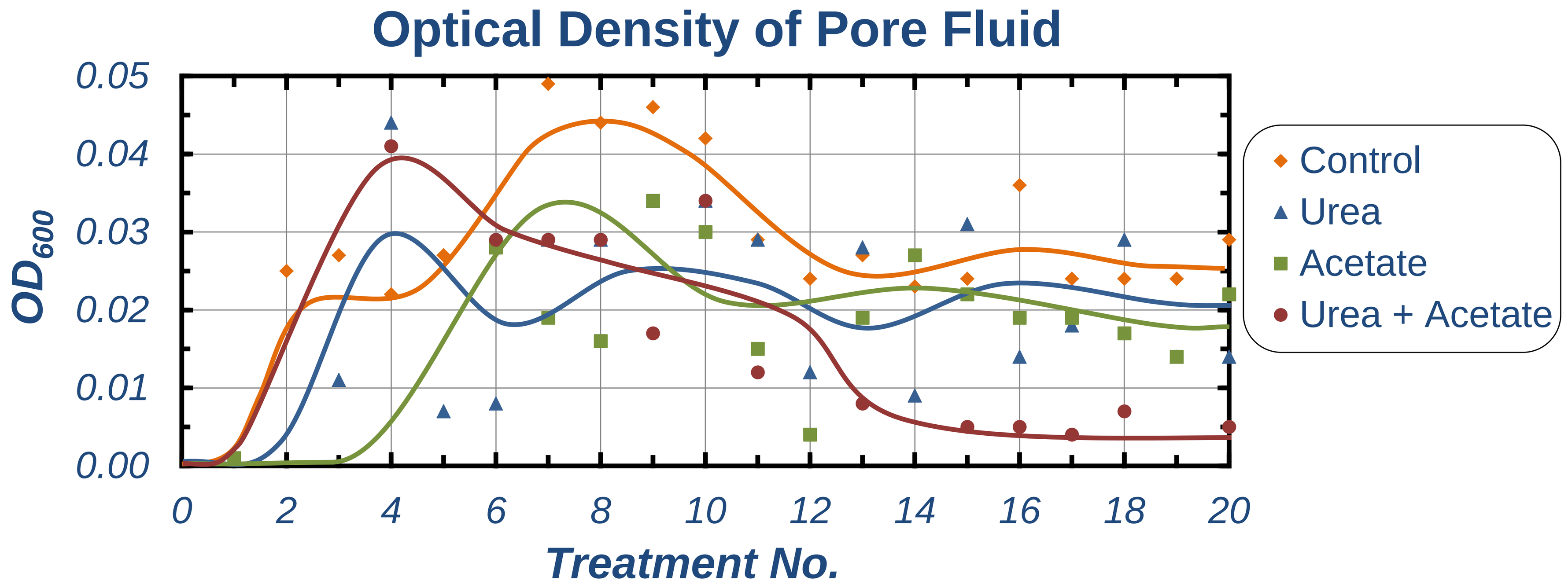
The overall reaction system is presented below.



Bacterial Growth

Treatments at twelve hour intervals for ten days were used to stimulate in-situ bacteria. The growth and activity were monitored using Optical density, pH and bacterial plating of the pore fluid and effluent.

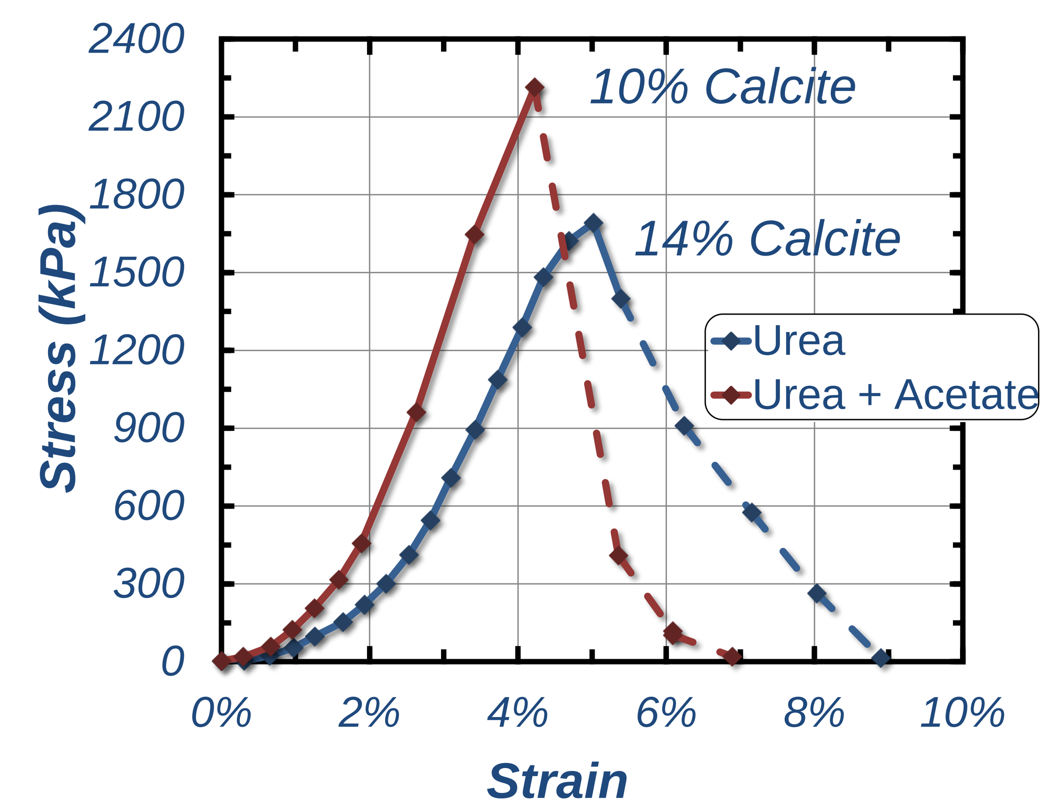
Optical Density of Pore Fluid



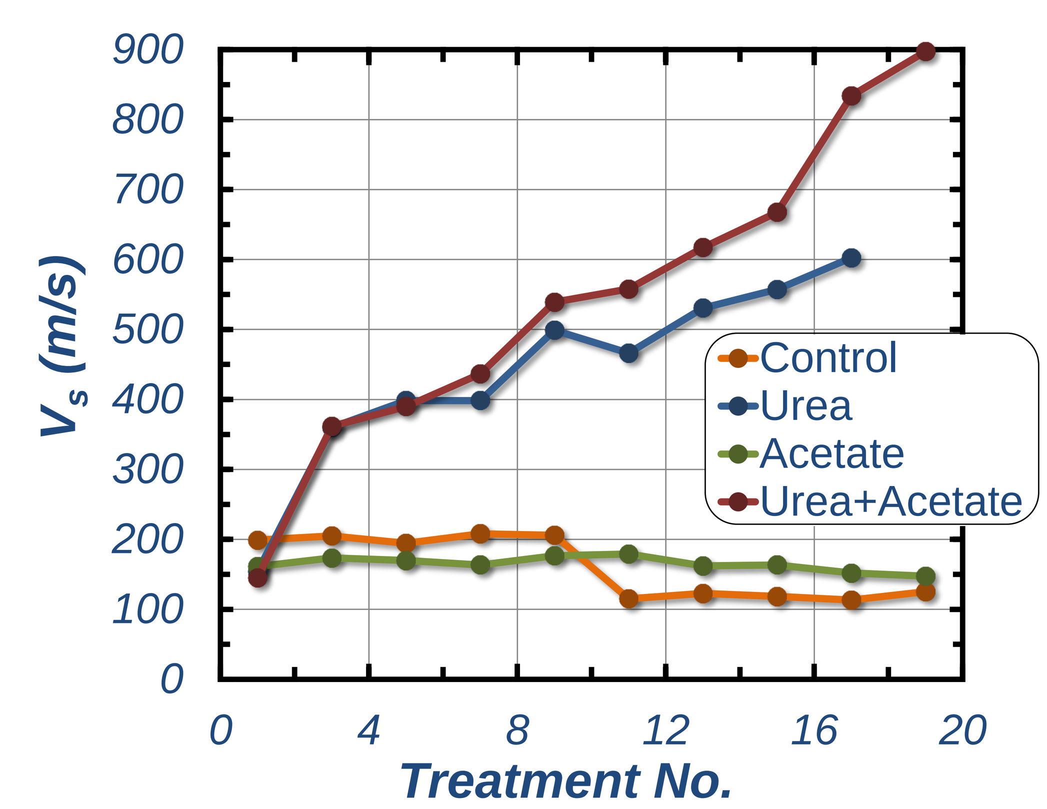
Calcite Precipitation

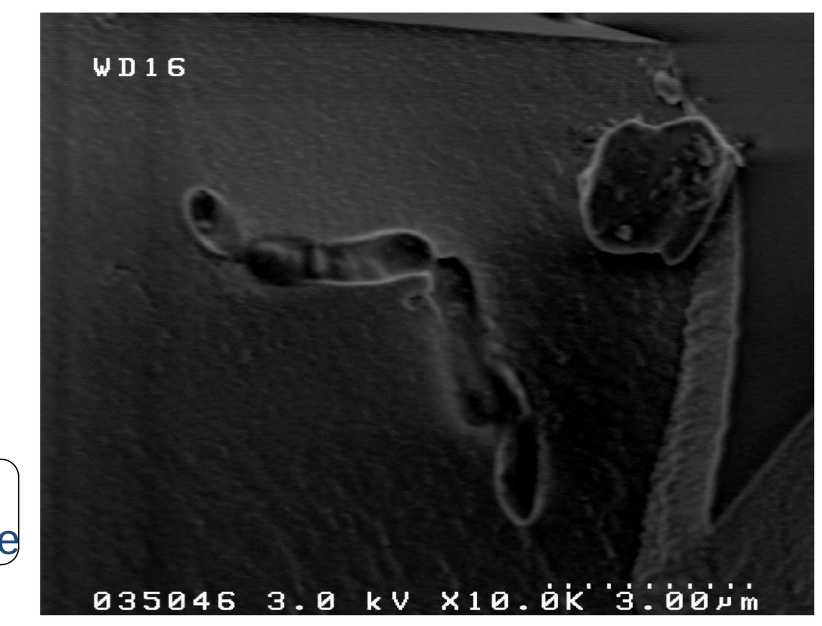
Cementation occurred through adding 250mM $CaCl_2$ to the bacterial growth solutions and injecting the solution every 12 hours for an additional ten days. At the end of treatment specimens were extruded and tested in unconfined compression. MICP was evident in the two samples containing urea in the treatment solution by examining the increase in shear wave velocity.

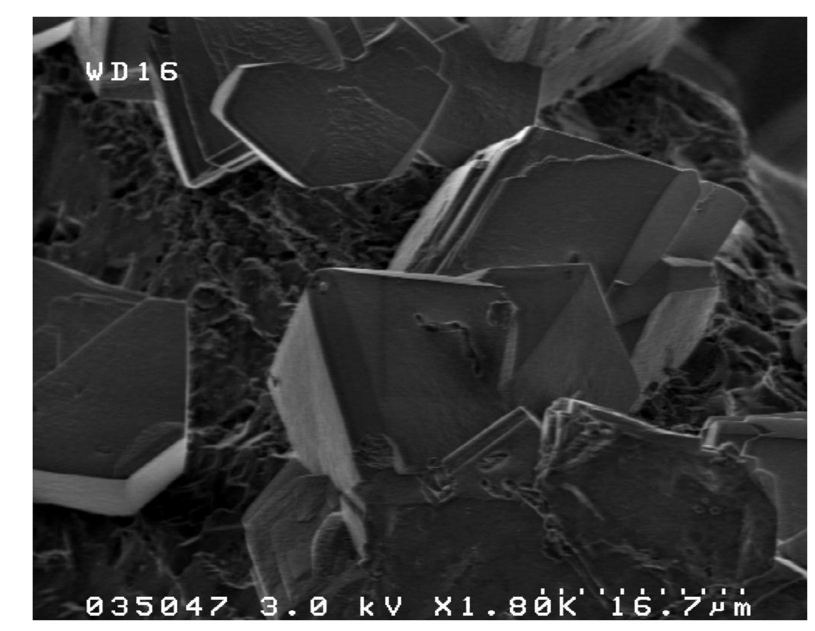
Unconfined Compression Tests

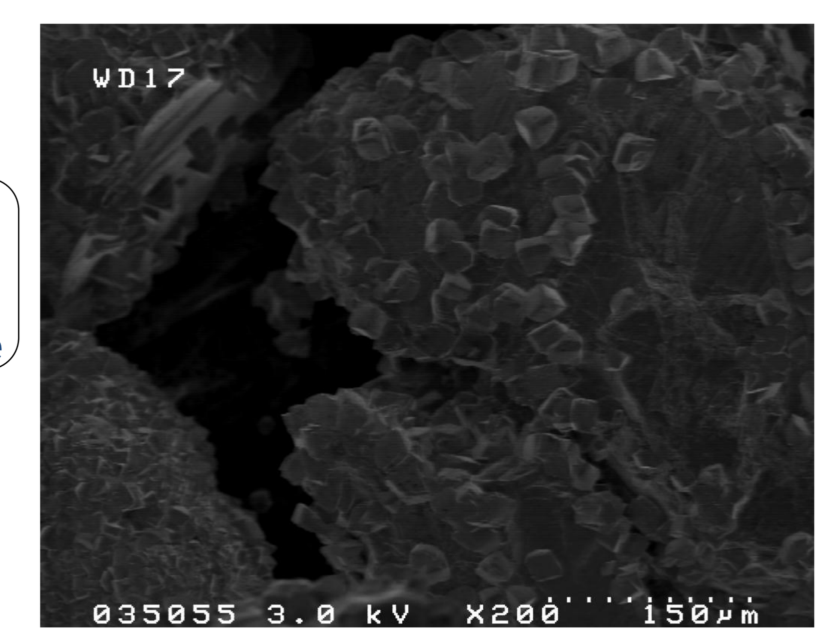


Shear Wave Velocity vs. Time









Summary

This pilot research project has demonstrated strong potential to stimulate bacteria that exist naturally in soil, eliminating the need to inject additional bacteria within soil. The primary observations are:

- All treatment solutions stimulated growth of natural bacteria.
- Only soils supplemented with urea contained precipitated calcite
- Shear wave velocity (V_s) increased up to 600% of initial values for soils stimulated with urea. No change in V_s occurred in the acetate only and control specimens.
- Calcite concentrations were 10% and 14% by mass for urea treated soils, and were 1.5% and 1.7% for acetate and control soils.
- Unconfined compression tests showed brittle behavior for urea treated soils, with high initial stiffness and peak strengths of about 2.2 MPa.

Questions

- What applications could this technology be useful for?
- What potential benefits do you see MICP having over traditional ground improvement methods?

Acknowledgements

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