Biostimulation of Native Bacteria for Biocementation of Sands

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Background

Microbially Induced Calcite Precipitation (MICP) is a biogeochemical reaction that utilizes metabolic capabilities of ureolytic bacteria to precipitate calcite at soil particle contacts.

$$(NH_2)_2CO + 2H_2O \rightarrow 2NH_4^+ + CO_3^-$$
$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3 \text{ (s)}$$

Biocementation can result in increased shear strength and G_{max} with modest reductions in permeability. Experiments have traditionally relied on the introduction of specialized bacterial strains (bioaugmentation), however recent research has focused on assessing the capabilities of native microbes (biostimulation). If native microbes can complete MICP at levels that are comparable to bioaugmentation, benefits with respect to treatment uniformity, cost, and soil ecology may be realized.

Experiment

In order to observe how soil properties change in time for a specific biostimulation treatment formulation, six soil columns (10.2 cm high, 5 cm diameter) were treated with identical solutions and disassembled at various stages of treatment. Treatment solutions were applied in two stages each which spanned 10 days. Stimulation solutions were applied during the first ten days and aimed to grow bacterial populations. Cementation solutions included the same nutrients as stimulation solutions but contained the addition of calcium to initiate the precipitation process. A control column received only water at similar volumes.

	Solution Type	
Constituent	**Stimulation**	**Cementation**
Urea (mol/L)	0.25	0.25
Ammonium Chloride (mol/L)	0.00625	0.00625
Sodium Acetate (mol/L)	0.085	0.085
Yeast Extract (g/L)	0.1	0.1
Calcium Chloride (mol/L)	-	0.125

Monitoring During Treatment:

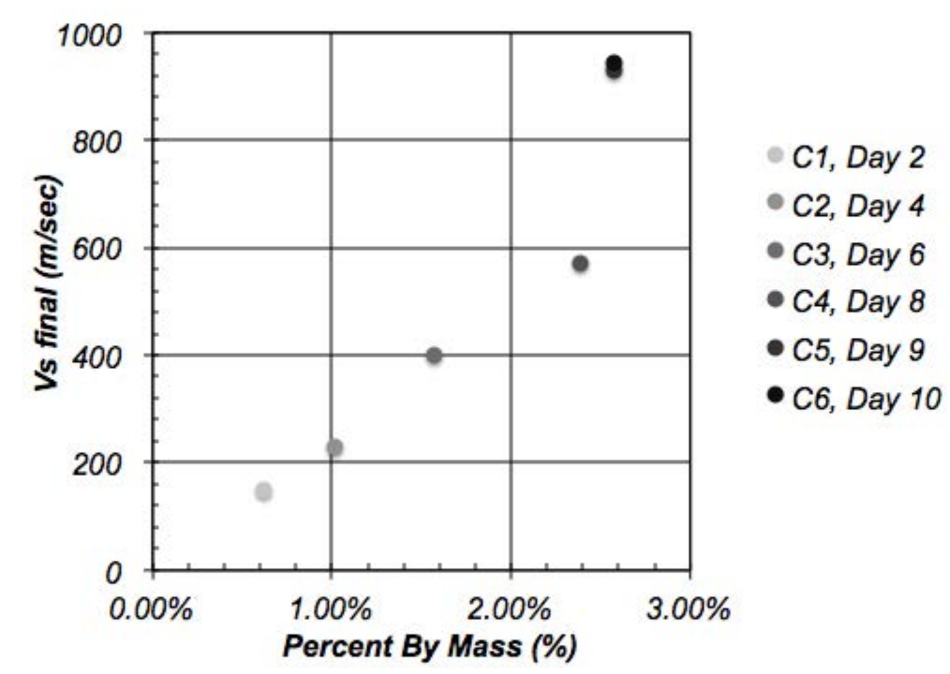
- Solution pH (influent/ effluent)
- Shear Wave Velocity (Vs)

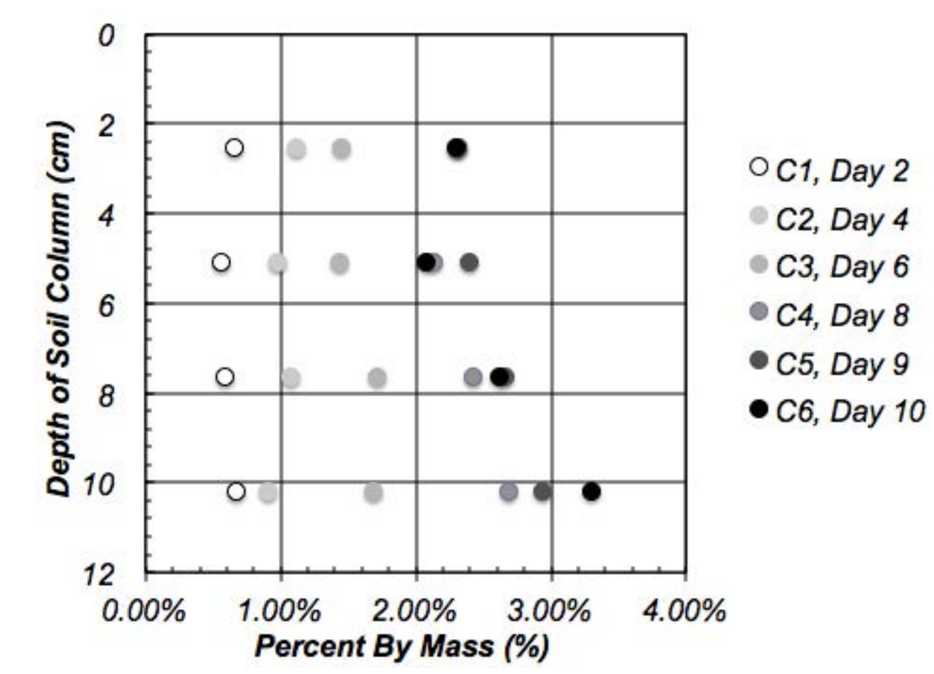
Measurements After Treatment:

- Permeability
- Calcite Content

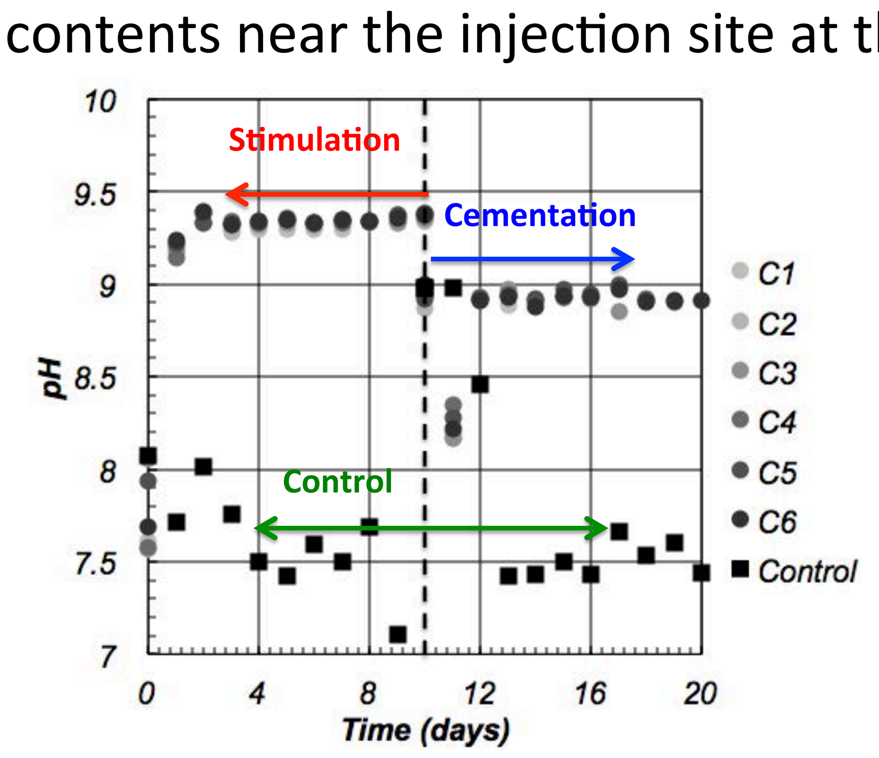
Soil columns were disassembled 2, 4, 6, 8, 9, and 10 days after the start of cementation to determine changes in properties with time.

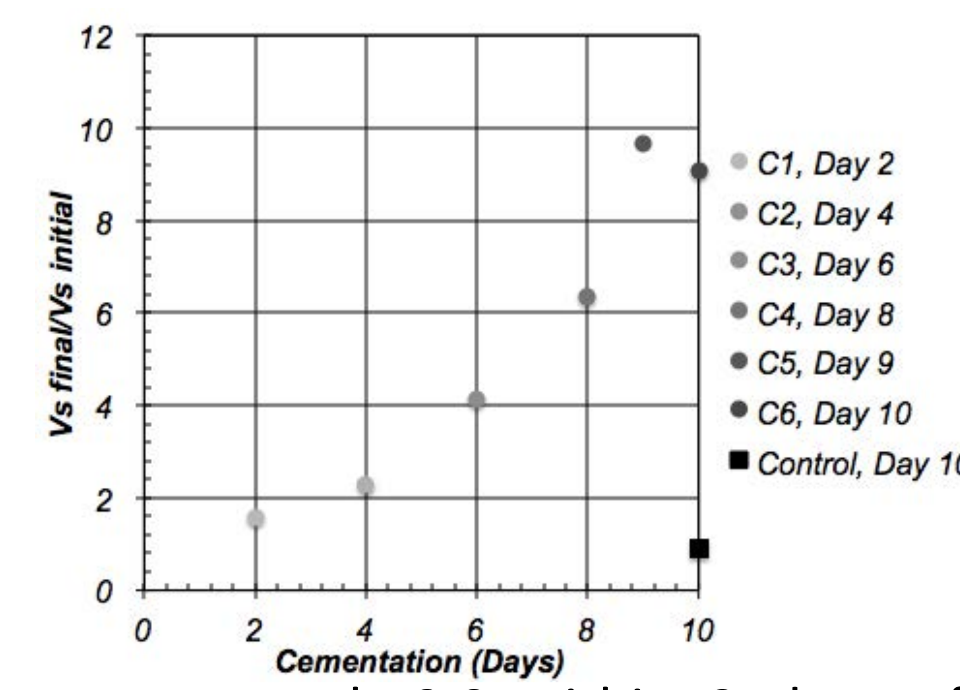
Results



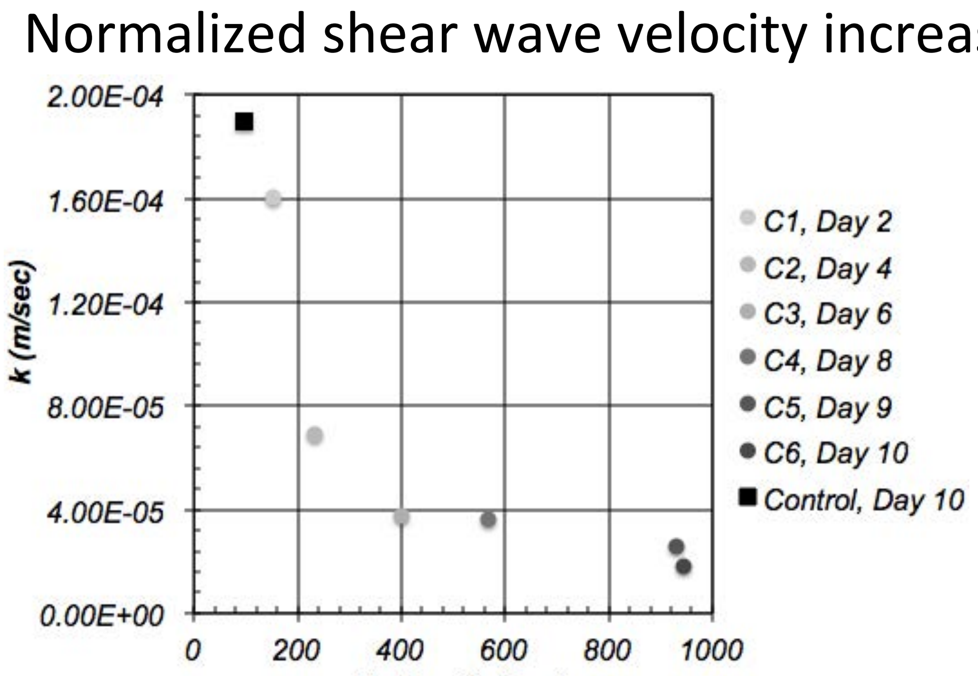


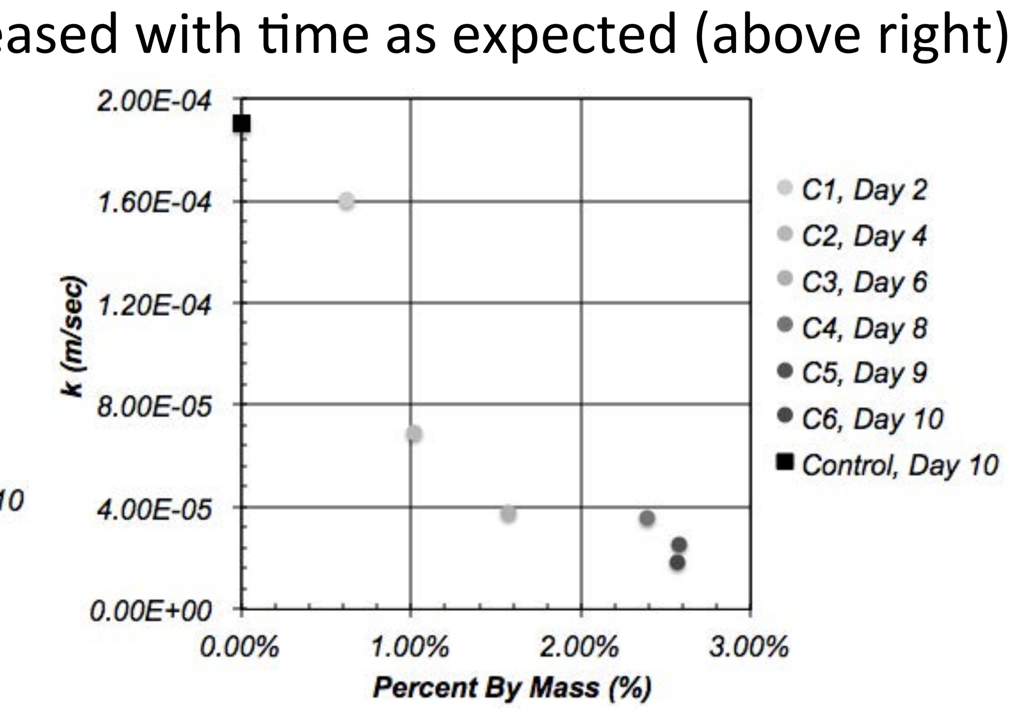
A linear relationship between calcite content and shear wave velocity was determined (above left). In addition, all soil columns had higher calcite contents near the injection site at the base of columns (above right).





The pH of effluent solutions were shown to reach 9.0 within 2 days of treatment indicating high ureolytic activity. Effluent pH was also shown to decrease following the addition of calcium during cementation (above left). Normalized shear wave velocity increased with time as expected (above right).





Permeability was shown to reduce with Vs due to calcite precipitation which reduced porosity (above left). As was expected the permeability also decreased with increased calcite mass (above right).

Conclusions

Results demonstrate the ability of native ureolytic bacteria to catalyze MICP and significantly improve soils. After ten days of calcium enriched cementation solutions, the shear wave velocity of soil columns were shown to increase by over 900%, calcite was measured as high as 3.3% by mass, and permeability was shown to decrease by nearly an order of magnitude.

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