Bio-Mediated CaCO₃ Production as a Method for Strength Improved Soils

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Rationale for Research
Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading. Liquefaction is most often observed to occur in saturated, low-density (uncompacted) sandy soils with low-drainage (i.e. under seams of impermeable sediments, as foundations of buildings, rail tracks, bridges, etc.). It has been responsible for tremendous amounts of damage in historical and recent earthquakes around the world.

At present, grouting and ground improvement techniques to reduce liquefaction induced damages are diverse with respect to treatment, cost, environmental impact, site requirements, etc. With a focus on grouting, all man-made grouting chemicals, with the exception of sodium silicate, are toxic and/or hazardous.

In addition, all grouting techniques lead to an irreversible loss in soil permeability, which limits their application to short range foundational strength improvements and seals.

In search of alternatives, biomediated ground improvement techniques show promise in their ability to improve soil strength while maintaining soil porosity.

Methods and Results

1. Selecting the Model Sand Type
Requirements:
- Poorly graded but uniform sandy soil
- Average pore volume between granules within range of bacteria size
- Readily available and cheap

2. Selecting the Model Bacterial Strain
Requirements:
- Novel species yet to be characterized in the literature
- Low biohazard threat (ATCC, biosafety rating 1 or less)
- Easily accessible, readily cultured and urease positive

3. Cell as a Nucleation Site

4. Urease Activity

5. Strength Enhancement

Summary
The preliminary study has shown that significant strength and stiffness improvements can be obtained in sands using a microbial additive in a urea-CaCl₂ solution base. The reagent, NiCl₂, was shown to increase urease activity with results suggesting it as a necessary agent in effectual soil cementation. In addition, a novel strain, S. urea, has been studied and deemed suitable as a biocatalytic agent in the cementation of sandy soils. However, the control and predictability of the in-situ distribution of bacterial activity and reagents for suitable and homogenous CaCO₃ production are not yet sufficient and pose the need for further research.

Research in Progress
(1) Up-regulating genetic expression of urease to increase cementation rate
(2) Tri-axial tests for determining undrained shear strength under cyclic and monotonic loads
(3) Shake-table test with large scale sandbox trial to simulate field conditions

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