

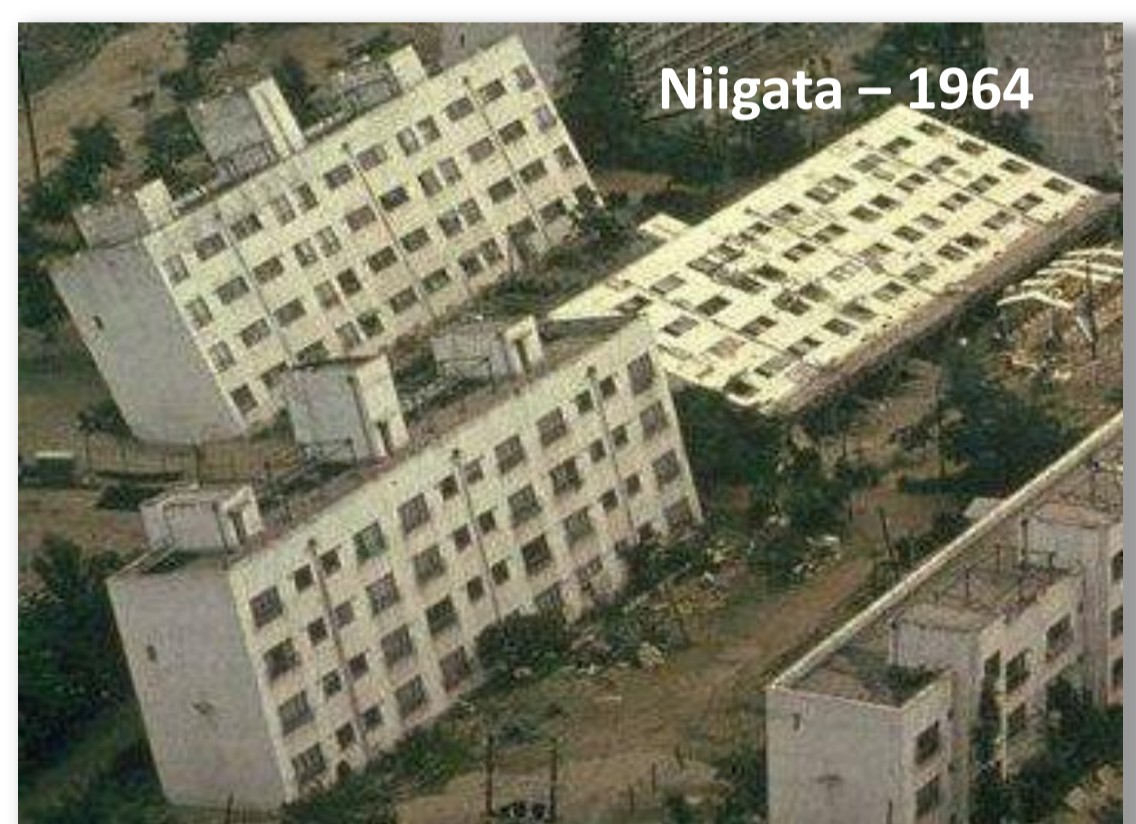
Bio-Mediated CaCO₃ Production as a Method for Strength Improved Soils

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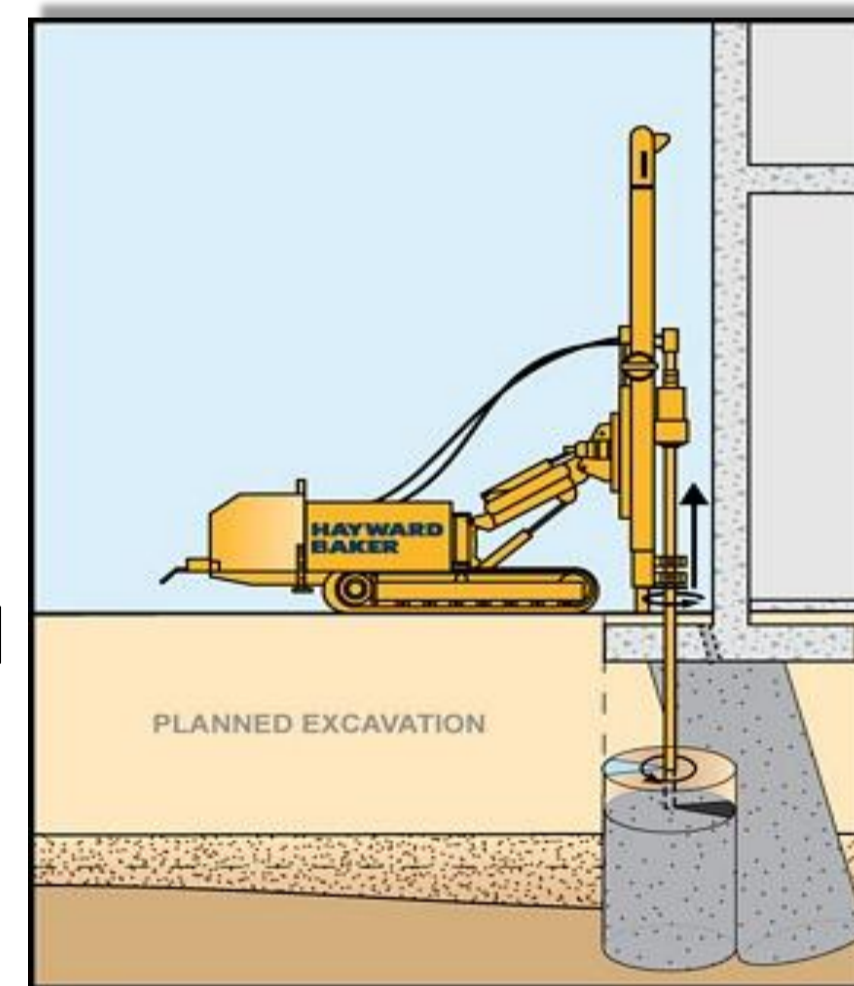


Rationale for Research

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.

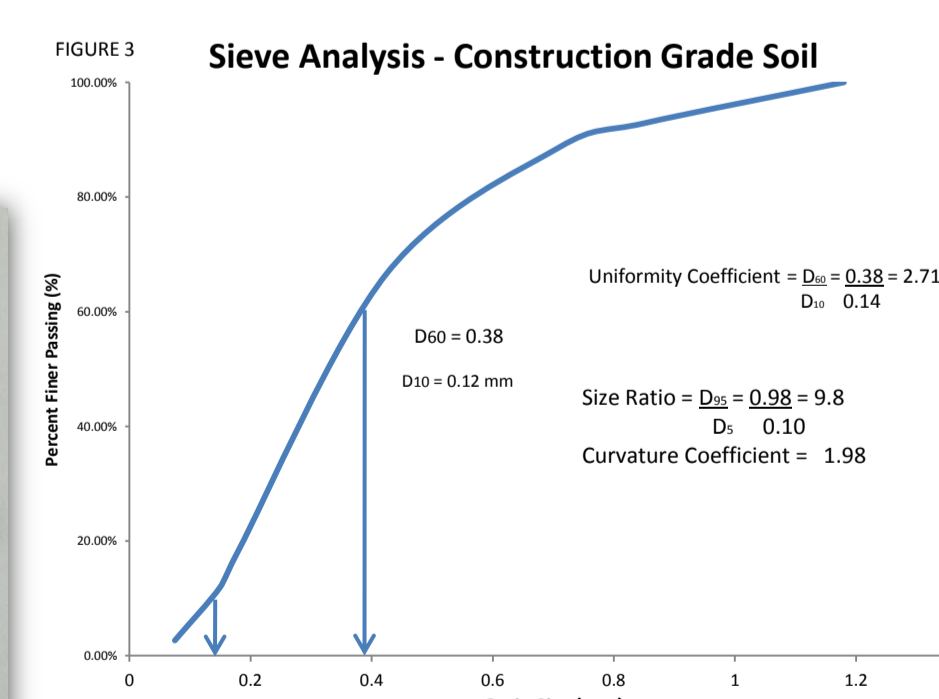
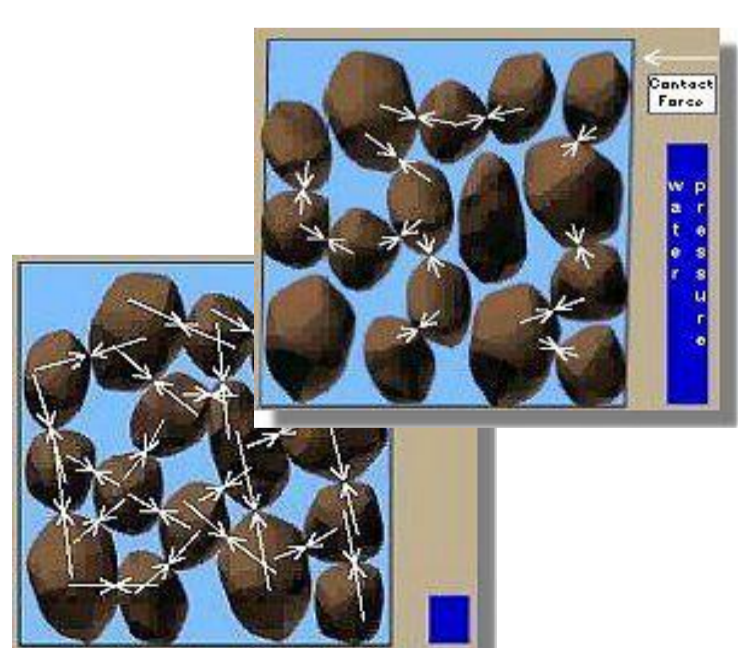


At present, grouting and ground improvement techniques to reduce liquefaction induced damages are diverse with respect to treatment, cost, environmental impact, site requirements, etc. With a focus on grouting, all man-made grouting chemicals, with the exception of sodium silicate, are toxic and/or hazardous. In addition, all grouting techniques lead to an irreversible loss in soil permeability, which limit 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.



Previous Research

A Focus on Geotechnics:



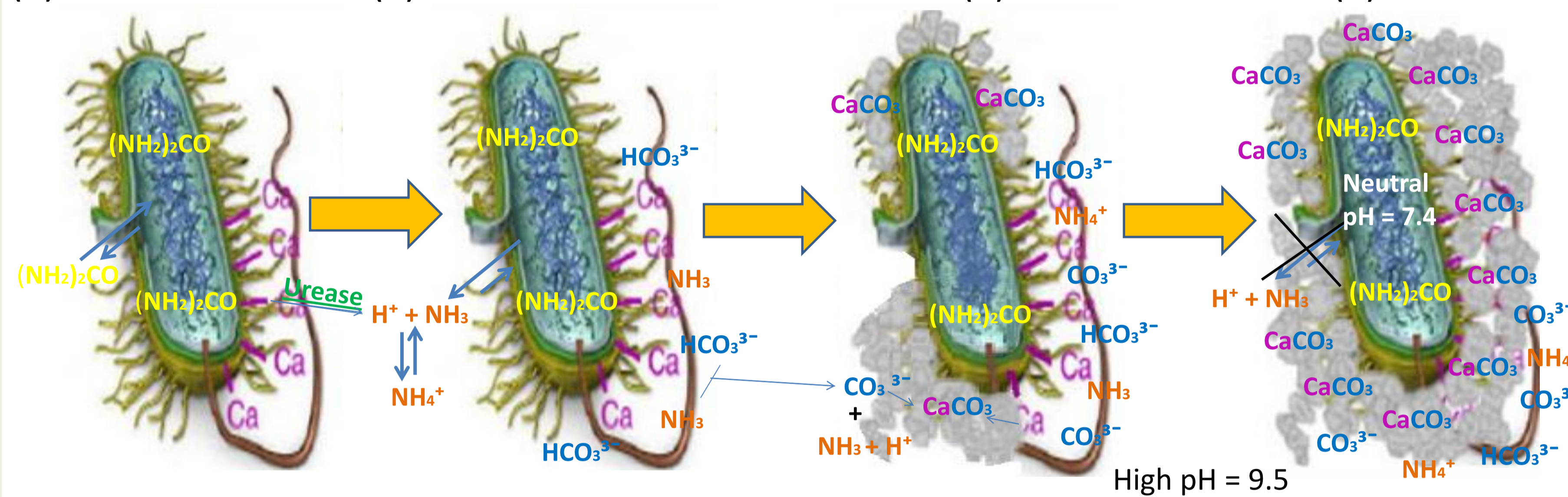
Objective

The key objectives of this research are : 1) Verify that microbial precipitation can consolidate loose material into a binding, strength enhancing matrix using appropriate cementation media 2) Characterize a novel strain of ureolytic bacteria, confirming its potential as a model for CaCO₃ precipitation 3) Validate the mechanistic role of bacteria in the biomineralization process, 4) Evaluate the economic benefits in other fields and cost effectiveness of biomediated soil improvement

Proposed Mechanism of Cementation

4-Step Process

(1) Cell-Ca²⁺ + Urea → (2) HCO₃³⁻ + NH₃ ↔ NH₄Cl + CO₃²⁻ → (3) Cell-Ca²⁺ + CO₃²⁻ → (4) Cell-CaCO₃



$$*S = (Ca^{2+}) \times (CO_3^{2-}) / K_{sp-max} * \leftrightarrow S > K_{sp-max} = CaCO_{3(s)}$$

Extending Applications

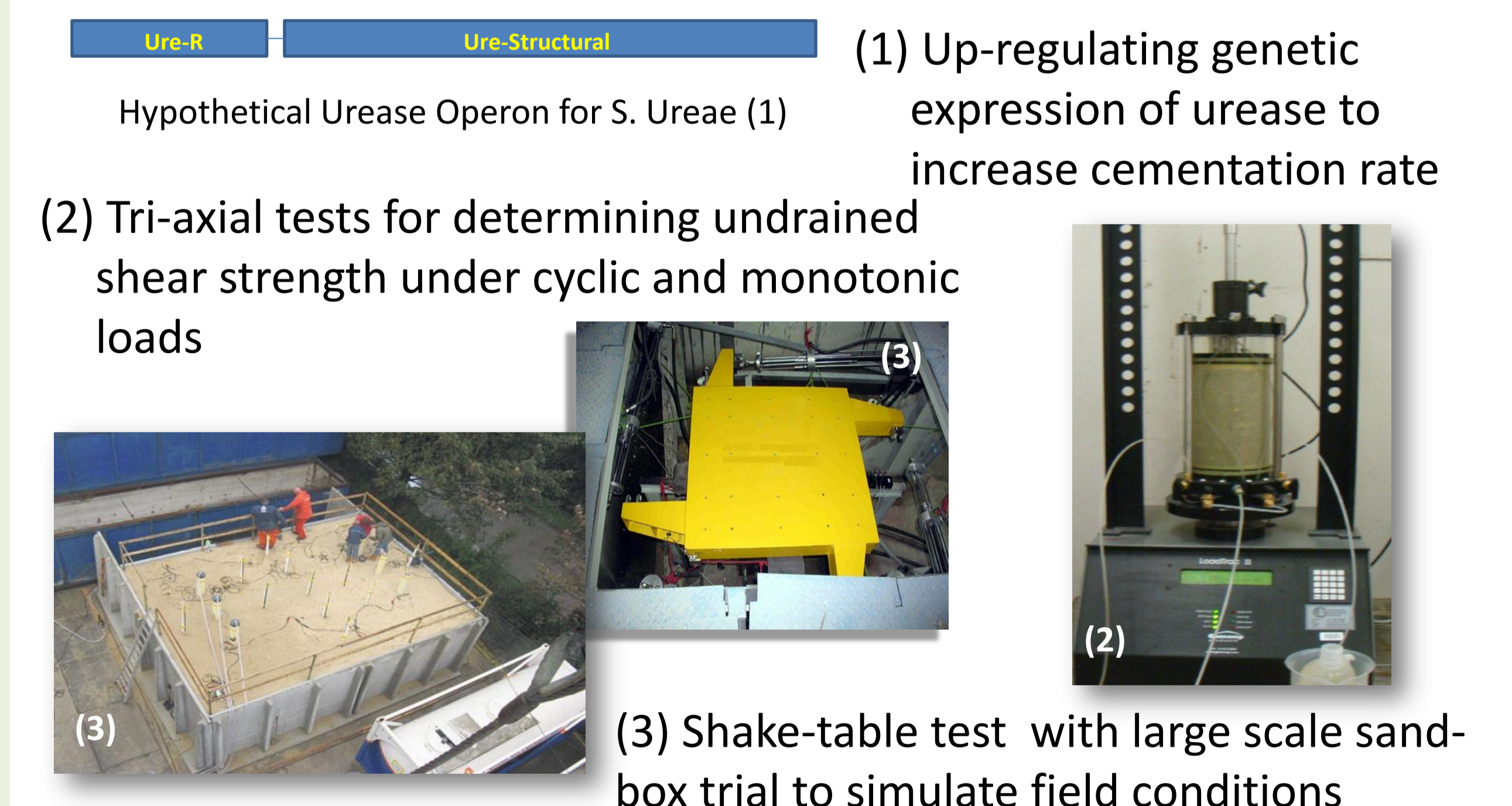


Application of bio-mediated soil improvement to enhance weather resistance and increase load bearing capacity of roads and railroad embankments built on sands. Also to prevent soil erosion in economic areas such as agriculture or construction, while maintaining degrees of porosity in deposits for adequate drainage.

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. ureae* 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

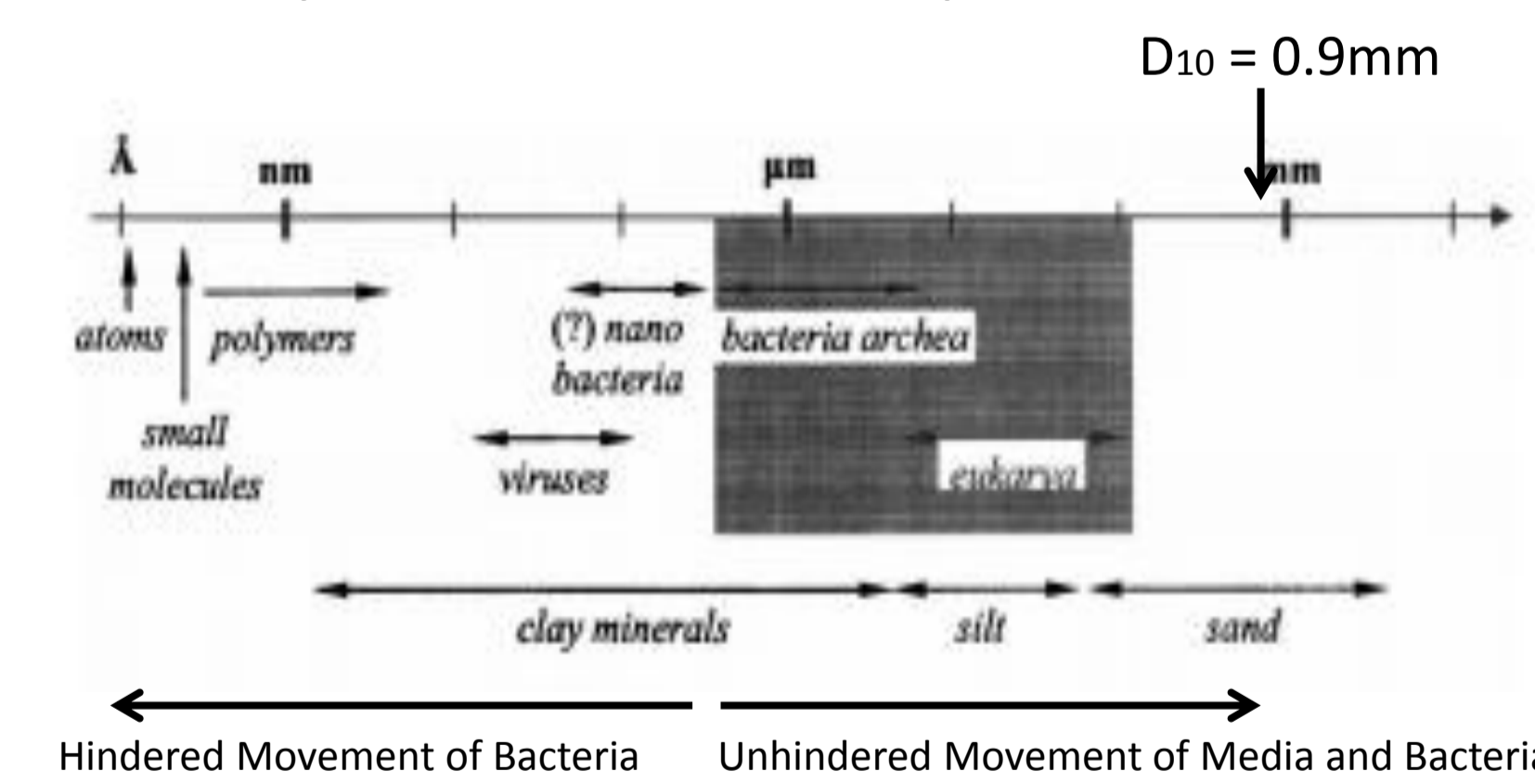


Methods and Results

(1a) 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



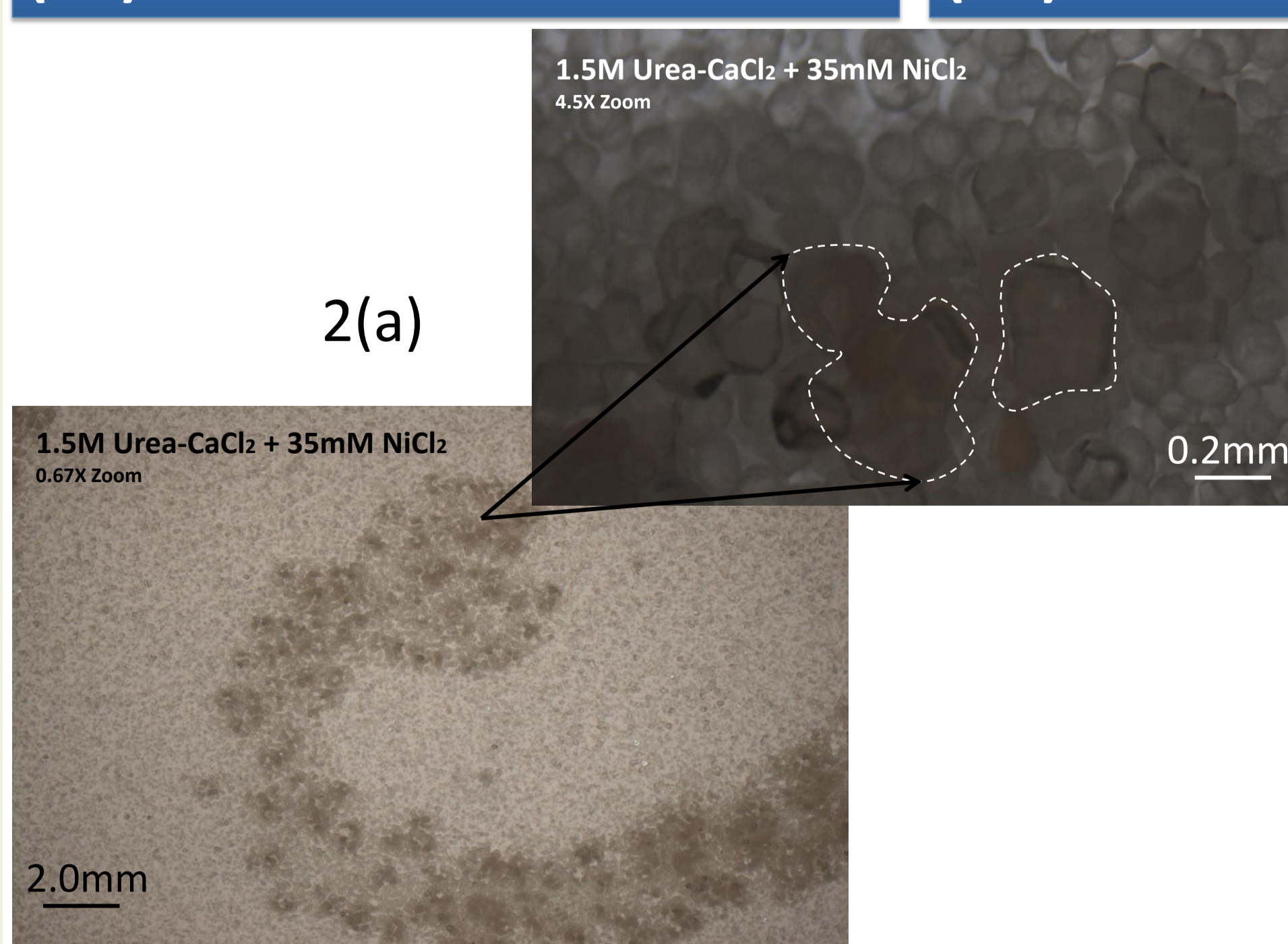
(1b) Selecting the Model Bacterial Strain

Requirements:

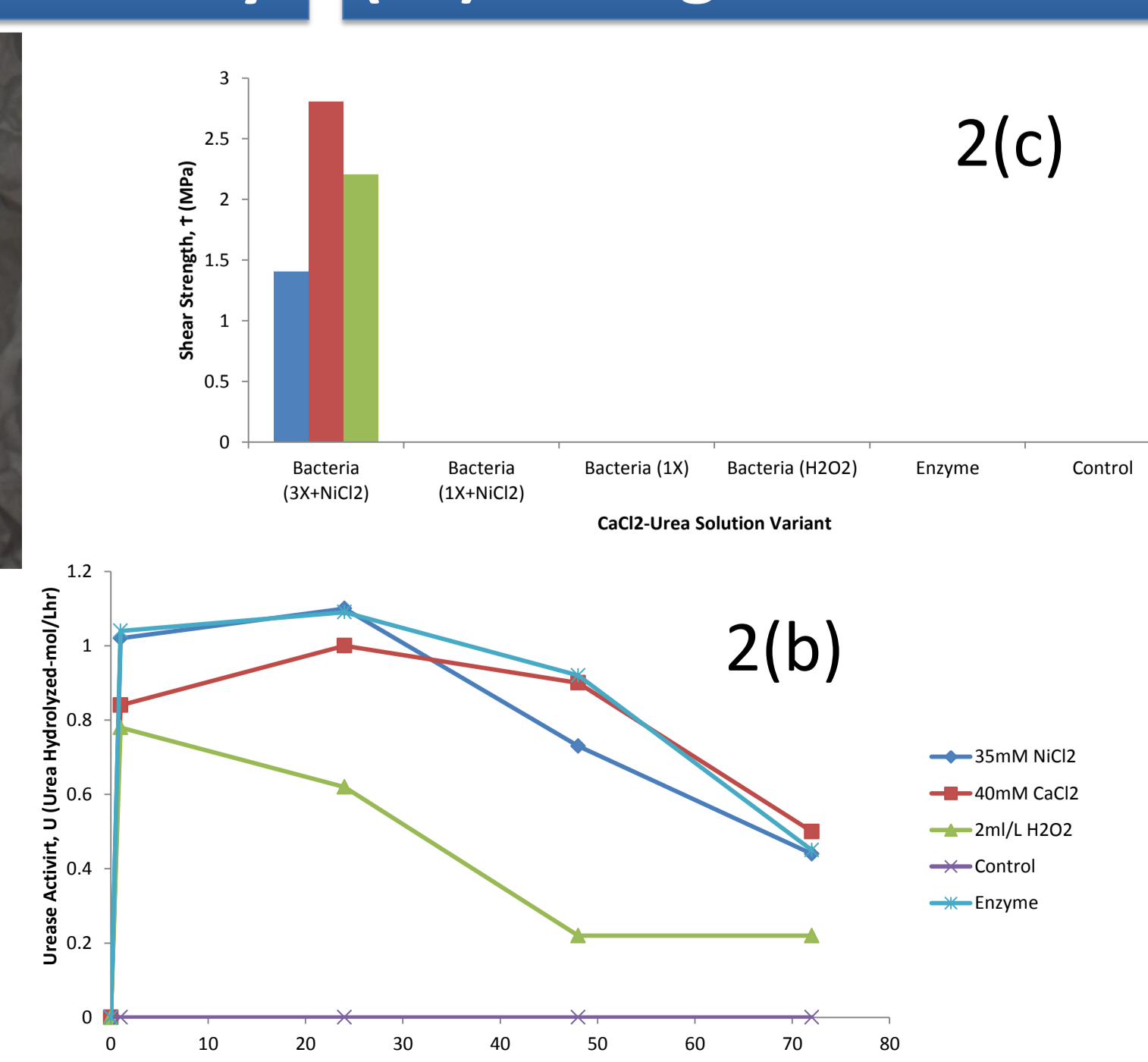
- Novel species yet to be characterized in the literature
- Low biohazard threat (ATCC biosafety rating 1 or less)
- Easily accessible, readily cultured and urease positive



(2a) Cell as a Nucleation Site



(2b) Urease Activity



(2c) Strength Enhancement

Acknowledgements

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