Urease Efficacy in Enzyme Induced Carbonate Precipitation (EICP) in Selected Soil Samples and Experimental Conditions

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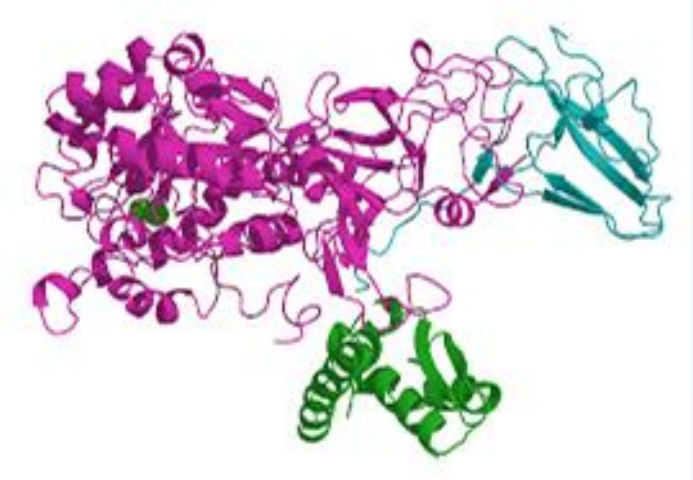
2023 Research Experiences for Teachers, Arizona State University

Research Background

- Erosion and dust formation are natural or man-caused phenomena that have significant economic, environmental, and health-related consequences. Strategies for dust control based on naturally occurring or induced chemical (such as EICP) or biological processes represent a more sustainable alternative to traditional dust control methods, especially to those that rely on and use large volumes of water
- This project attempts to determine the efficacy of EICP in selected experimental conditions and soil samples used in current geotechnical engineering research



Enzyme induced carbonate precipitation (EICP):

$CO(NH_2)_2 + 3H_2O + \text{urease} \rightarrow CO_2 + 2NH_4^+ + 2OH^-$

General $CaCO_3$ precipitation mechanism:

1) $HCO_3^-{}_{(aq)} + OH^-{}_{(aq)} \leftrightarrow H_2O + CO_3^{2-}{}_{(aq)}$
2) 2) $Ca^{2+}{}_{(aq)} + CO_3^{2-}{}_{(aq)} \rightarrow CaCO_3(s)$

Research Objectives

- To test and quantify the efficacy of EICP treatment in Ottawa 20/30 B-2.5 and B-1.5 soil samples by performing Unconfined Compression Strength (UCS) testing and scanning electron microscopy (SEM) (Fig. 1)
- To test and quantify the efficacy of different EICP solution concentrations in soil samples from Minnesota iron mine tailings by conducting Carbonate, Ammonium, and penetrometer measurements on pan crusts (Fig. 2)

Figure 1: Ottawa 20/30 B-2.5 (left) and B-1.5 (right) soil samples

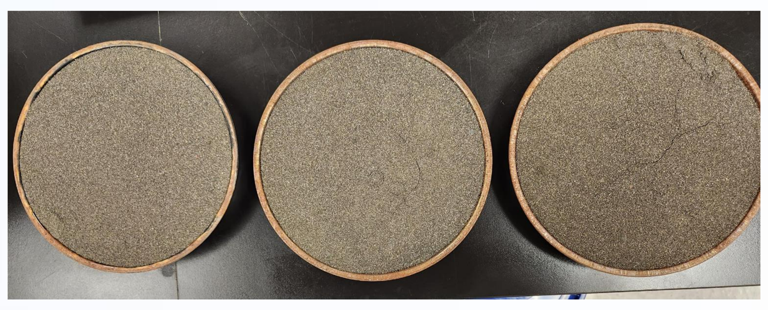


Figure 2: Minnesota iron mine tailings soil samples

Research Conclusions

- Ottawa 20/30 B-1.5 soil is better suited for EICP experimentation (Fig. 3). 1M urea, 0.67M $CaCl_2$ EICP solution is the optimal concentration for further EICP treatment experimentation of Minnesota iron mine tailings soil (Fig. 4)

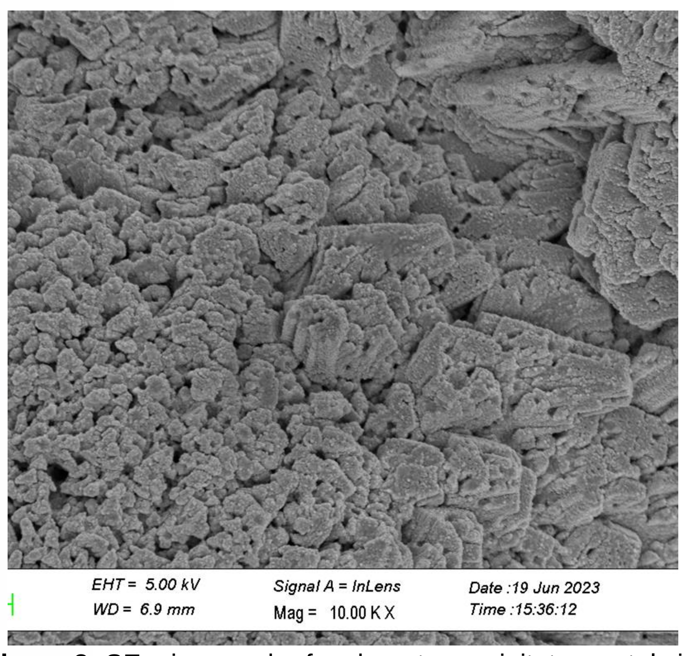


Figure 3: SE micrograph of carbonate precipitate crystals in treated Ottawa 20/30 EICP-milk B-2.5 soil samples

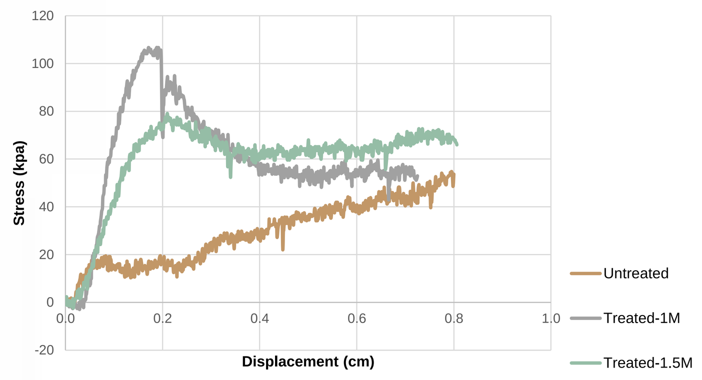


Figure 4: Stress values (kpa) for untreated and treated Minnesota iron mine tailings soils

Lesson Description

Problem Based Learning: Students are introduced to the problems associated with dust control and to alternative, more sustainable control methods that rely on biomediation, such as EICP and to urease, the enzyme that catalyzes EICP. Students are then asked to list environmental factors that can impact the efficacy of EICP, and what experimental design needs to be in place to test them**.**

Course-based Undergraduate Research Experiences (CUREs): The project is designed and implemented as a CURE, expanding for 6-8 weeks out of a 16- week semester.

Lesson Objectives

- Describe connections between geotechnical engineering, soil science, and biochemical processes
- Describe fugitive dust and soil erosion and current methodologies used for their control
- Describe the economical, environmental and health related problems associated with fugitive dust and erosion
- Describe the most common types of bio mediated methodologies to control fugitive dust and erosion, including EICP
- Identify and describe the role of enzymes and supplemental proteins in biogeochemical reactions through EICP
- Demonstrate how experimental conditions affect the efficacy of urease and of EICP

Lesson Outcomes

- Introduce environmental and health problems associated with fugitive dust. Introduce EICP as a solution to mitigate fugitive dust effects
- Students perform literary research on the topic and present results. Discussion of limits of EICP and factors influencing urease activity (pH,T, concentration of urea)
- Students choose two factors that can affect EICP efficacy and discuss with class
- Engineered solution and experimental design. Execution & testing using standard Ottawa 20-30 sand
- Results and Conclusion
- Presentation of Results

Acknowledgement This material is based upon work primarily supported by the Engineering Research Center Program of the National Science Foundation under NSF Cooperative Agreement No. EEC-1449501. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation.

CBBG Center for Bio-mediated & Bio-inspired Geotechnics

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