Summer 2018 RET Project Descriptions

Arizona State University

Fugitive Dust Mitigation

Description: Wind-blown soil particles, or fugitive dust, is a significant health hazard in the southwestern United States and many other parts of the world. Maricopa County is designated by the US Environmental Protection Agency as an air quality non-attainment zone because of fugitive dust levels. Available methods for controlling fugitive dust include: using a water truck to keep the soil wet, which uses large quantities of potable water and vehicle fuel and is of limited effectiveness in the summer; application of a salt solution, which can adversely impact surface and ground water quality; and application of synthetic polymers, which are expensive and potentially toxic. In this project, the use of enzyme induced carbonate precipitation (EICP) is being explored as a “one-and-done” solution for fugitive dust control through use of the ASU/NASA Planetary Wind Tunnel (to develop an optimal EICP recipe) and a device that accelerates the ageing of materials using ultra-violet radiation (to evaluate durability).

Suggested Background/Interests: geotechnical engineering, wind erosion, fugitive dust control, biopolymer enhancement for soils (hydrogels)

Principal Investigator: Dr. Ed Kavazanjian

Student Mentor: Miriam Woolley

Stabilization and Control of Clay Swelling via Plant Extracted Silicate Solution

Description: Lime stabilization and Portland cement stabilization are the two most common ways of improving strength and controlling volume change when problematic soils are present, especially in residential construction and low-volume unpaved roads. While there is a desire to use chemical stabilization; according to EPA, the cement industry is the third largest source of environmental pollution, producing 500,000 tons per year of carbon monoxide, nitrogen oxide and sulfur dioxide, and 829 million tons of carbon dioxide. Furthermore, lime stabilization is a process that results in soil gypsification if sulfates are present, which in turn increases the swell potential, aggravating the problem.

The primary goal of this project is to establish protocols for conducting efficient and economically competitive chemical stabilization design for problematic soils using plant-extracted silicate solution. To accomplish this goal, the research team is optimizing silicate precipitation techniques and conducting laboratory studies to determine the most effective processes. Results will contribute to prevent and mitigate damages caused by problems associated to expansive clay materials and to establish alternative stabilization of low volume roads technique by using a product that is not toxic to the environment.

Suggested Background/Interests: geotechnical engineering, unsaturated soils, chemical engineering, sustainability

Principal Investigators: Dr. Claudia E. Zapata and Dr. Hamed Khodadadi Tirkolaei

Student mentor: Hani Alharbi
**Fluid Flow Models for Microbial Induced Carbonate Precipitation (MICP) for Soil Improvement**

**Description:** The use of the microbial denitrification process to precipitation of calcium carbonate in soil is being investigated as a practical alternative to the use of Portland cement to stabilize soil. Denitrification uses concepts from chemistry, biology, unsaturated soil mechanics and fluid flow analysis. Laboratory testing is being conducted to determine a method for determining the unsaturated permeability in a soil column as calcium carbonate precipitation occurs. Work on this project will include preparation of MICP-improved soil specimens, saturated and unsaturated permeability testing, development of soil water characteristic curves, and testing of engineering properties of MICP-improved soil.

**Suggested Background/Interests:** geotechnical engineering, fluid flow, microbiology, unsaturated soils

**Principal Investigator:** Dr. Leon van Paassen and Dr. Claudia Zapata

**Student Mentor:** Elizabeth G. Stallings

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**Biodeposition as a Surface Treatment Method to Increase Concrete Durability**

**Description:** This study intends to explore if Portland cement based systems can be surface treated with biodeposition using carbonate precipitating bacteria to enhance the long term durability of such systems, especially in the built infrastructure. The idea is to develop bio-based coating systems for concrete subjected to chloride penetration, sulfate attack, and carbonation induced corrosion. The bio-based system will be compared to a system coated with sodium silicates. The waterproofing properties of the coating system including its microstructure and properties will be subjected to in-depth study using advanced characterization tools.

**Suggested Background/Interests:** Engineering students with interest in novel materials, mechanics of materials, and the application of civil engineering materials for unique applications. Should have a junior standing or higher, in civil, mechanical, chemical, or materials engineering.

**Principal Investigator:** Dr. Narayanan Neithalath

**Student Mentors:** Aashay Arora and Matthew Aguayo
Georgia Institute of Technology

Geotechnics of bio-locomotion systems
Description: Traditional methods for exploration of the subsurface for site characterization and monitoring purposes have involved insertion of devices from the surface. Historically, this has involved advancing near vertical penetrations that traverse what are often predominantly near horizontal strata. We seek to explore how subsurface bio-locomotion systems that can move in any orientation in the subsurface can provide new insights that can be ultimately leveraged to enhance the sustainability and resiliency of subsurface space development for infrastructure construction and hazard mitigation purposes.
Research Approach: The research team will use a combination of microscale experimental methods in conjunction with Discrete Element Modeling simulation systems to develop new insight into the geotechnics of bio-locomotion systems (e.g. worms). The experimental methods will seek to characterize and understand what factors contribute to the geometry of the subsurface network of tunnels excavated by worms while the particulate modeling simulations will study issues such as the role of force chains in the overall stability of real subsurface structures.
Preferred Background/Interests: Civil infrastructure, microscopy, computer modeling
Principal Investigator: Dr. David Frost
Student mentors: Prashanth Vangla, Post-doctoral Fellow and Rodrigo Borela, PhD Student

Geotechnics of self-excavating systems
Description: Traditional methods for accessing underground spaces has involved the construction of tunnels that involve boring or pushing tube like structures into the ground. Recent studies have shown that ants are able to construct tunnels using less than 0.1% of the energy per unit volume of soil removed that the most efficient human tunnel boring machine.
Research Approach: The research team will use a combination of microscale experimental methods in conjunction with Discrete Element Modeling simulation systems to develop new insight into the activities of self-excavating systems (e.g. ants). The experimental methods will seek to characterize and understand what factors contribute to the geometry of the subsurface network of tunnels and chambers excavated by ants while the particulate modeling simulations will study issues such as the role of force chains in the overall stability of real subsurface structures. One of the REU positions will lead laboratory experiments while the other will lead field experiments although the students will have the opportunity to work on both aspects of the work.
Preferred Background/Interests: Civil infrastructure, microscopy, computer modeling
Principal Investigator: Dr. David Frost
Student mentors: Prashanth Vangla, Post-doctoral Fellow and Karie Yamamoto, MS Student
Root system inspired anchors

**Description:** The overarching goal of the proposed research is to provide insight into the performance of multi-function root systems which can lead to the development of novel construction configurations and techniques for the enhancement of common infrastructure anchorage systems, such as deep pile foundations and retaining structure reinforcement systems. This project aims to elucidate the anchorage and failure mechanisms of roots of varying architecture subjected to typical plant loading situations, including pullout extension (herbivores), compression (self-weight), and lateral (wind) forces. Analogous synthetic root structures, instead of living roots, will be designed and utilized based on simplified optimal root architectures revealed in previous experimental studies.

**Research Approach:** Observation of the failure mechanisms of 3-D printed root analogues during pull-out tests will allow for a conceptual model to be formulated to predict the system capacity under different loading scenarios for various root analogues structures. The role of the root shape and surface characteristics will be evaluated. This may serve as a starting point for bridging biology and physics, enabling new design heuristics of synthetic tree-like structures inspired by root branching morphogenesis. Experimental studies will be complemented by Discrete Element Model simulations of root-particulate systems.

**Preferred Background/Interests:** Civil infrastructure, biology, computer modeling

**Principal Investigator:** Dr. David Frost

**Student mentors:** Prashanth Vangla, Post-doctoral Fellow and Seth Mallett, PhD Student

Geotechnics of termite mounds

**Description:** Termite mounds are resilient structures that rely on bio-cementation of granular soils to create above ground structures that can house millions of termites. The potential to emulate the construction techniques used by termites to build these structures offers significant potential in a range of geotechnical problems ranging from settlement to liquefaction. We seek to explore how bio-cementation utilized by these self-excavating systems can provide new insights and thus concepts that can be ultimately leveraged to enhance the sustainability and resiliency of subsurface space development for infrastructure construction and hazard mitigation purposes.

**Research Approach:** The research team will use a combination of microscale experimental methods in conjunction with Discrete Element Modeling simulation systems to develop new insight into the geotechnics of termite mound construction. The experimental methods will seek to characterize and understand what factors contribute to the geometry of the above ground network of tunnels and chambers created by termites while the particulate modeling simulations will study issues such as the role of force chains in the overall stability of these structures.

**Preferred Background/Interests:** Civil infrastructure, biology, microscopy, computer modeling

**Principal Investigator:** Dr. David Frost

**Student mentors:** Prashanth Vangla, Post-doctoral Fellow and Nimisha Roy, PhD Student.