Tree Root Inspired Foundations: Root System Modeling and Optimization

Students: Matthew Burrall, Khoa Tran (UC Davis), Yoon-Ah Kim, Min-Kyung Jeon (KAIST)
Advisors: Jason T. DeJong, Alejandro Martinez, Daniel W. Wilson (UCD), Tae Hyuk Kwon (KAIST)

Architecture Characterization and Modeling

- 3D models and structural skeletons were constructed from extracted orchard tree root systems
- Root systems were analyzed for morphology (Figure 1, for example) and branching structure, and mechanically relevant parameters were described statistically
- Synthetic root systems (Figure 2) were generated and calibrated to the real root systems to define and explore the parameter space of root inspired anchor architecture

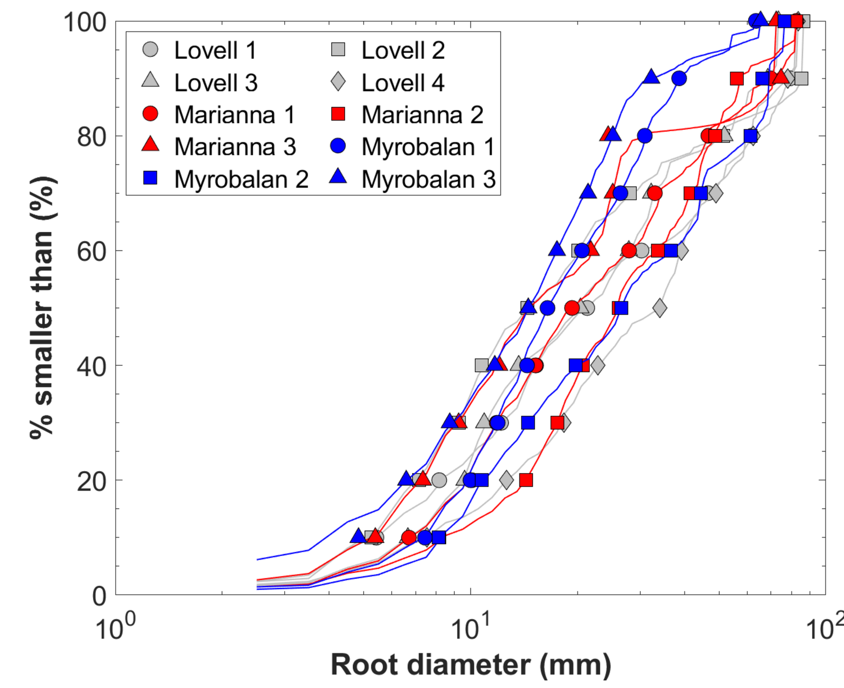


Figure 1 (left). Cumulative distribution of root volume as a function of root diameter

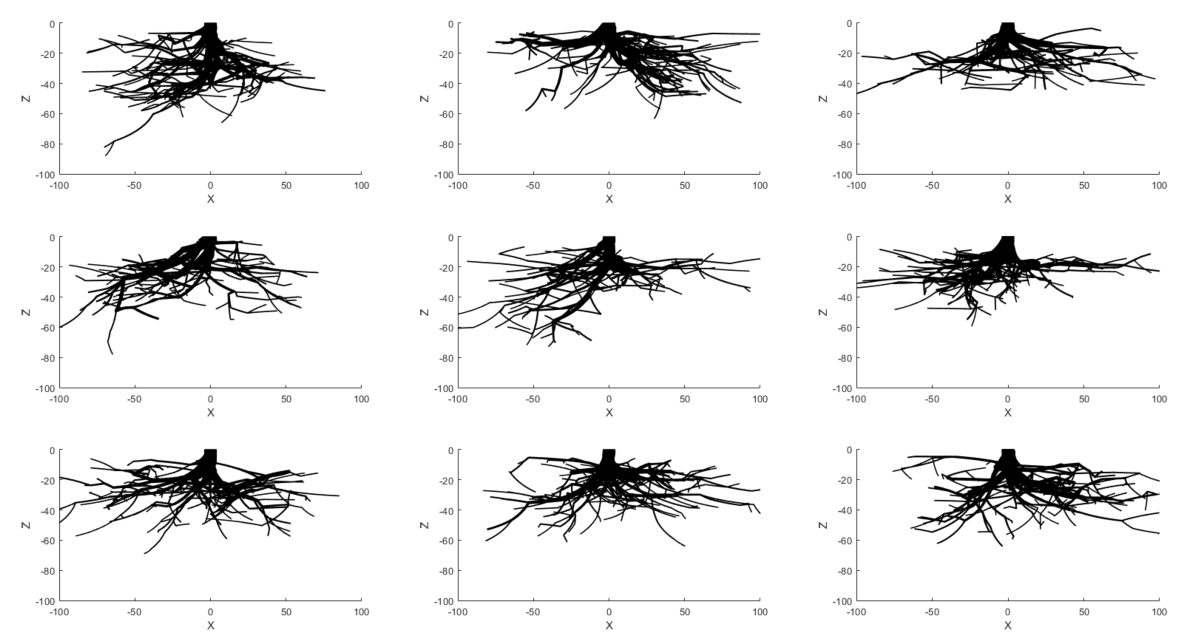


Figure 2 (below). Simulated representative root systems

Mechanical Model Findings

- A soil springs model was developed that calculates compatible deformations of a flexible beam subject to combined axial and transverse components of resistance
- Vertical pullout with three different initial shapes (Figure 3) reveals that inclination and curvature affect the distribution of resistance (Figure 4) along the structure as well as the stiffness and capacity (Figure 5)
- The curved shape allows the bearing resistance to be mobilized much further along the structure

Figure 3. Undeformed structure shapes

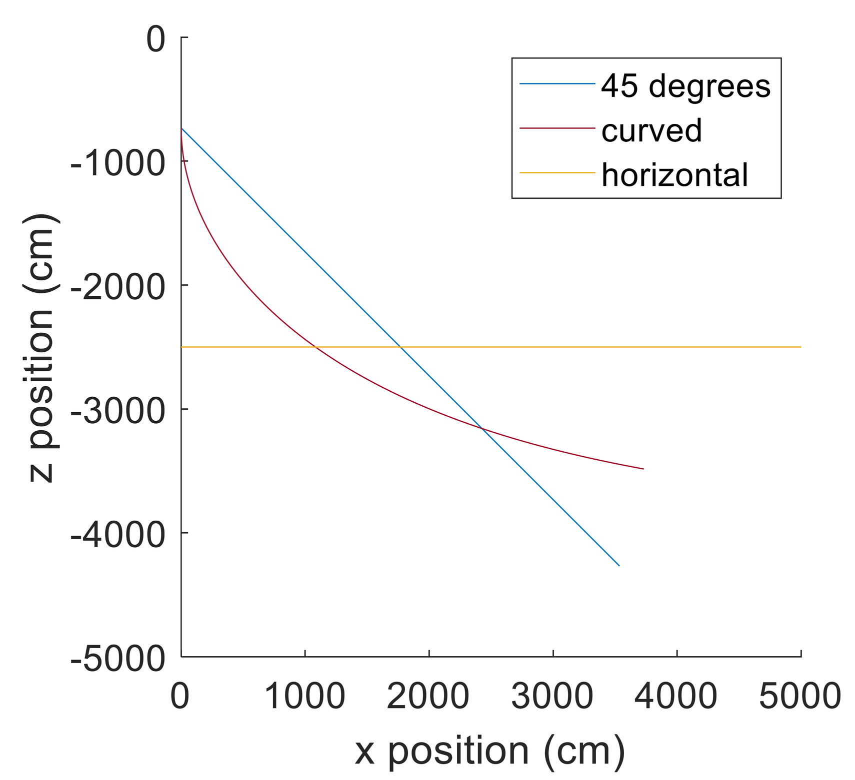


Figure 4. Distribution of bearing resistance

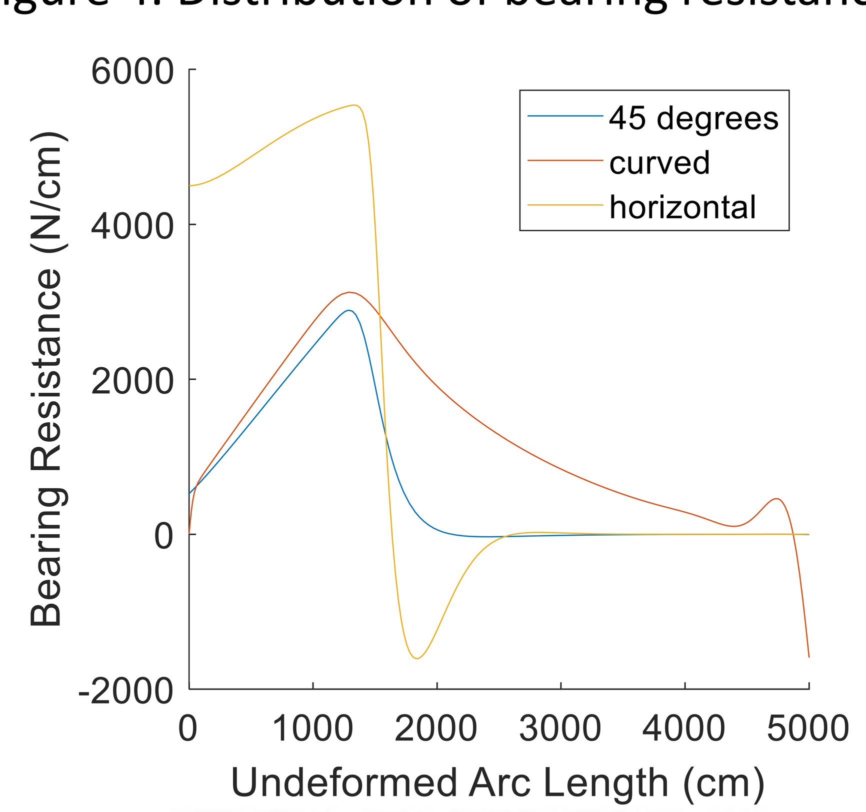
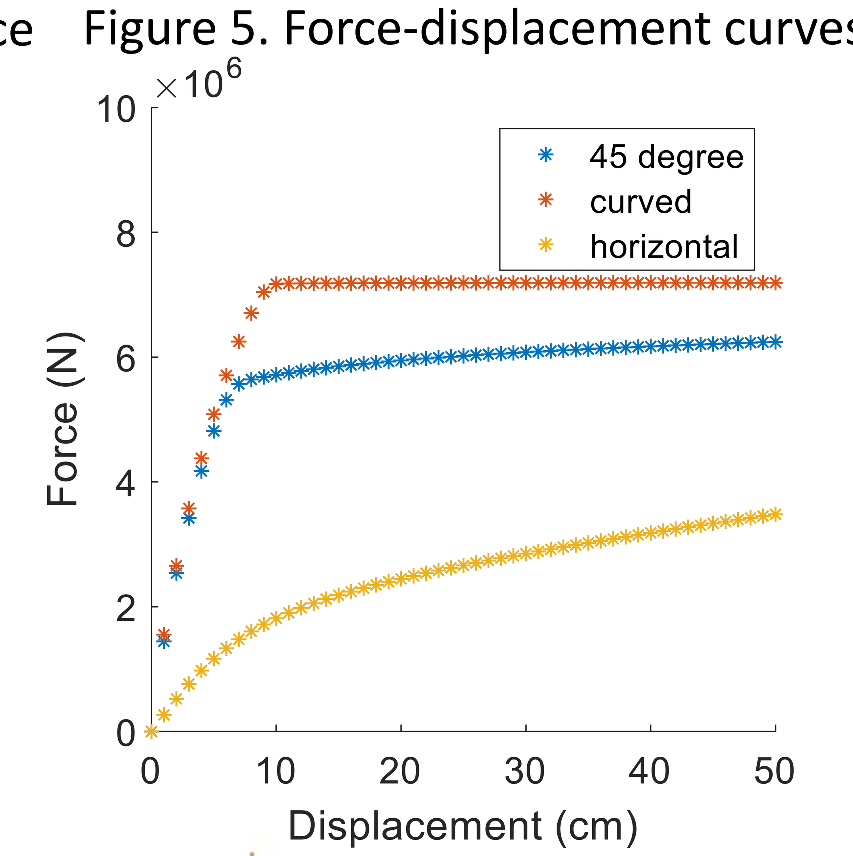


Figure 5. Force-displacement curves



1g Pullout Test Suite

- Simplified root anchor shapes (Figure 6) were 3D printed and tested in vertical pullout using the UR16e robotic arm
- Effects of shape, number of elements and inclination were investigated
- Peak pullout resistance varies linearly with projected area for initial depth of 18cm in loose sand (40% relative density) and pipe diameter of 0.5cm and pipe length of 2cm (Figure 7)

Figure 6. Array of root anchor shapes

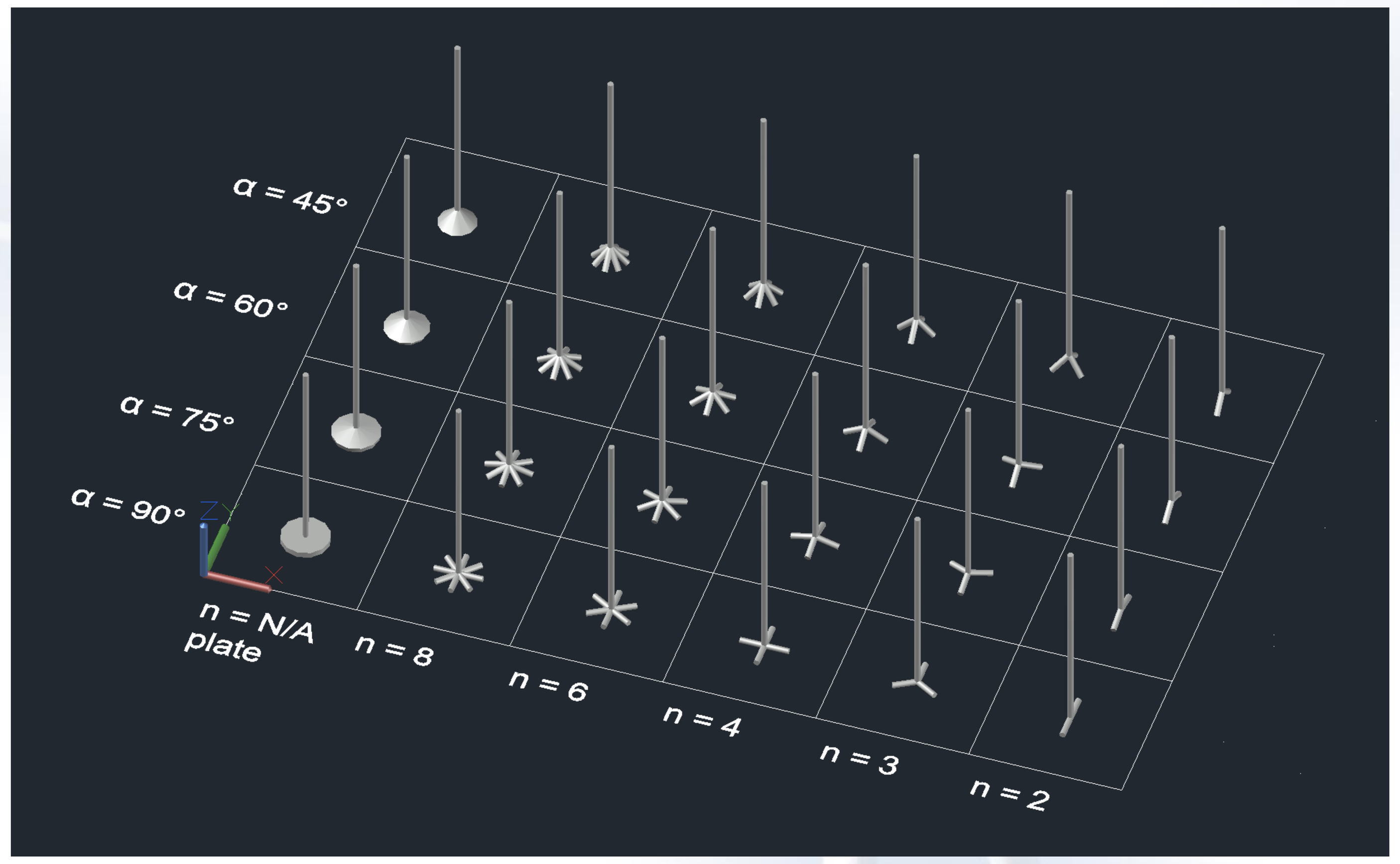
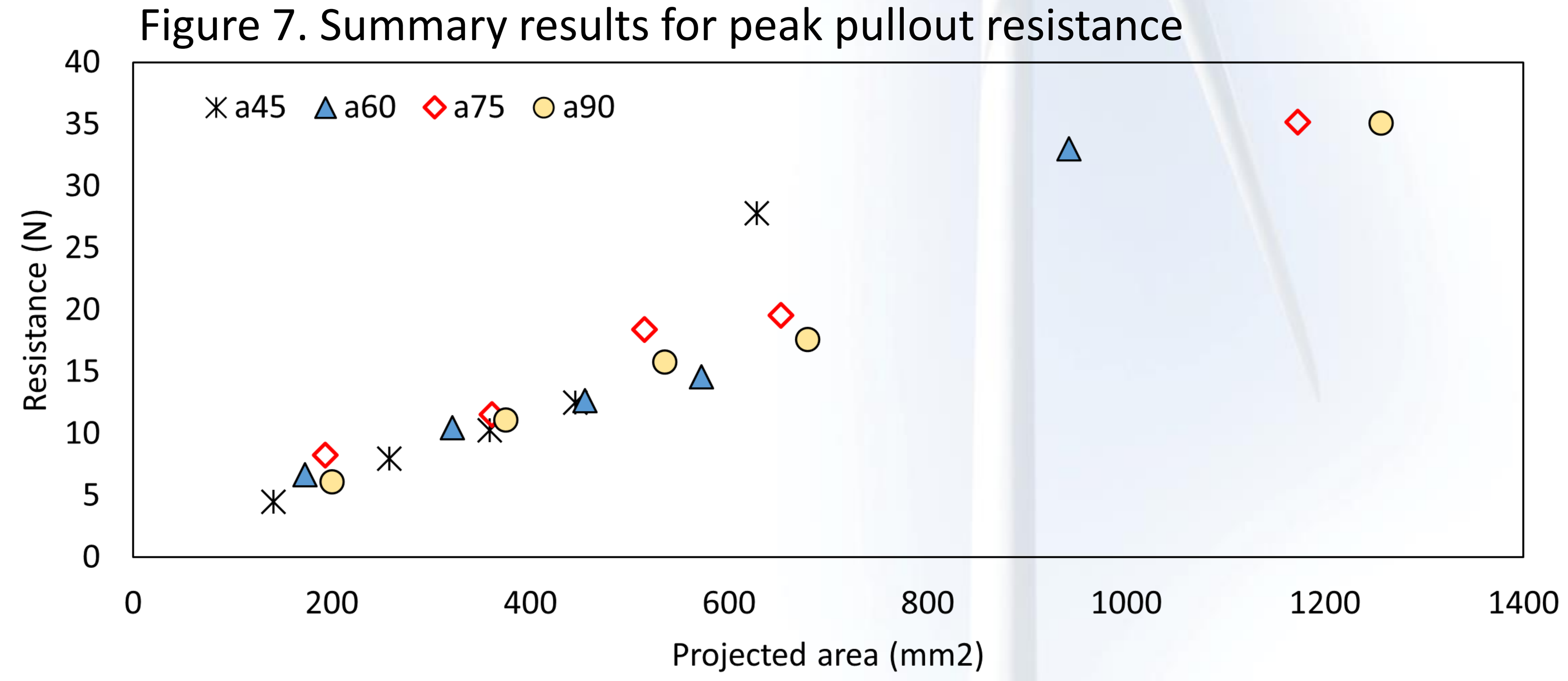


Figure 7. Summary results for peak pullout resistance



Year 7 Plans

- Complete 1g testing of both simplified models and models of varying complexity
- Test select models at realistic stress conditions in the 1m centrifuge
- Investigate flexible models of intermediate complexity
- Calibrate structural models to physical testing
- Optimize design of the anchor architecture

Supplementary Analytical Findings

- Optimal shape of a rigid cylindrical anchor element for vertical pullout capacity if bearing and skin friction resistance vary linearly with depth defined by constants "b" and "a" respectively, depth f(s) parameterized by arc length "s," with total length "L" takes the form:

$$f(s) = \frac{L}{\operatorname{atan}\left(\frac{b}{a}\right)} * \sin\left(\frac{\operatorname{atan}\left(\frac{b}{a}\right)}{L} * s\right)$$

- Solutions for flexible and varying diameter are forthcoming
- Solutions for hybrid branched systems will follow

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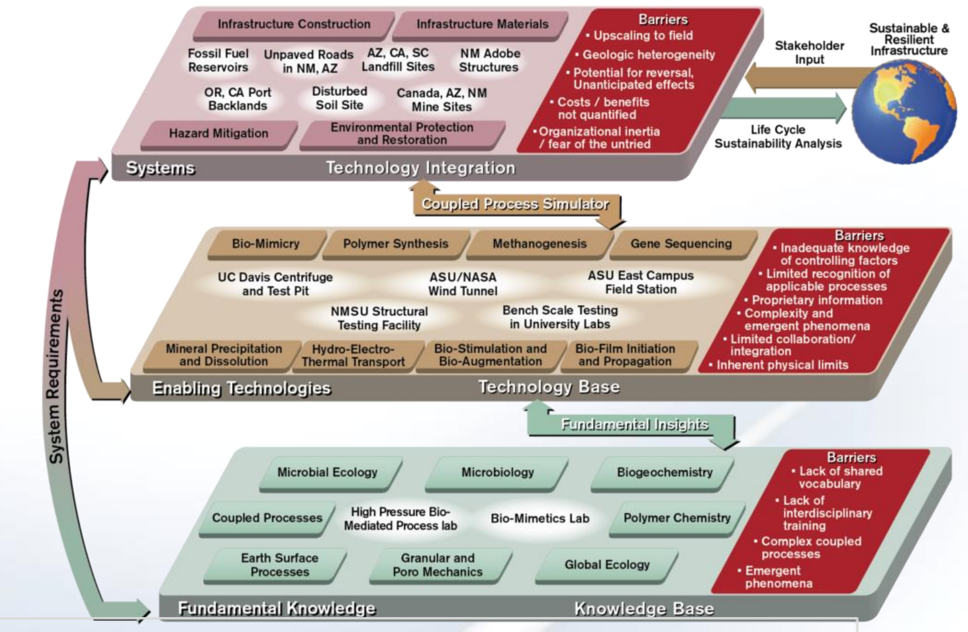
Field Installation of Root-Inspired Ground Anchor Prototypes



Presenters: John Huntoon
Advisors: Dr. J. David Frost
Thrust: Infrastructure Construction
Use Case: Ground Anchors
Institution: Georgia Tech
Project: #10

Background & Motivation

Utilize the principles of root systems to enhance geotechnical infrastructure subject to pullout forces

Anchor System	Capacity (kip)		Required Bonded Length (ft)
	Cohesive Soils	Non-Cohesive	
Gravity-Grouted Tieback	5 - 45	11 - 90	10 - 40
Post-Grouted Tieback	13 - 111	27-222	10 - 40
RIGA	Similar or Greater	Similar or Greater	Potentially 5 - 10

Research Objectives

Design an anchor system that:

- Develops capacity independent of ‘bonded length’
- Has fewer spatial constraints
- Addresses sustainability concerns by minimizing material used and installation effort

Methods & Materials

- Intermediate-scale field tests of anchor installation and pullout
- Future trials to involve lab and field scale experimental work and numerical modeling

PCT International Patent Pending:

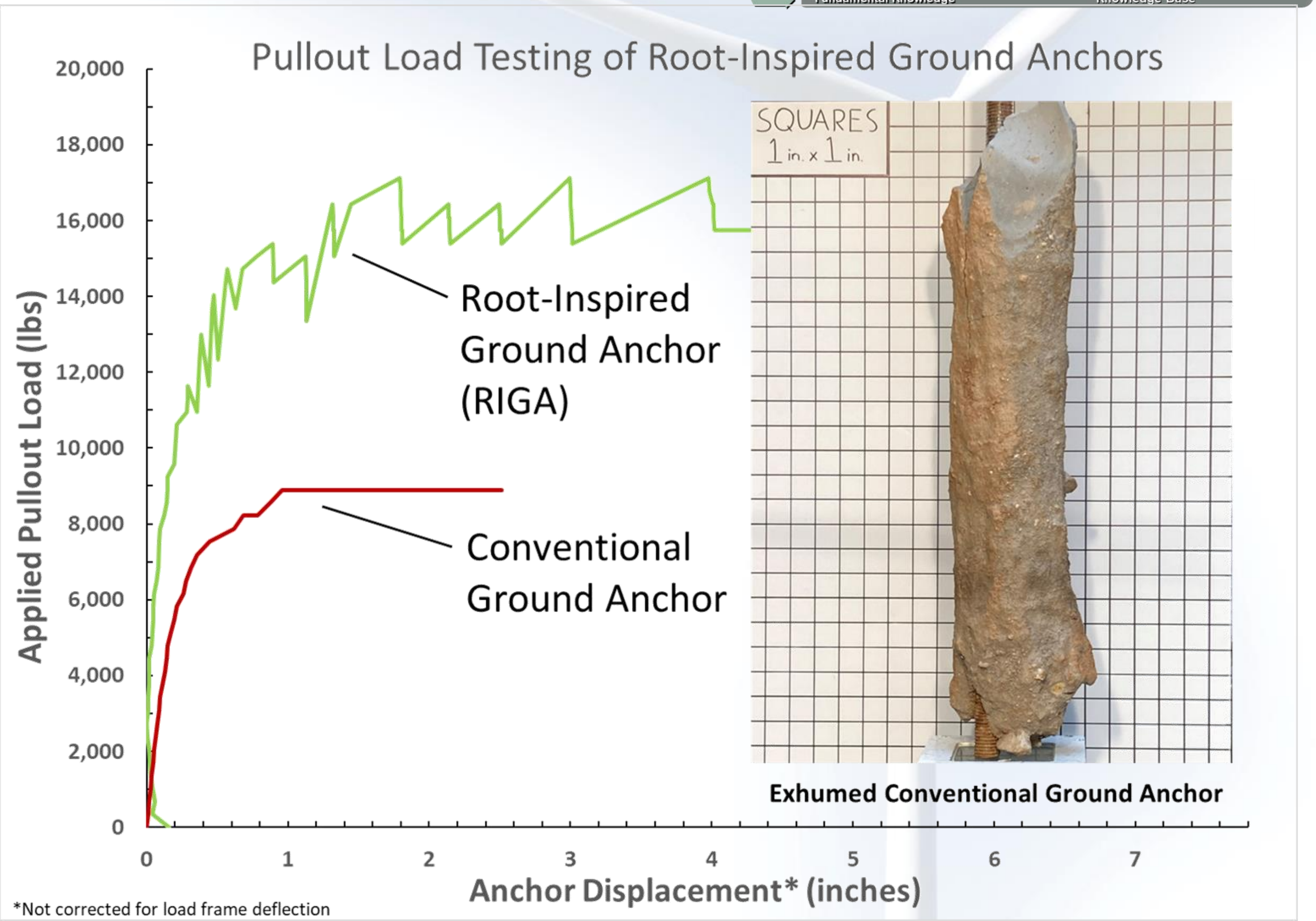
Ground Anchoring Apparatus and Method – Attorney Docket No. 10034-046WO1 8424

Conclusions & Year 7 Work

- Prototype installation has been performed
- Explore commercialization – NSF I-Corps
- Perform life cycle sustainability assessment
- Instrumented prototype field installation
- Installation procedure and anchor capacity must be verified in numerical and field trials

RIGA Prototypes

Installed, tested, and exhumed Root-Inspired Ground Anchor prototype



A Young Scholar collects data during pullout load testing – June 2021

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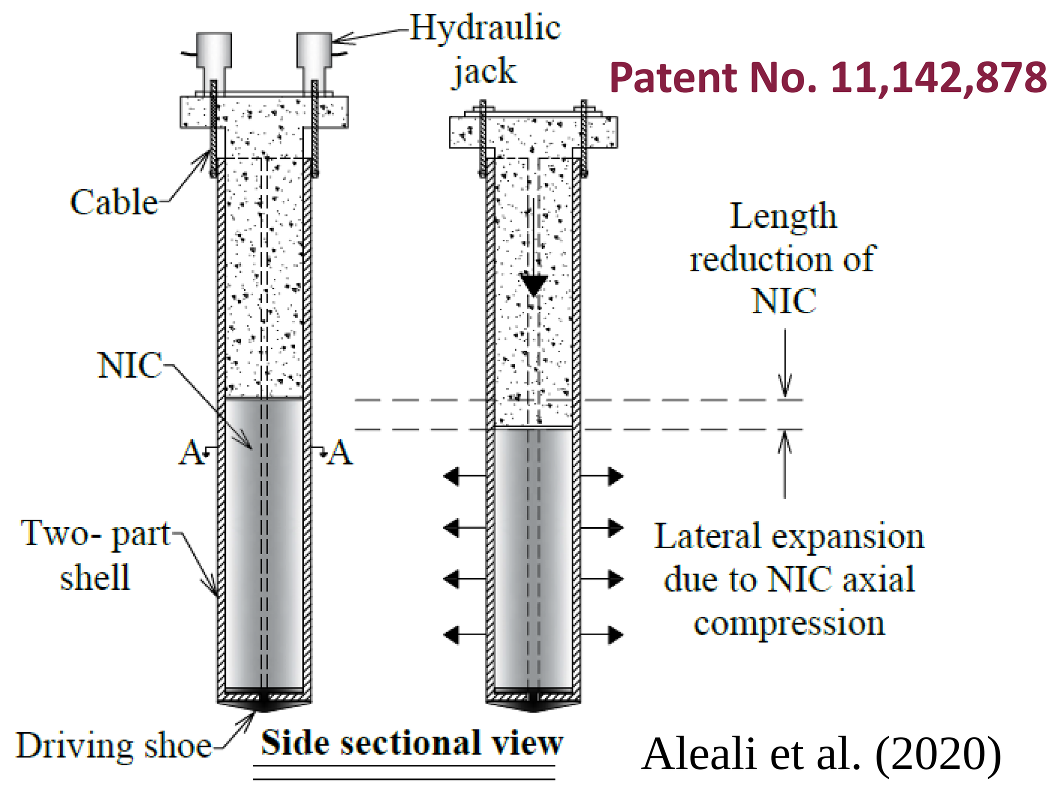
Numerical Simulation of Bioinspired Radially Expansive Piles

Presenter: S. Ali Aleali Advisors: Dr. Paola Bandini and Dr. Craig Newtson Institution: NMSU Collaborator: Dr. Dipanjan Basu (University of Waterloo)

Background

Goal: Develop a deep foundation system through bioinspiration that provides significantly greater shaft resistance (in axial compression and/or tension) compared to conventional cylindrical piles and demonstrate the advantages of the new pile system with numerical modeling.

Bioinspired Radially Expansive Pile (BREP)

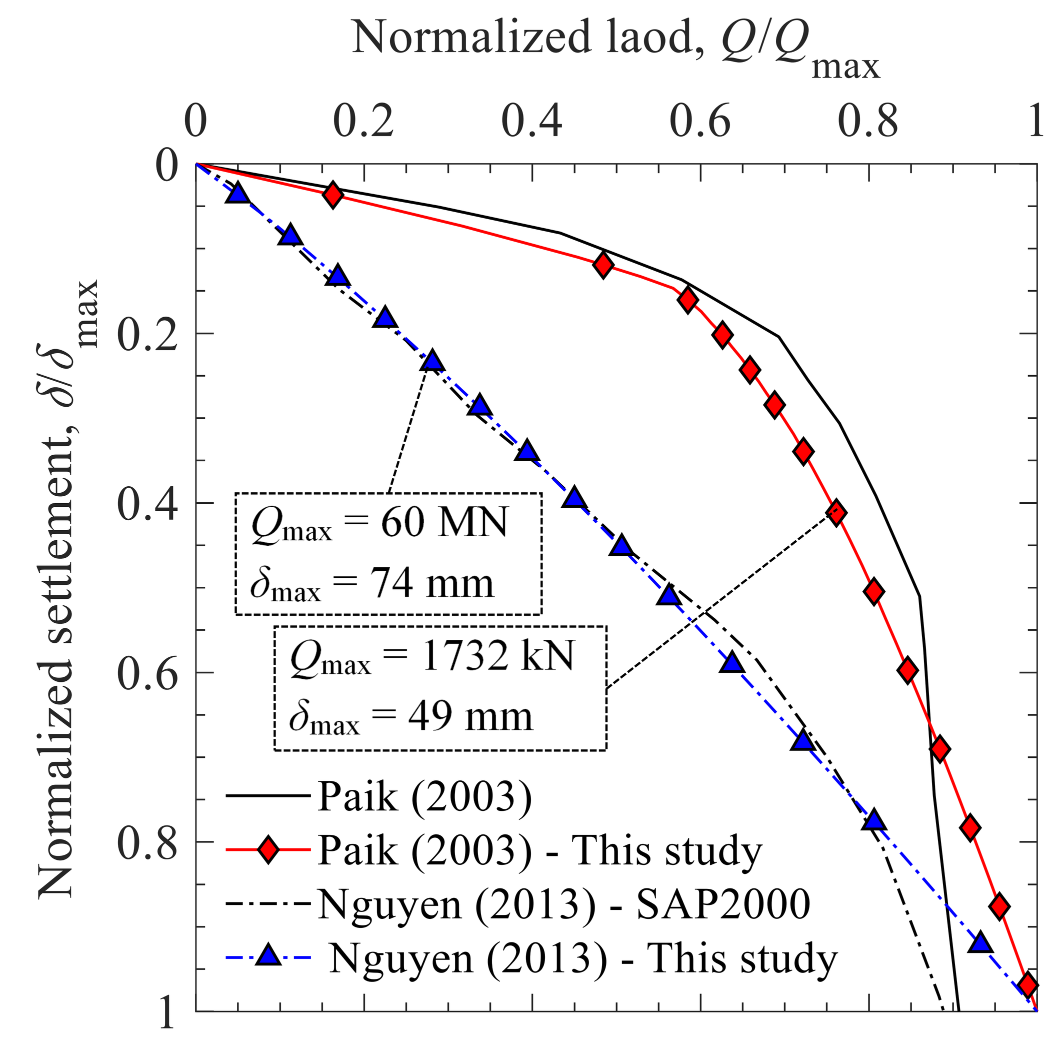


Aleali et al. (2020)

Framework for Finite Element (FE) Analysis

- Soil constitutive model: CASM (Yu, 1998, 2006)
- FE software ABAQUS® (2017)
- Triaxial verification tests on Erksak 330/0.7 sand (very loose, medium dense, and very dense)
- Pile load test validations considering the effect of installation of displacement pile in sand.
- Parametric study considering most influential BREP parameters.

Validation and verification studies



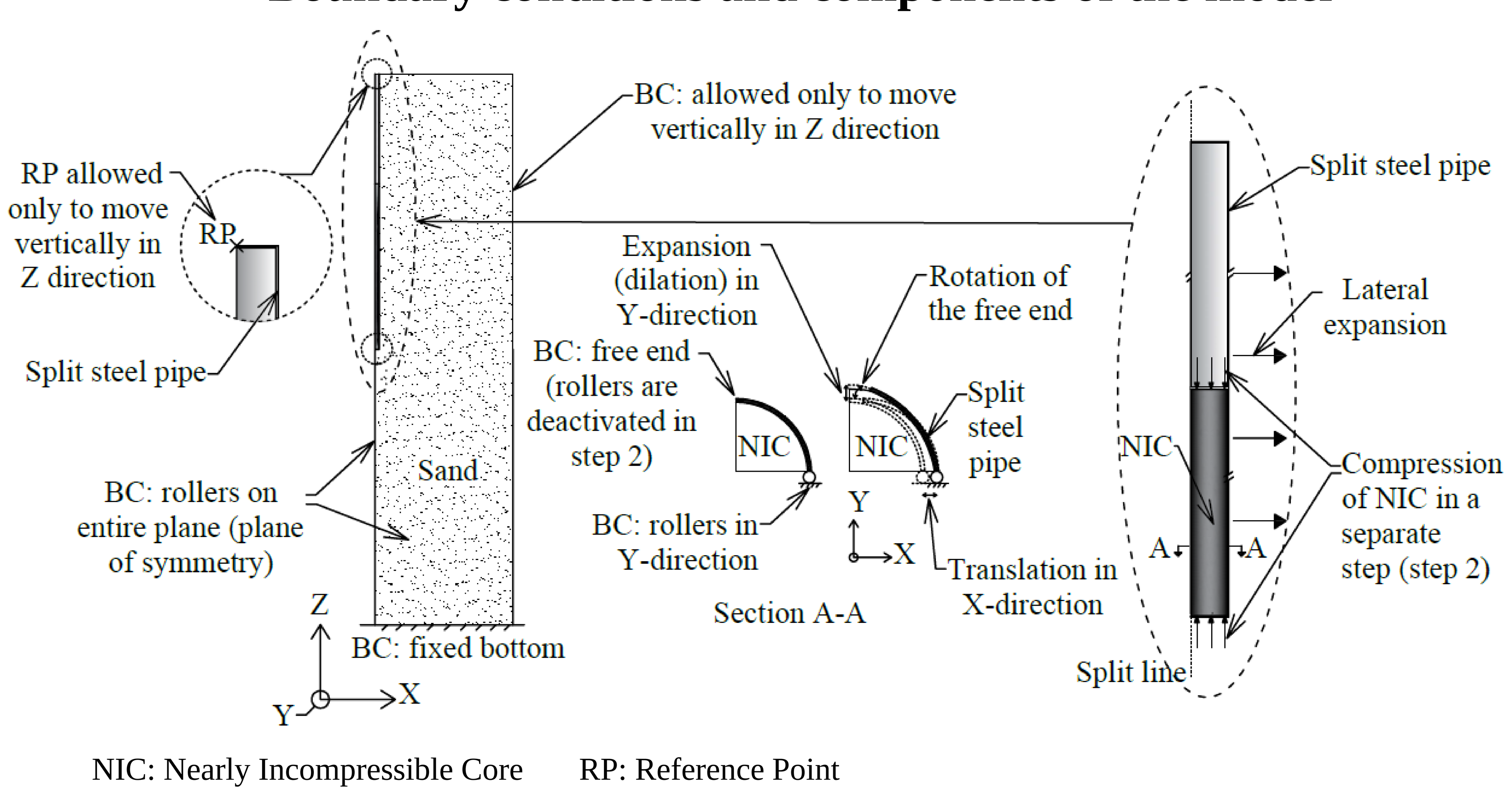
Parametric study plan

Target parameter	Specifications selected to investigate each target parameter: L^*	p_{core} (MPa)	Density state	K_0
Expansion components	**0.33, 0.5, 0.67**	**3, 5, 8, 10**	Medium dense	0.5
Initial density	0.67	5, 8	**Loose, Medium dense, dense**	0.5
In-situ lateral earth pressure	0.67	5	Medium dense	**0.4, 0.5, 0.65**

Note: D_r of loose, medium dense and dense sands are 30%, 50% and 70%, respectively.

FEM Features

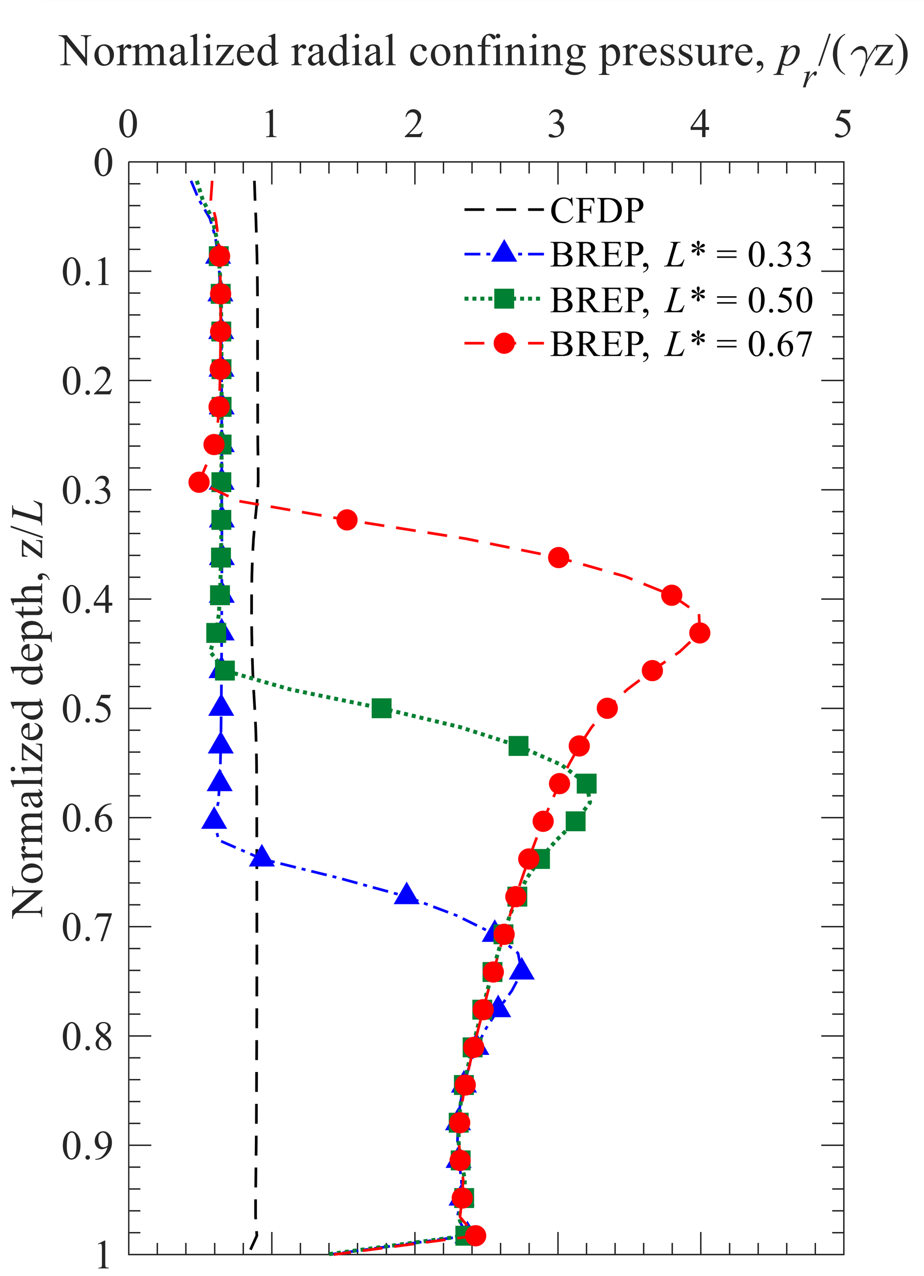
Boundary conditions and components of the model



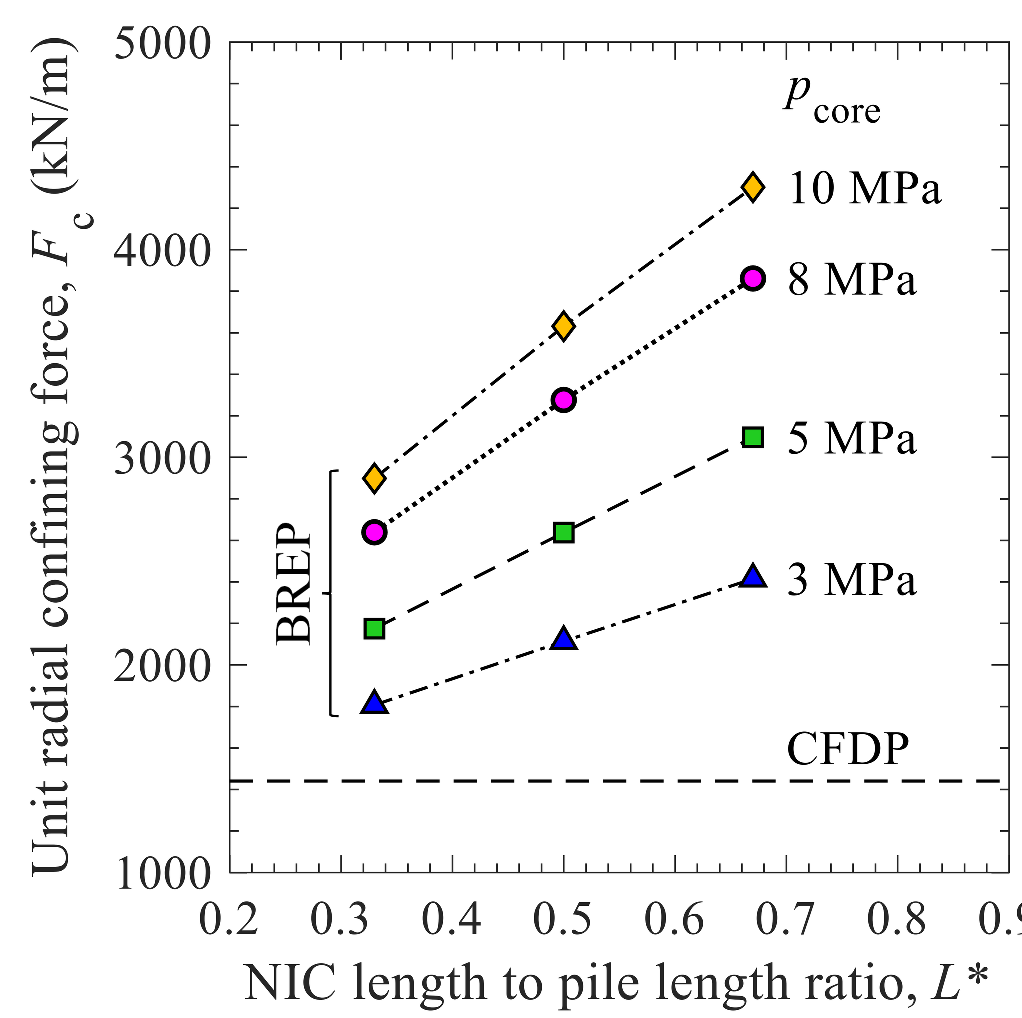
NIC: Nearly Incompressible Core RP: Reference Point

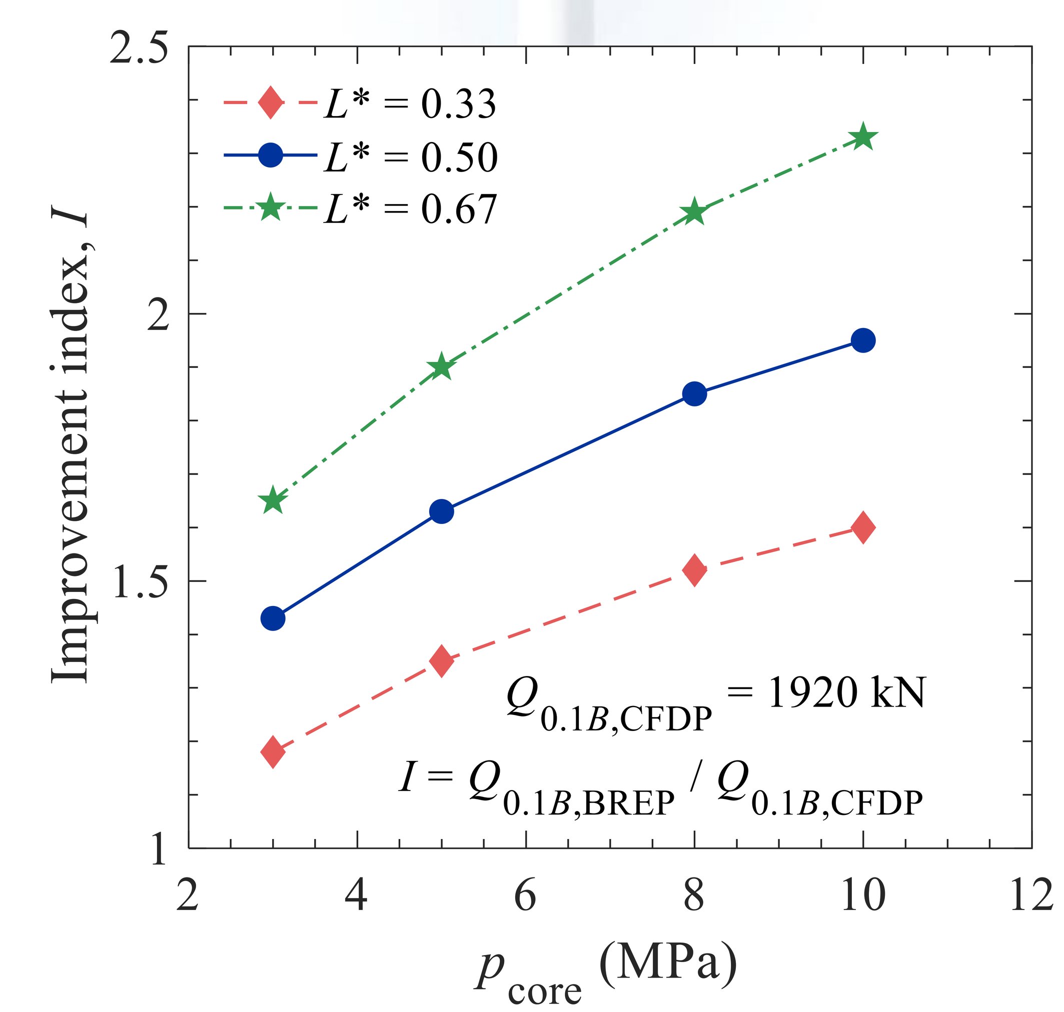
- Quarter model due to problem symmetry
- Three steps: 1 – Geostatic, 2 – Expansion, 3 – Axial loading
- NIC has properties of rubber, Poisson ratio $\nu_r = 0.48$
- Steel and NIC: Linear elastic materials
- Sand: Critical state properties using CASM
- Two sand types: Erksak 330/0.7 and West Kowloon
- Three density states: Loose, medium, very dense

FEM Results, Conclusions, and Future Work



CFDP: Conventional fully displacement pile
L^*: NIC length to pile length ratio
p_{core}: NIC compression pressure





Future work: Publish results; conduct FEM of BREP loaded in axial tension (pull-out); conduct FEM of bioinspired expansive soil anchors; calibrate FEM and CASM using data from the mid-scale BREP prototype tests in the CBBG Test Pit; and advance the LCSA for BREP.

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Comparison of Heat Transmission in Adobe Masonry and Conventional Housing Systems

Presenter: Eduardo Davila **Advisors: Paola Bandini, Brad D. Weldon, John Onyango.**

Background

Adobe masonry is used in semi-arid regions throughout the world due to its ease of construction and material availability. Adobe construction can be found in historic landmarks, traditional dwellings, and modern construction. It uses local soils and requires little energy and water. Adobe possesses thermal properties which may reduced environmental footprint due to lower demands of heating/cooling. To further explore the sustainable aspect of adobe structures, heat transfer rates expressed as u-values were measured at the Amador House, an adobe masonry structure built circa 1866, in Las Cruces, New Mexico. The measured values were compared to u-values of traditional construction systems such an apartment complex with a wood frame and a concrete masonry unit (CMU) house also collected in Las Cruces.

Methods and Instrumentation

Heat flux and temperature sensors were used to measure u-values in the different structure systems (traditional adobe, wood frame, and CMU). Two temperature sensors were used, one inside the structure and the other outside to calculate the change in temperature between the wall system. The heat flux sensor was placed indoors next to the inside temperature sensor. To facilitate placement, sensors were positioned near an opening, such a window or a door. The sensors were left to collect rate of thermal transmittance data for at least three days before changing their location.

Figure 1. Amador House, West wall w/o plaster.

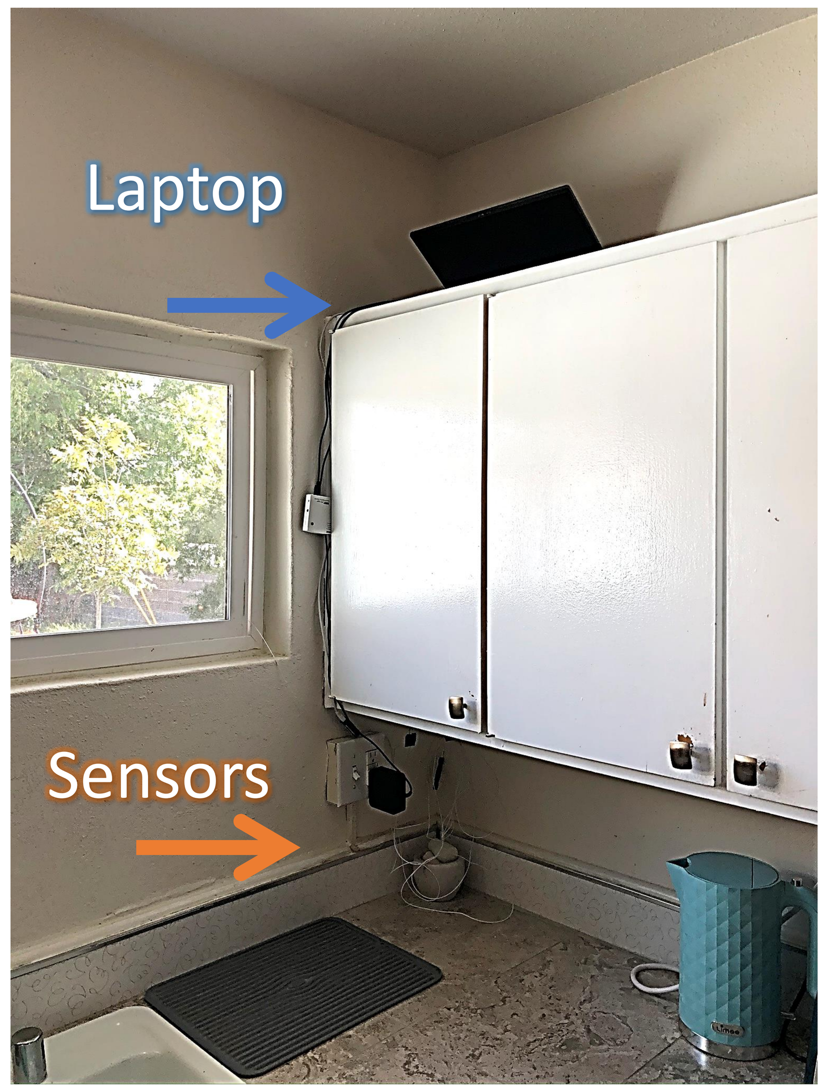

Figure 2. CMU masonry house.

Figure 3. Amador House South Wall

Research Objective

- Understand thermal transmittance better to assess the sustainable aspects of adobe wall systems.
- Recognize the thermal impact of an adobe structure
- Compare u-value data results to commonly used structural systems to evaluate the impact of using of adobe masonry construction.

Results

Location	U - Value, W/(m²K)
Wood Frame - South	7.01
Wood Frame - North	14.19
Adobe Amador House - West	7.36
Adobe Amador House - North	4.01
Adobe Amador House - West w/o plaster	3.47
CMU House - North	33.32
CMU House - South	27.79

Conclusions and Future Work

- Adobe structure showed the lowest u-value average data of 4.95 W/(m^{2}K). The average u-value for the wood frame apartment and CMU house were 10.6 W/(m^{2}K) and 30.6 W/(m^{2}K), respectively.
- From this data set, adobe showed to be more efficient than the wood frame apartment and the CMU house by 214% and 618%, respectively. Adobe could provide a pleasant inside temperature by one-half to one-sixth of the energy than wood frames or CMU structures require.
- Data from modern adobe will be compared to historic adobe and the same locations will be recorded again throughout the seasons to monitor any changes (if any).

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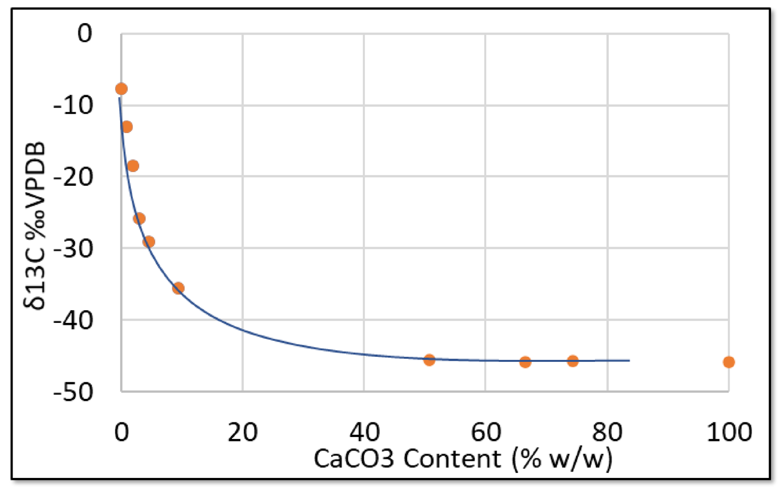
Engineering Applications of EICP – Fugitive Dust Control

Presenter: Miriam Woolley **Advisors: Ed Kavazanjian, Nasser Hamdan** **Institution: ASU**

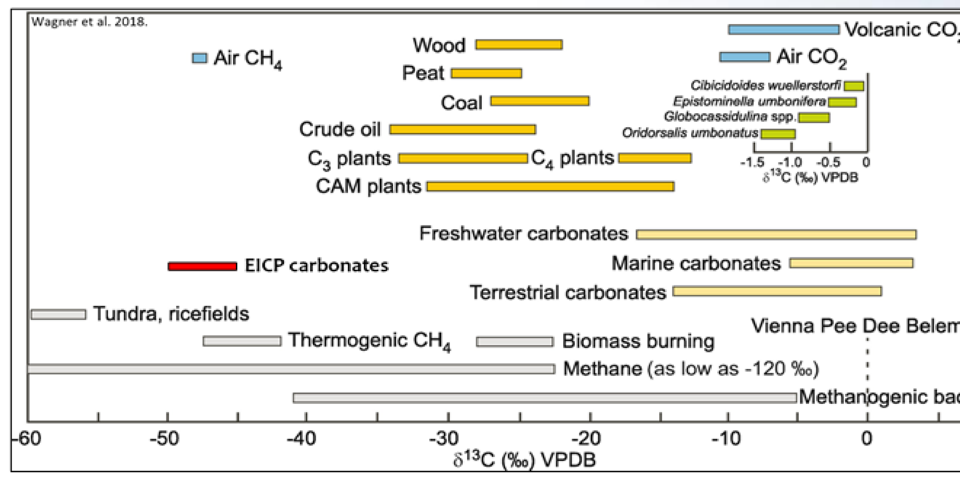
Year 6 Accomplishments

- Analyzed Phase I Field Trial data
  - Isotope Analysis to identify calcium carbonate ($CaCO_3$) source
- Developed air jet test (to wind erosion test at higher velocities)
  - Compared air jet to wind tunnel testing
- Began Portable In-Situ Wind Erosion Laboratory (PI-SWERL) testing



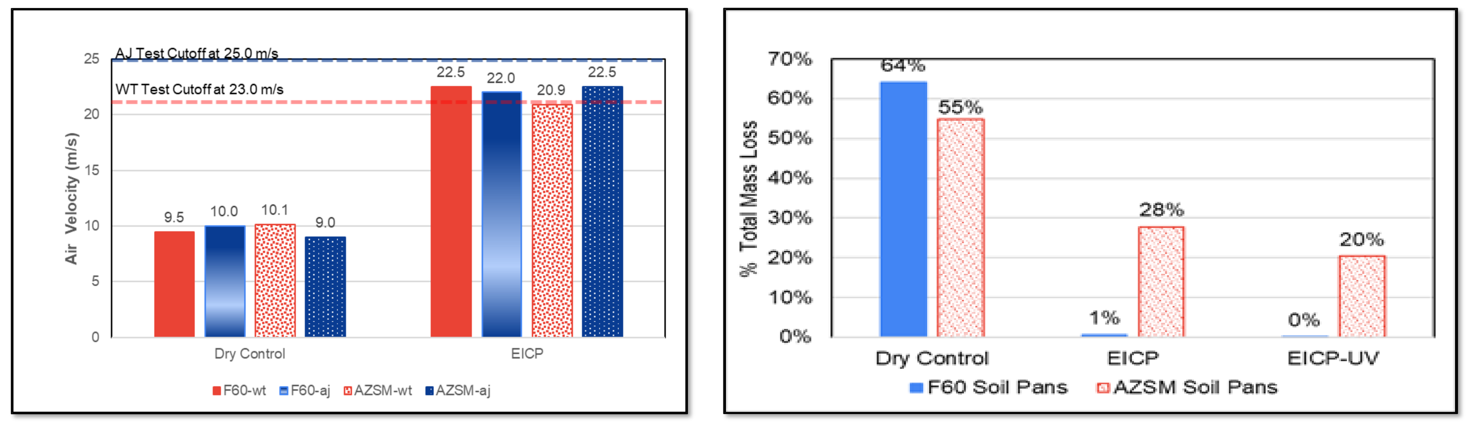
Specimen Type	δ13C ‰ VPDB	δ18O ‰ VSMOW
Untreated soil (0% added EICP-carbonate)	-7.51 to -8.09	-6.77 to -7.84
0.78% added EICP-carbonate	-12.97	-8.89
1.88% added EICP-carbonate	-18.43	-10.60
3.02% added EICP-carbonate	-25.75	-13.00
4.44% added EICP-carbonate	-29.10	-14.03
9.34% added EICP-carbonate	-35.58	-15.97
50.67% added EICP-carbonate	-45.55	-20.11
66.52% added EICP-carbonate	-45.79	-20.04
74.32% added EICP-carbonate	-45.65	-19.20
100% EICP carbonate (no soil)	-45.90	-19.94

δ13C ‰VPDB from EICP-carbonate added to soil specimens.

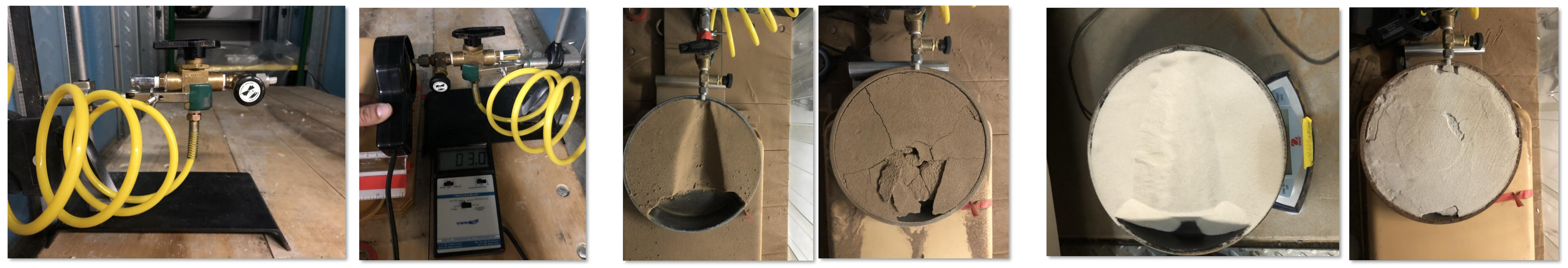


Isotopic variations of δ13C ‰VPDB adapted from Wagner et al. 2018 and modified with EICP carbonate band (approx. -45 to -50 ‰VPDB).

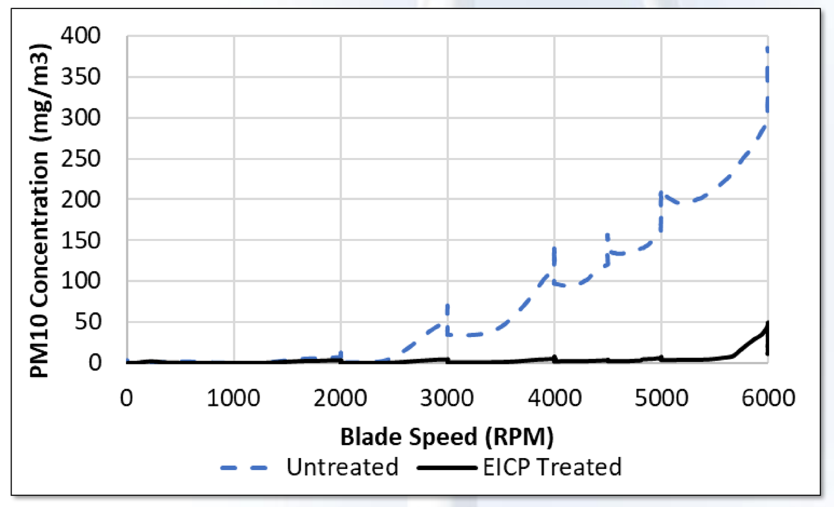
PI-SWERL test of an EICP treated soil pan.



Comparison of wind erosion test methods, wind tunnel and air jet, in a clean (F60) and a silty sand (AZSM).



Wind erosion testing of untreated and EICP treated soil pans with the air jet setup.



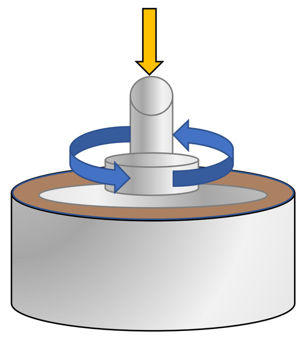
Comparison of untreated to EICP treated AZSM soil pans.

Phase I Trial Lessons

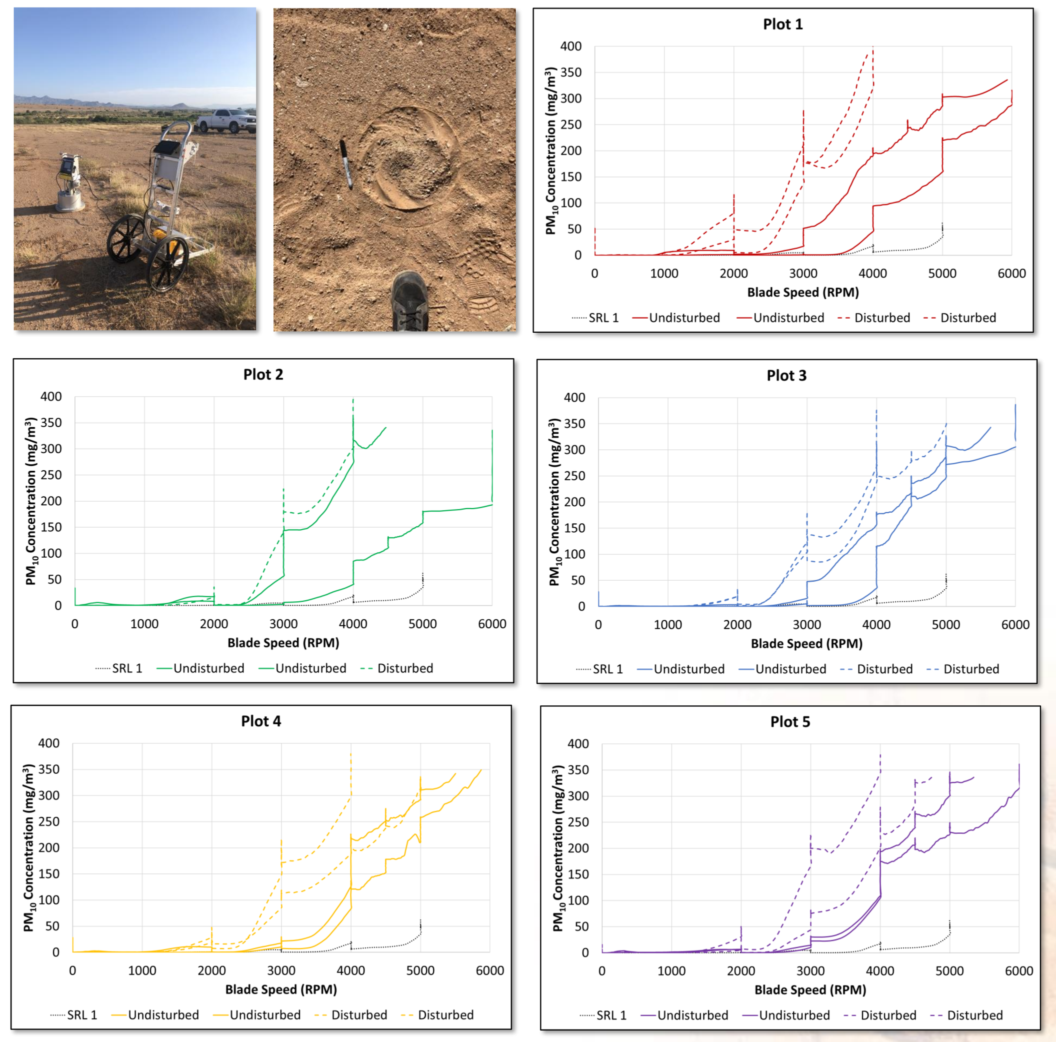
- Developed and tested an application system to combine EICP component solutions.
- Developed procedures for sample collection and field measurements.
- Identified issues to be addressed in Phase II
  - Inadequate mixing of components the application system
  - Uneven treatment (due to low concentrations),
  - Evaluation methods have low resolution, high uncertainty

Year 7 Plans

- Conduct Phase II field trial
  - Incorporate lessons from Phase I
  - Include MICP section
  - Induce dust generation
  - Include PI-SWERL tests
- Conduct rheometer tests for threshold friction velocity
- Compare all laboratory methods for dust potential
  - Wind tunnel
  - Air jet setup
  - PI-SWERL
  - Vortex generator
  - Rheometer



Dynamic shear rheometer applies normal and shear stresses to the soil surface.



PI-SWERL measurements of the dust emissivity for the baseline condition of the field site.

Measurement of background site conditions including wind speed/direction, dust emissivity, and carbonate content.

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Development of EICP Treatment Application Methods for Erosion Control of Sands in Sloping Ground

Researchers: Rashidatu Ossai (PhD 2021), Oswaldo Marvez, Lucas Rivera, Paola Bandini (Senior Investigator)

New Mexico State University

Introduction

EICP treatment methods:
(1) Spray-on
(2) Percolation by gravity
(3) Percolation by injection
(4) Mix and compact

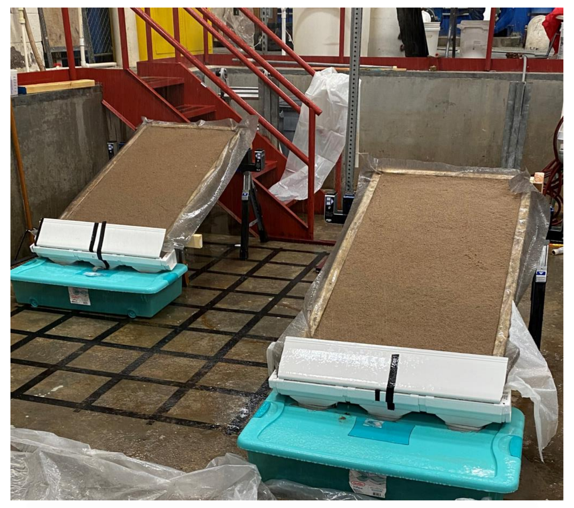
Limitations of these methods:

- Spray-on: Forms thin crust, not applicable when thicker layer is needed (for rainfall-induced erosion)
- Percolation by gravity: Can cause early precipitation, clogging, solution ponding
- Percolation by injection: Used in deeper soil (e.g., EICP columns)
- Mix and compact: Not feasible at field scale

Research Objectives

- Develop EICP treatment application method(s) feasible at the field scale for soil erosion control.
- Assess the effectiveness of the new EICP treatment methods for erosion control under simulated rainfall.

10 x 10 x 5 cm block



60 x 120 x 5 cm specimens

Description of Materials

Natural Sands:

Native New Mexico sand (NS), poorly graded, ~3% fines, C_u = 2.5, C_c = 1.0, sampled from ramp embankment

Ottawa 20-30 (OT), clean, poorly graded, used as control

Target D_r = 55%

EICP components:

$CaCl_2$, urease enzyme, non-fat dry milk, urea, deionized water

Crude extract urease enzyme: Jack beans, glass wool

Enzyme activity check: Electrical conductivity (EC) meter

Molds: Blocks 10 x 10 x 5 cm, Boxes 60 x 120 x 5 cm

Treatment Methods

Existing methods:

P - One-step percolation
MC - One-step mix-compact

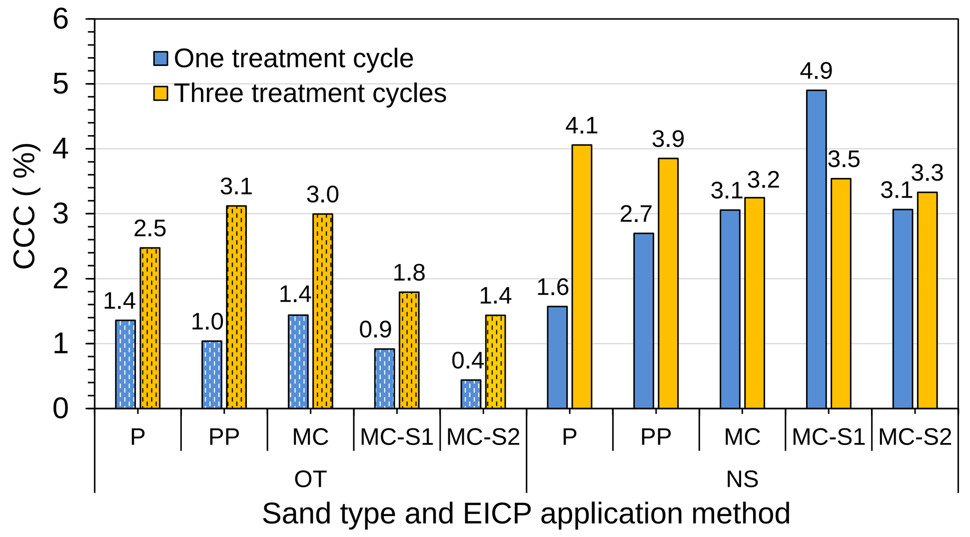
New methods:

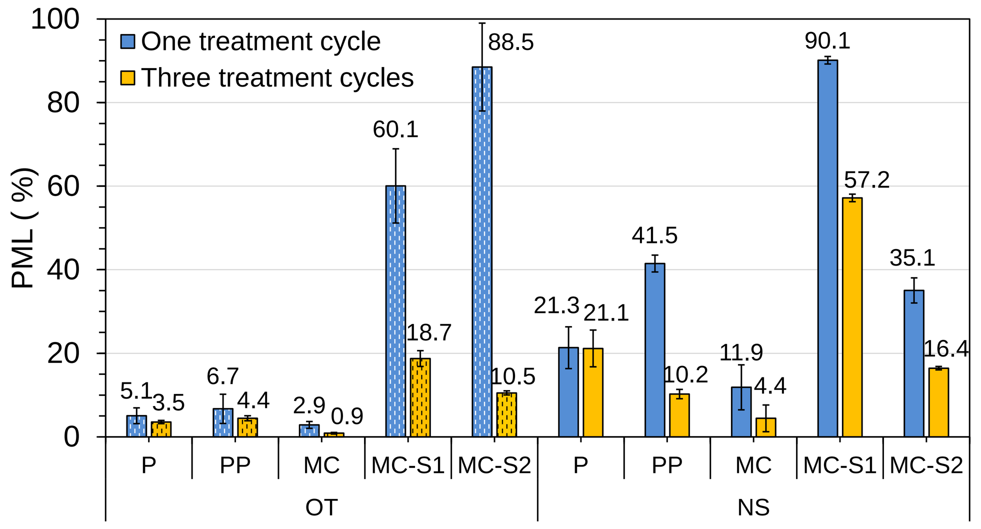
PP -Two-step percolation
MC-S1 - Two-step mix-compact, Sequence 1
MC-S2 - Two-step mix-compact, Sequence 2

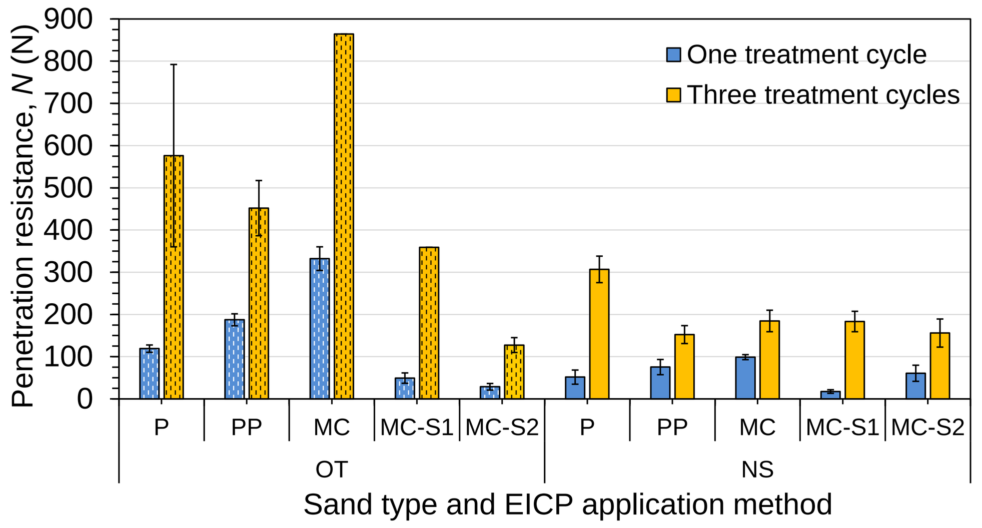
- New two-step methods: EICP components are not mixed before applying to the soil. Enzyme + milk solution is applied to the soil separately from the urease + calcium chloride solution, so precipitation does not occur outside the soil.

Development of New EICP Application Methods

Calcium carbonate content (CCC), percent mass loss (PML), and strength

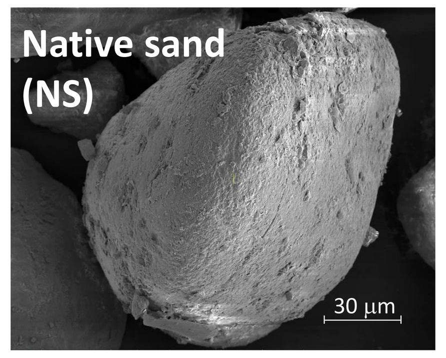


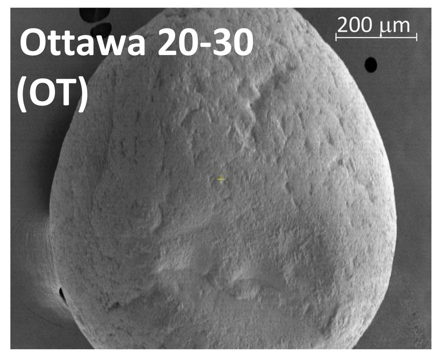


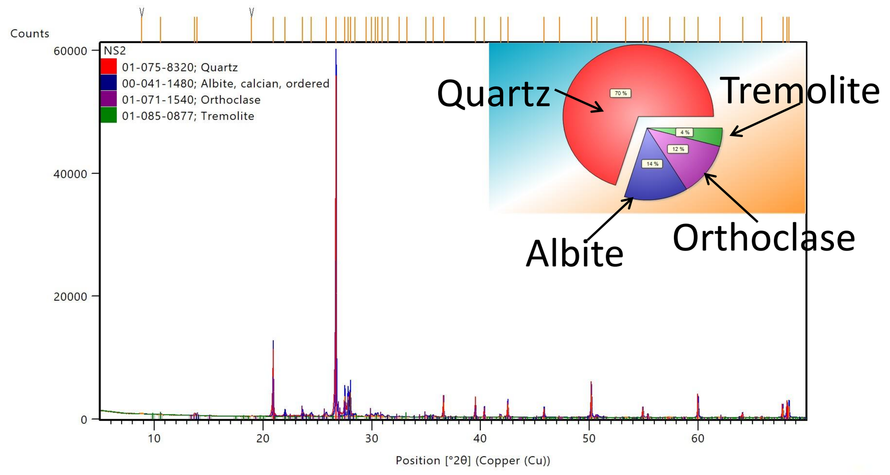


- Higher CCC for NS than OT though less cementation
- Improved cementation with three cycles (more significant for MC-S1 & MC-S2)
- White carbonate on the surface of OT & NS with P & MC methods
- P method: stronger cementation near surface
- Comparable *N* for NS prepared with MC, MC-S1, and MC-S2
- NS contained non-quartz grains and thin coating of clay-size particles. XRD of untreated NS shows albite, orthoclase, and tremolite

Block tests – SEM & XRD





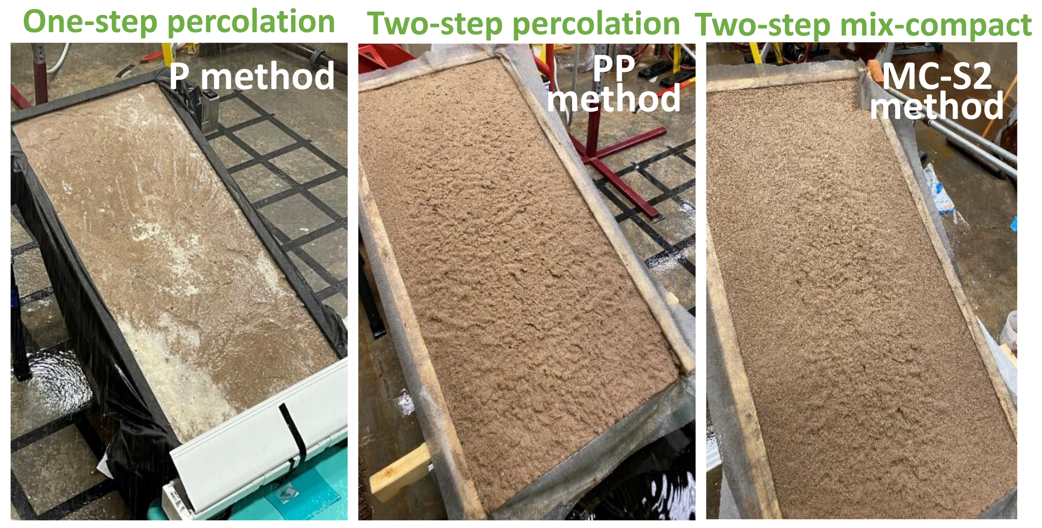


Intermediate-scale Erosion Tests

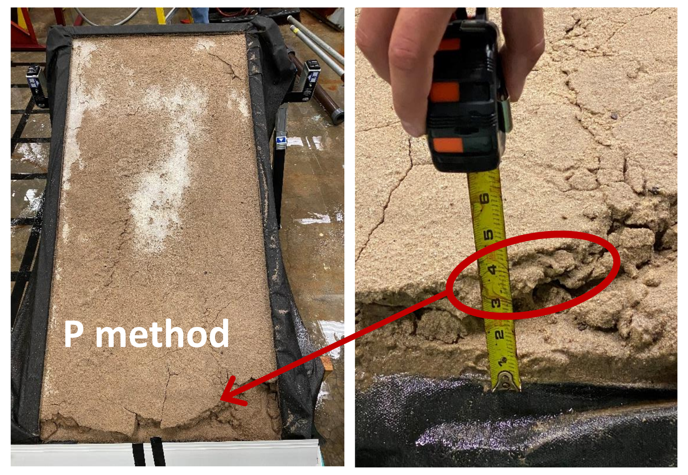
Lab-scale rainfall simulator

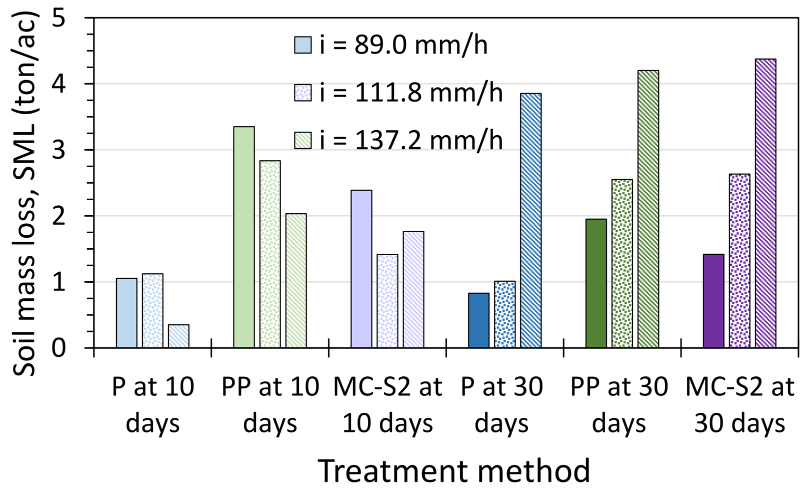
Spray area: 2.4 m x 2.4 m

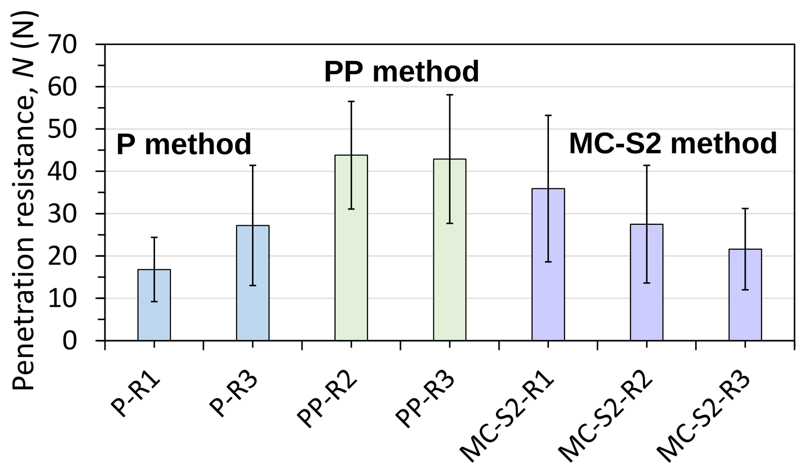
- Erosion tests: 10 and 30 days after last treatment
- Sand type: NS
- Treatment: 3 cycles (1 Mol concentration)
- Rainfall intensities: 89, 112, 137 mm/h, 20 minutes each
- Avg. drop size: 1-2 mm
- Slope: 3H:1V, 3 replicates



- Treatment methods:
  - **P** - Percolation
  - **PP** - Two-step percolation
  - **MC-S2** - Two-step mix-compact







- P method had the most surface cementation, but mostly in upper 0.5 inch
- White carbonate on surface of P method
- Relatively high increase in soil mass loss (SML) for P method at 30 days during 137.2 mm/h rainfall event
- PP method had the highest *N* values. P method had the lowest *N* values
- Low *N* values for P method confirm cementation mostly at the surface

Conclusions

- New EICP treatment methods showed promising results with multiple treatment cycles
- New two-step methods avoid premature precipitation and allow controlling the thickness of the cemented layer
- Soil properties (e.g., fines content, mineralogy) influence the cementation in native sand
- EICP-treated sands showed resistance to erosion in terms of soil mass loss (SML) in simulated rainfall conditions

Year 7 Plans

- Determine optimum number of treatment cycles for erosion control (currently testing 5 treatment cycles)
- Apply EICP treatment in field plots (Earth dam site)
- Continue studying effects of sand chemistry and mineralogy on EICP cementation
- Continue parameter optimization for calcium carbonate determination with acid washing (e.g., acid concentration, rinsing time, sample size, sample location)
- Design systems-level scenario(s) for LCSA

Acknowledgements

This project collaborates with the CBBG EICP research team led by Prof. Edward Kavazanjian Jr. at Arizona State University (ASU). New Mexico State University (NMSU) research assistants Brianna Medrano, Alejandra Cano, Lesley Nayarez, Eugenio Campos, Pam Natera and Peter Zelkowski helped in several parts of the experimental program. Prof. Martha Mitchell of NMSU Department of Chemical and Materials Engineering co-supervises research assistants and collaborates in the research. Prof. Salim Bawazir and Prof. Manoj Shukla of NMSU provided advice for the erosion testing.

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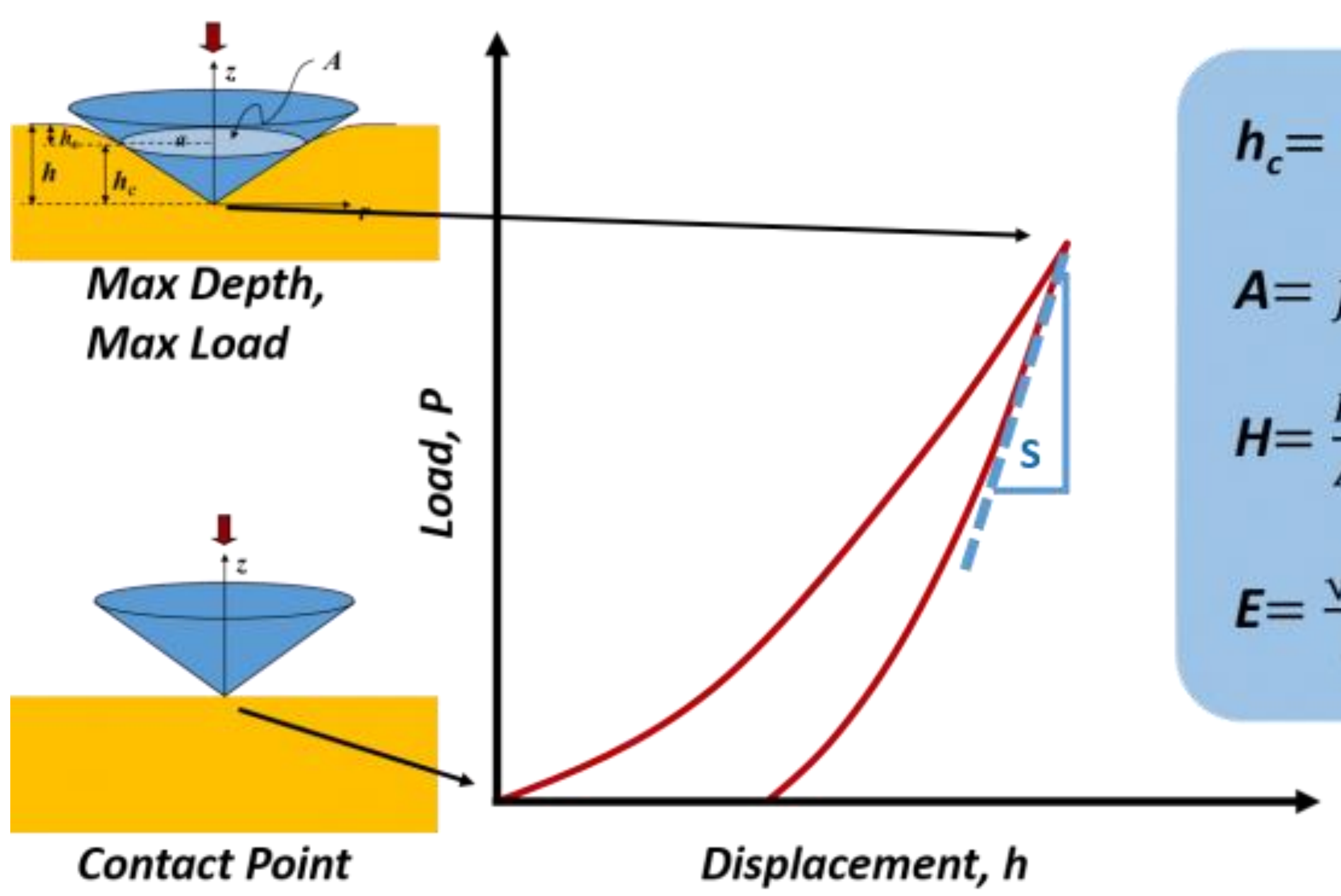
Nanomechanical Characterization of Enzyme Induced Carbonate Precipitates

Presenter: Vinay Krishnan Advisors: H. Khodadadi Tirkolaei, M. Kazembeyki, L. A. van Paassen, C. G. Hoover, E. Kavazanjian Institution: ASU

Background

Two types of precipitates studied using nanoindentation

- Baseline precipitate: urea, $CaCl_2$, urease
- Modified precipitate: includes nonfat dry milk (results in higher strengths)



$$h_c = h - \varepsilon \frac{P}{S}$$

$$A = f(h_c)$$

$$H = \frac{P}{A}$$

$$E = \frac{\sqrt{\pi}}{2} \frac{S}{\sqrt{A}}$$

Schematic of a nanoindentation test
(https://www.nanoscience.com/techniques/nanoindentation/)

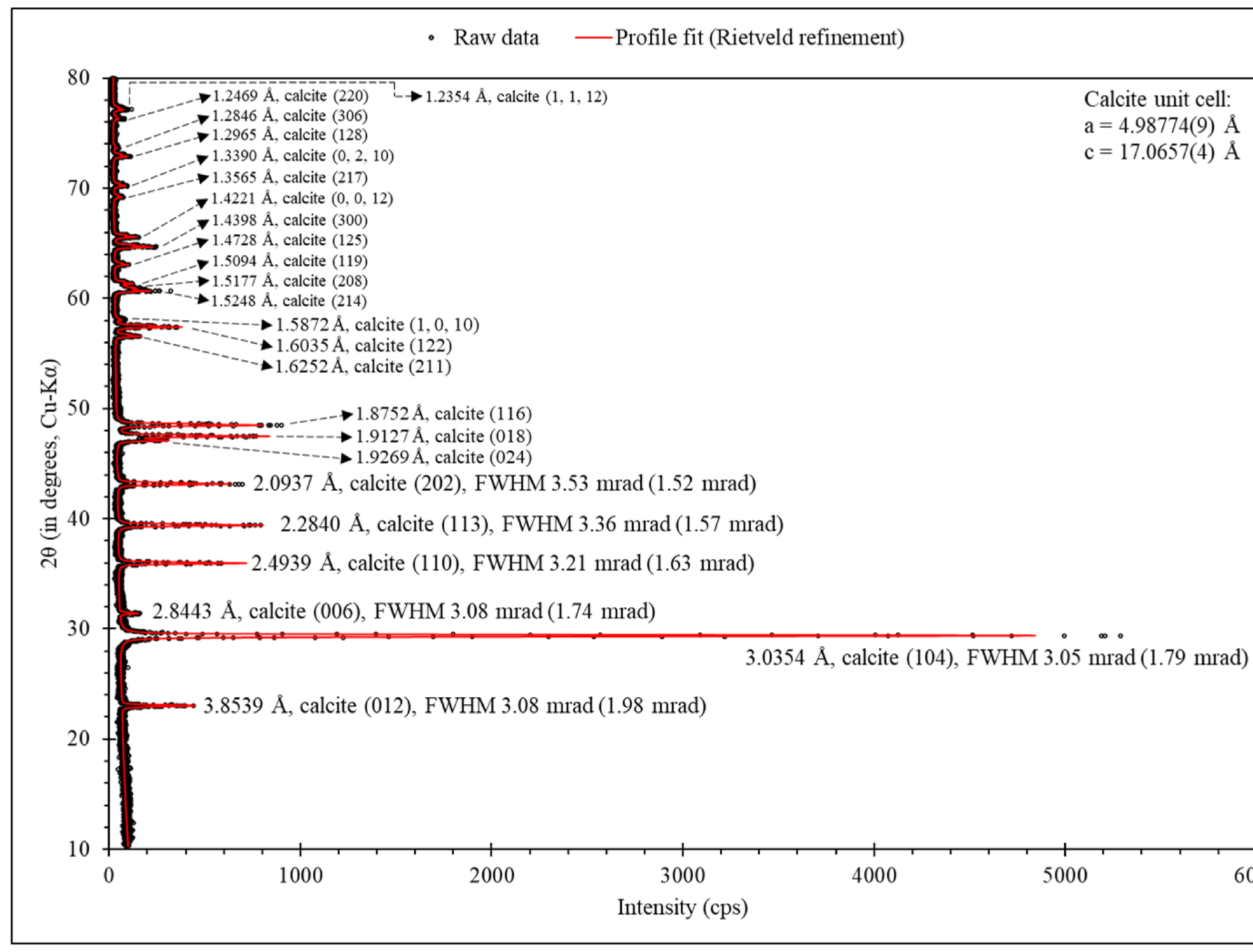
Materials and Methods

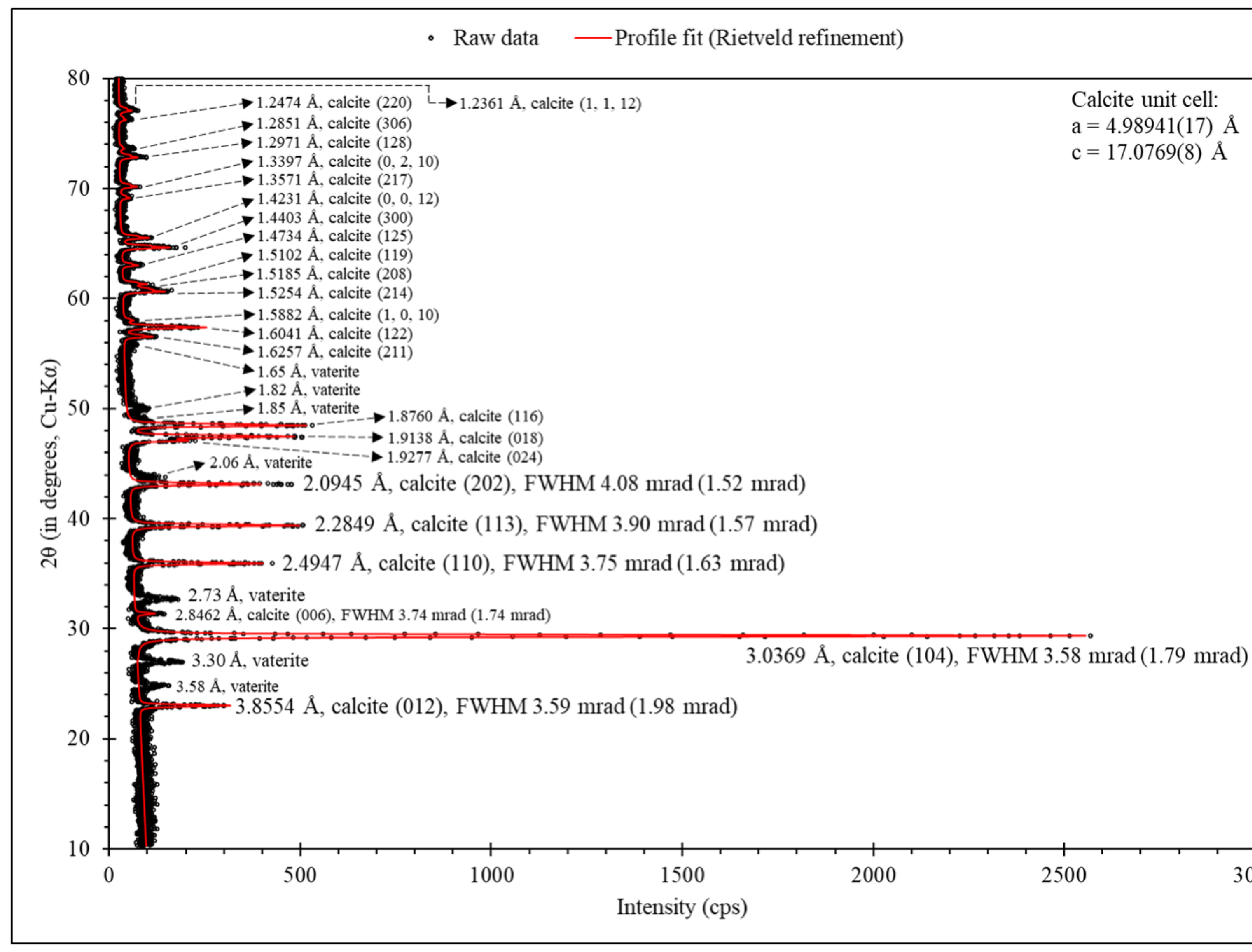
- Baseline solution: 1.0 M urea, 0.67 M $CaCl_2.2H_2O$, and 3.0 g/L urease (from Fisher Scientific)
- Modified solution: Baseline solution + 4.0 g/L nonfat dry milk
- Precipitates separated from supernatant after 72 h
- Characterized using X-ray diffraction and Fourier-transform infrared spectroscopy
- Prepared by casting in epoxy, grinding, and polishing

Results

X-ray diffraction:

- Baseline precipitate: entirely calcite
- Modified precipitate: predominantly calcite with small amounts of vaterite
- Diffractogram of modified precipitate exhibited broadening of peaks
  - Smaller mean domain size and/or greater lattice microstrain

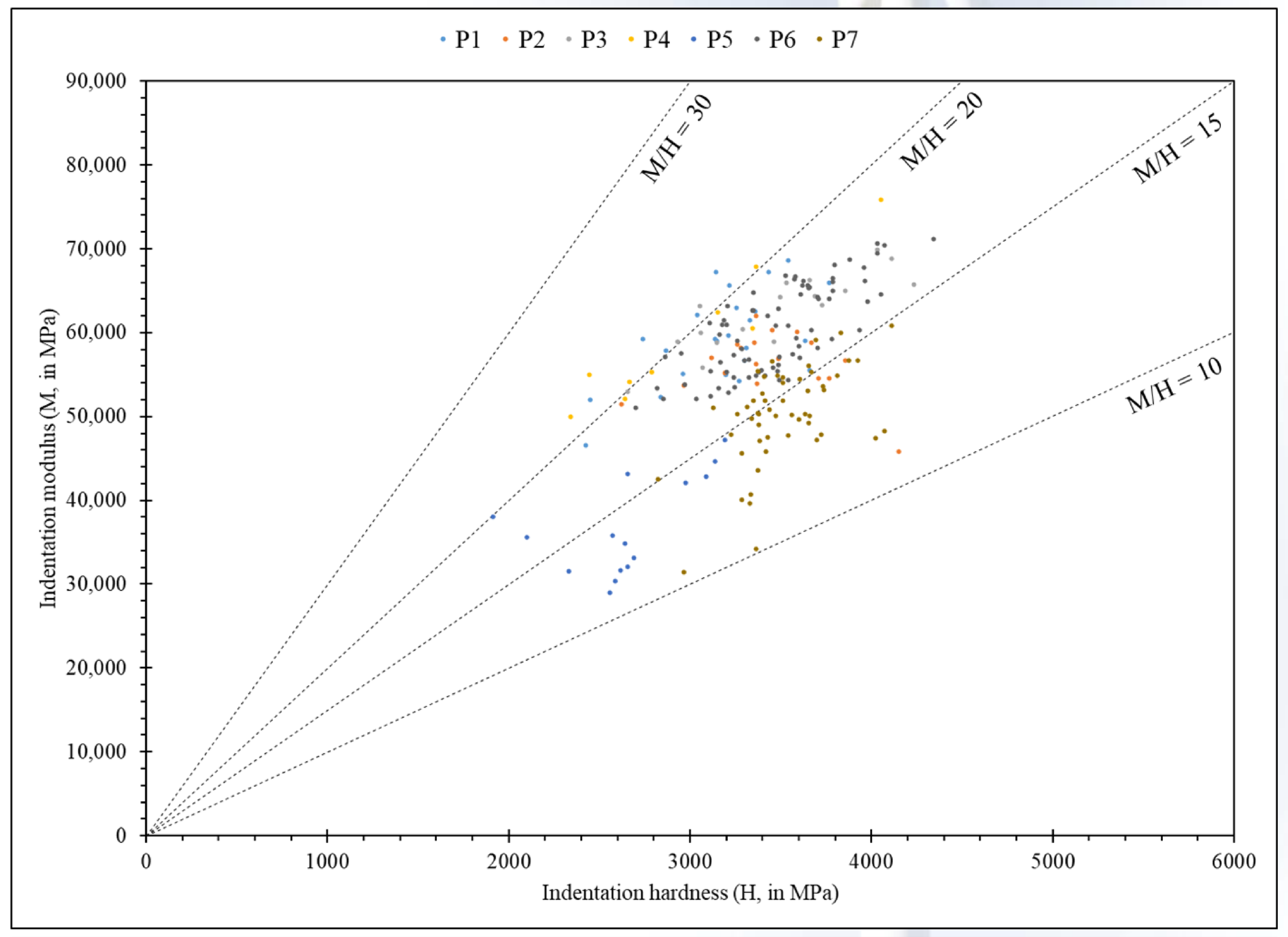


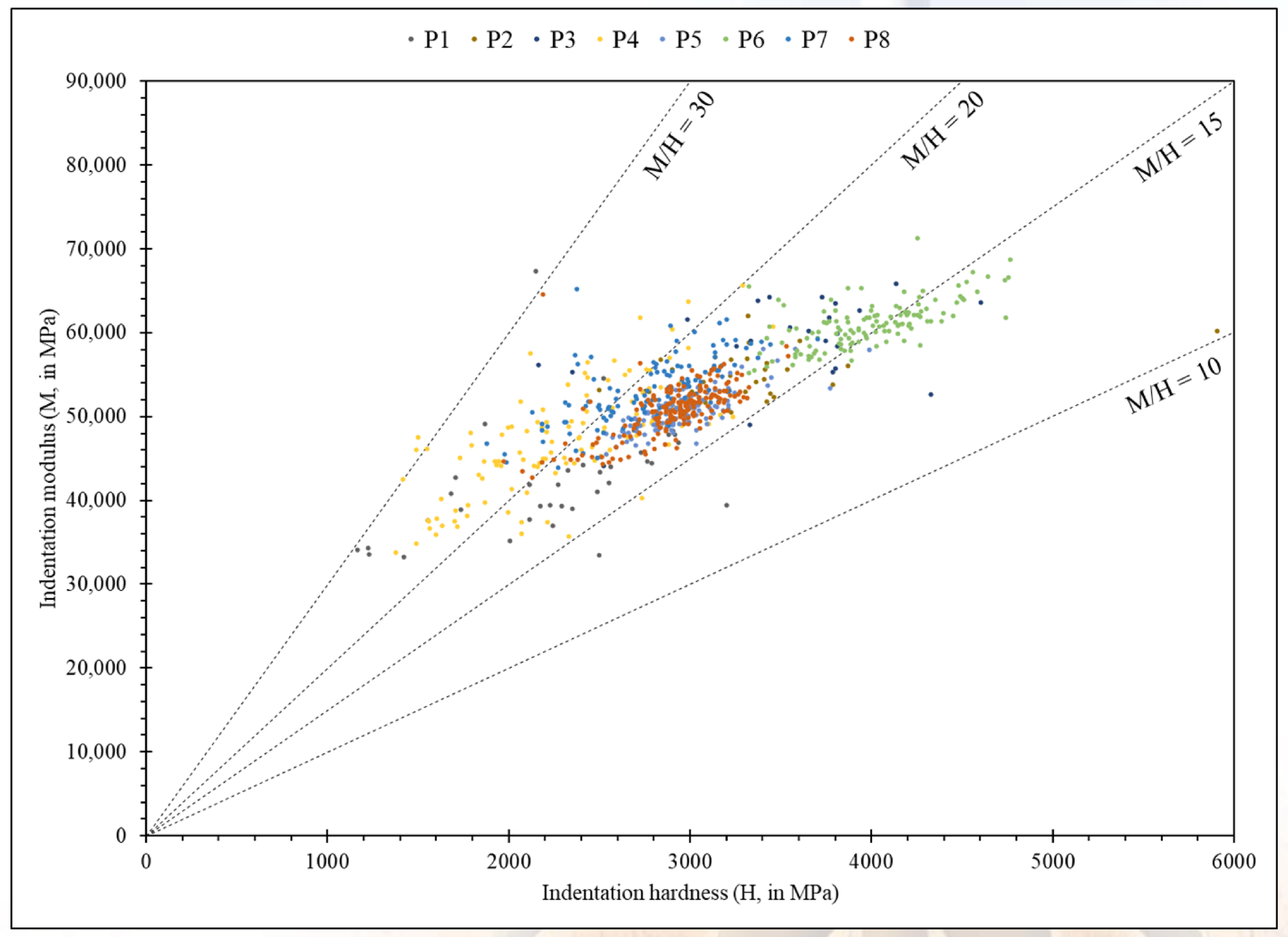


X-ray diffractograms of baseline (top) and modified (bottom) precipitate. Total line broadening of prominent peaks is shown (instrumental broadening in parentheses).

Results (contd.)

Nanoindentation: Modified precipitate had a lower hardness, modulus, but higher M/H ratio (indicates ductility)





Modulus (M)-Hardness (H) clusters of baseline (top) and modified (bottom) precipitate.

Conclusion

- Baseline and modified precipitate: higher hardness and lower modulus compared to single calcite crystals
- Modified precipitate more ductile than baseline precipitate

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Prototype Testing of Laterally Expansive Piles

Peter Zelkowski (Ph.D. student) and S. Ali Aleali (Ph.D. student)

Faculty Advisors: Dr. Paola Bandini and Dr. Craig Newtson, Department of Civil Engineering, New Mexico State University

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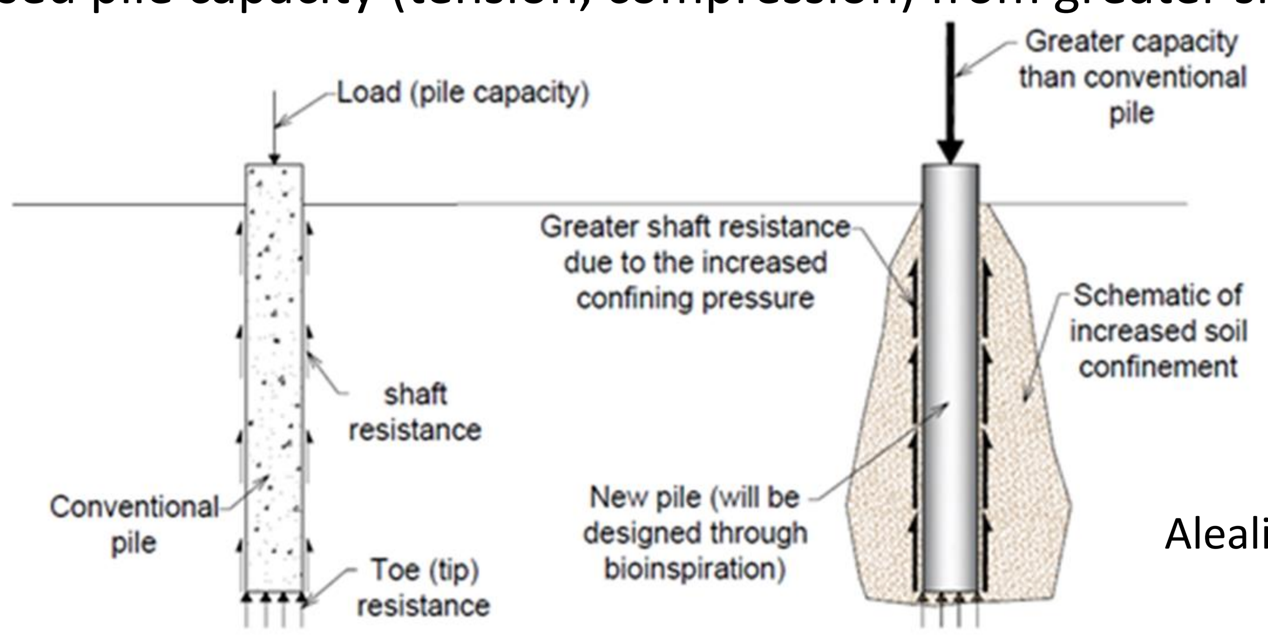
Introduction and goal

Project goal: Design, construct and test small-scale and mid-scale prototypes of the Bioinspired Radially Expansive Pile (BREP) (U.S. Patent No. 11,142,878) to provide a proof of concept and demonstrate increase in pile capacity due to pile expansion in sand.

Motivation:

- Seek new cost-effective pile system with greater capacity and lesser environmental impact
- Increased pile capacity (tension, compression) from greater shaft resistance



Aleali et al. (2020)

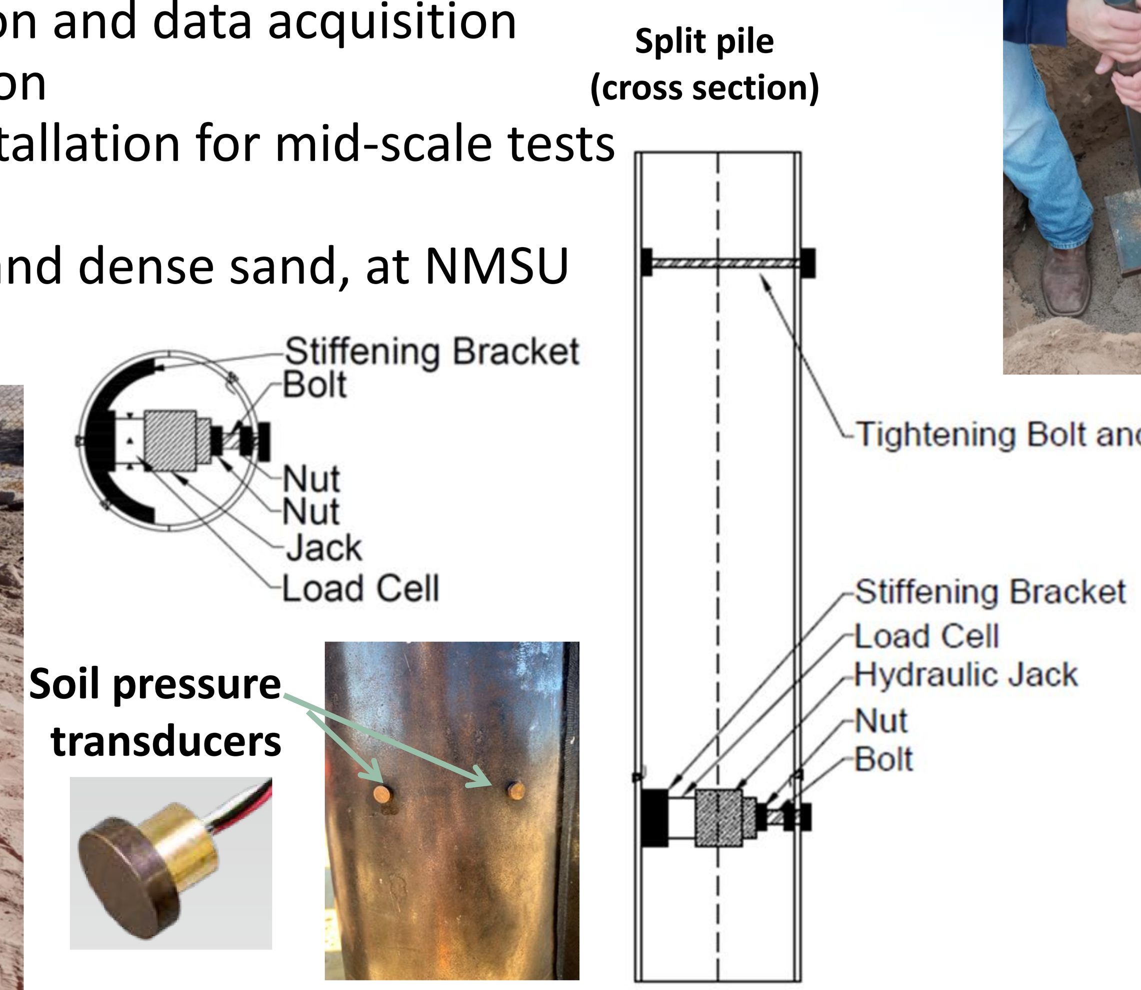
Small-scale pile prototype - Expansion tests

Goals of the small-scale pile prototype tests:

- Become familiar with sensor installation and data acquisition
- Streamline mechanism of pile expansion
- Obtain data to improve design and installation for mid-scale tests

Three tests for expansion only, in loose and dense sand, at NMSU

Small-scale pile test



Small-scale pile prototype design

Small-scale pile installation

Bioinspiration

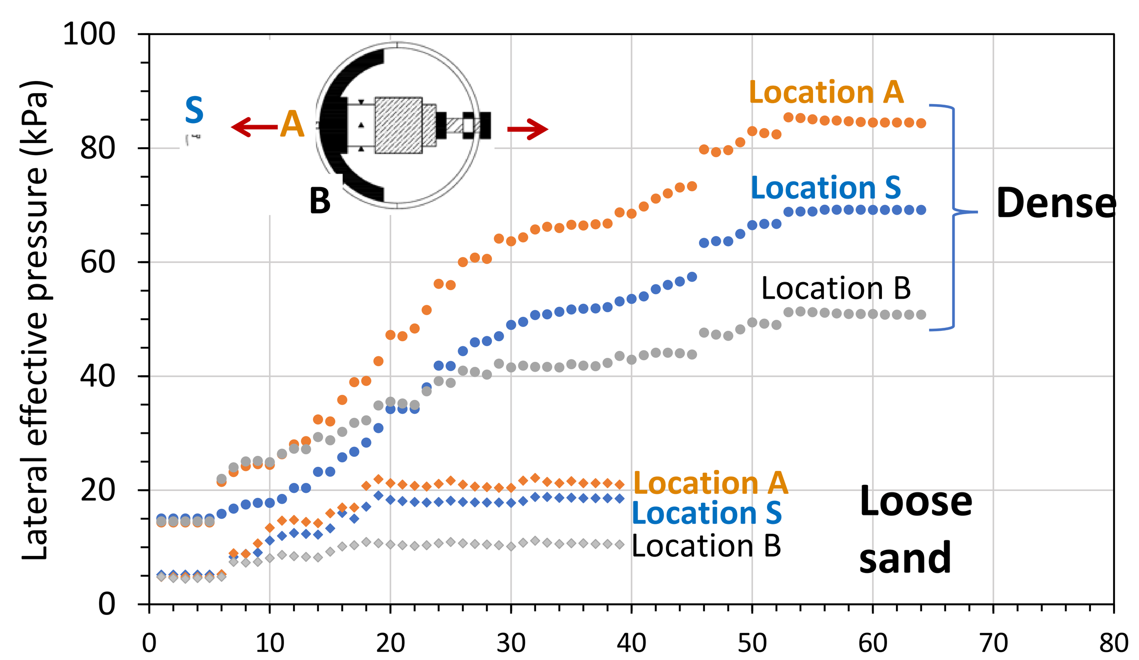
Laterally expansive pile concept inspired by bio-strategies for load transfer and anchorage of:

- Hydrostatic skeletons
- Earthworm
- Razor clam
- Tree roots

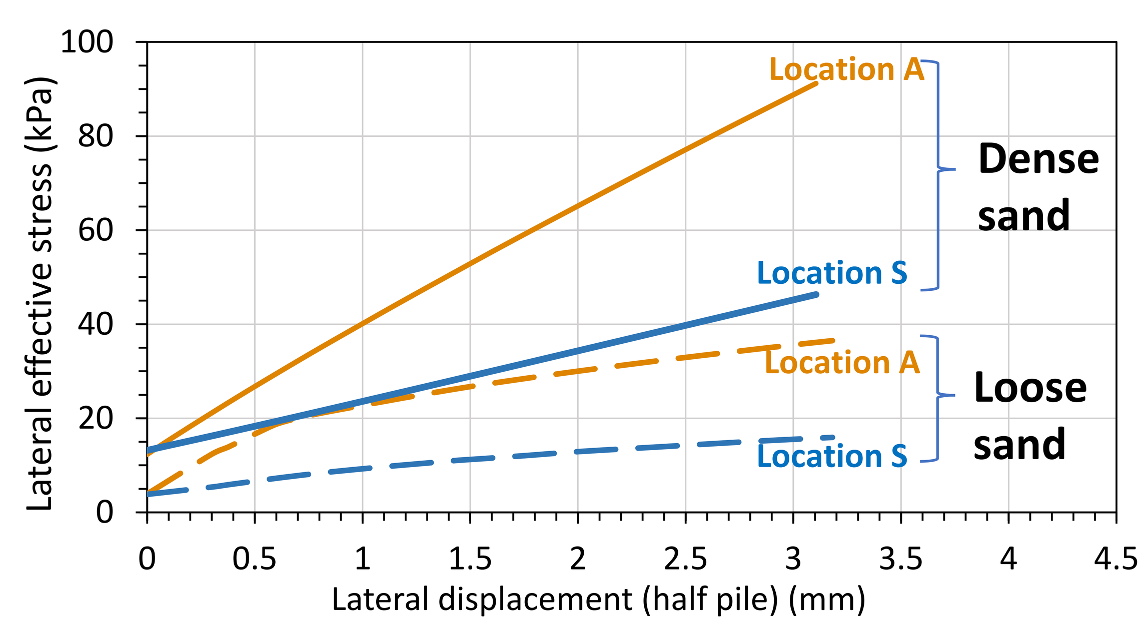
Work in Years 7 and 8

- Conduct prototype testing (axial compression) at CBBG Test Pit (October 2021) and analyze data
- Calibrate soil model and numerical model with prototype test data (for low confinement condition)
- Develop test plan and conduct centrifuge tests (compression, tension, pile group interaction, lateral loading)

Results of small-scale prototype tests



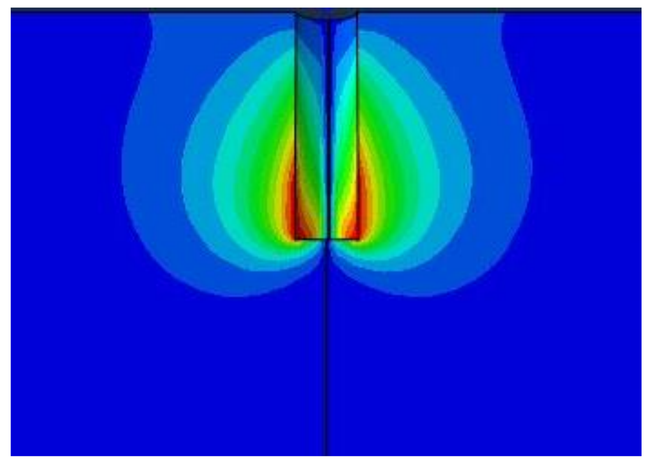
Small-scale test - Experimental



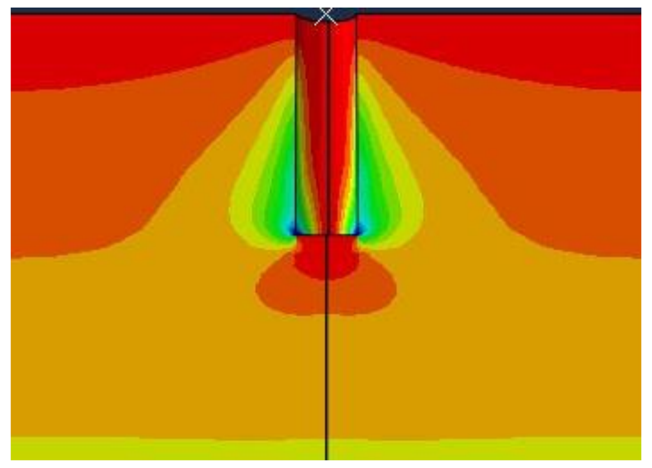
Small-scale test – Finite element results

Pile expanded in dense sand:

Lateral displacement contours



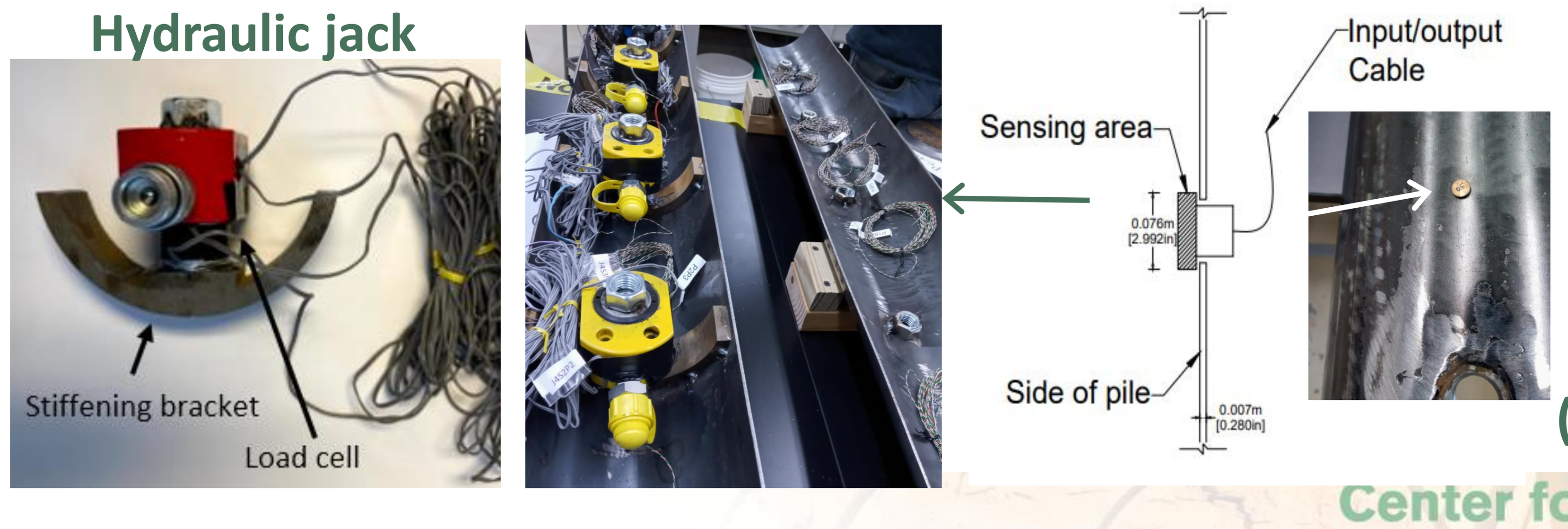
Lateral stress contours

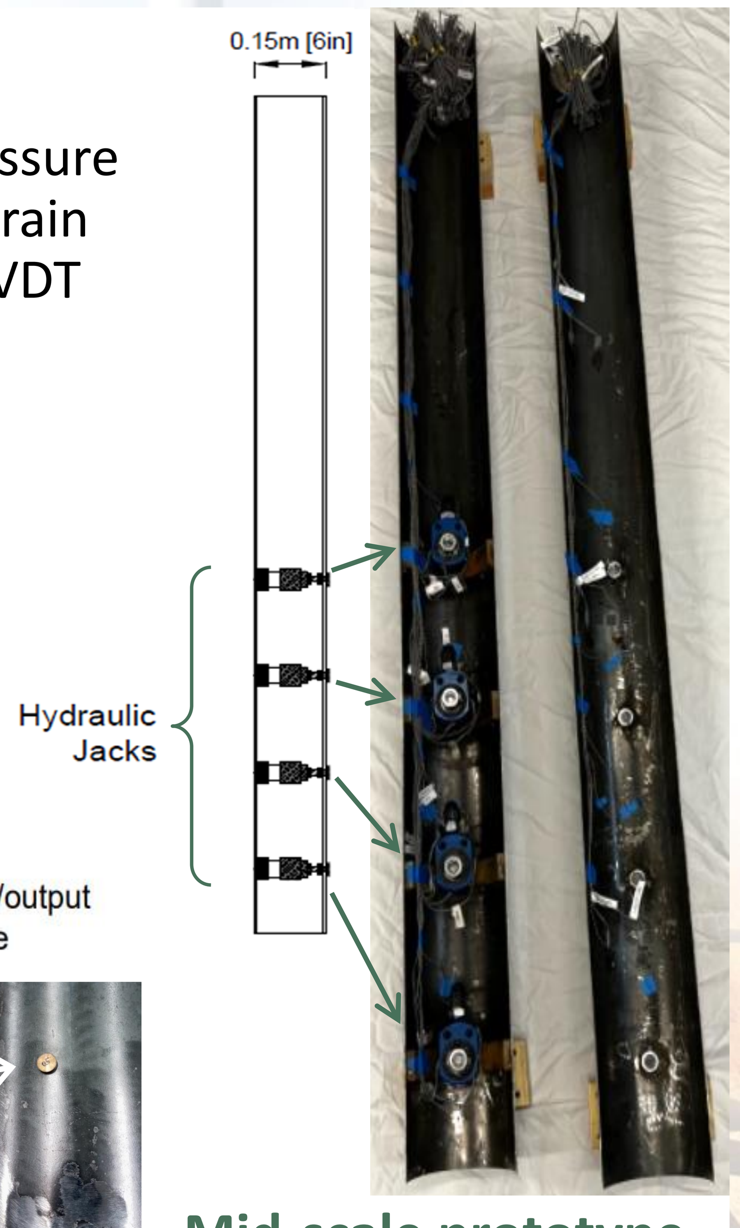


Mid-scale prototypes – Test pit plan

- Five steel pipe piles, 6-inch diameter, 6.5-ft long
- Embedded 6 ft in dry sand, medium dense (Pit depth: 12.5 ft)
- Instrumentation during expansion and axial compression: Pressure transducers on pile sides and soil, strain gauges along piles, strain gauges on load cells of each jack, hydraulic pressure (jacks), LVDT for pile settlement, cameras to monitor pile expansion
- Mini-CPT to characterize the sand after pile loading

Pile label	Expansion mechanism	Bottom steel plate
EP1-C	Split pipe and jacks	Not welded to pipe
EP2-C	Split pipe and jacks	Welded to pipe
EP3-C	Split pipe and wedge mechanism	Not welded to pipe
CP1-C	No expansion (Control)	Welded to pipe
CP2-C	No expansion (Control)	Welded to pipe





Mid-scale prototype (split pipe, inside view)

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Large Outdoor Rainfall and Infiltration Simulator (LORIS)

Presenter: Eric A. Escoto Advisors: Edward Kavazanjian, Enrique Vivoni, Nasser Hamdan Institution: ASU

Background

Goals:

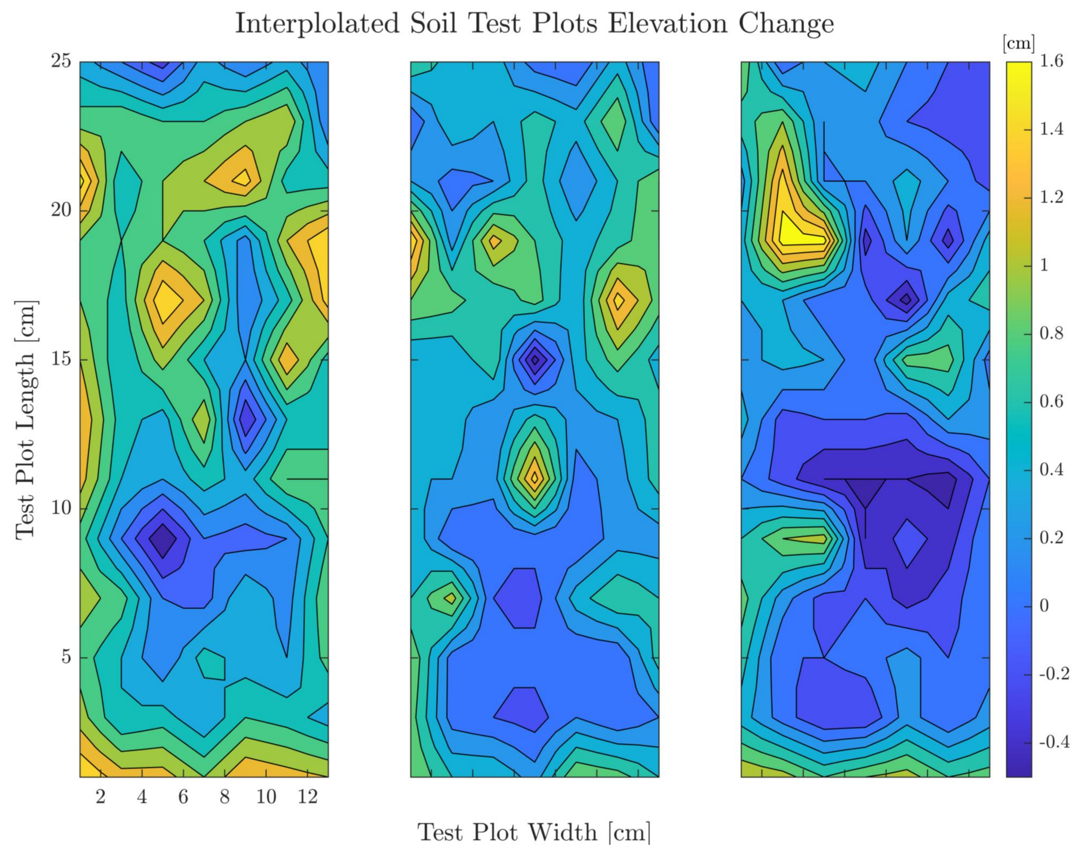
- Startup of apparatus that simulates rainfall on slopes up to 30° at field scale.
- Contextualize synthetic rainfall characteristics to natural rainfall in the southwest.

Research Objectives

I. Determine uniformity of rainfall delivered.

II. Determine drop size and velocity characteristics.

III. Determine erosive potential on bare soil conditions.



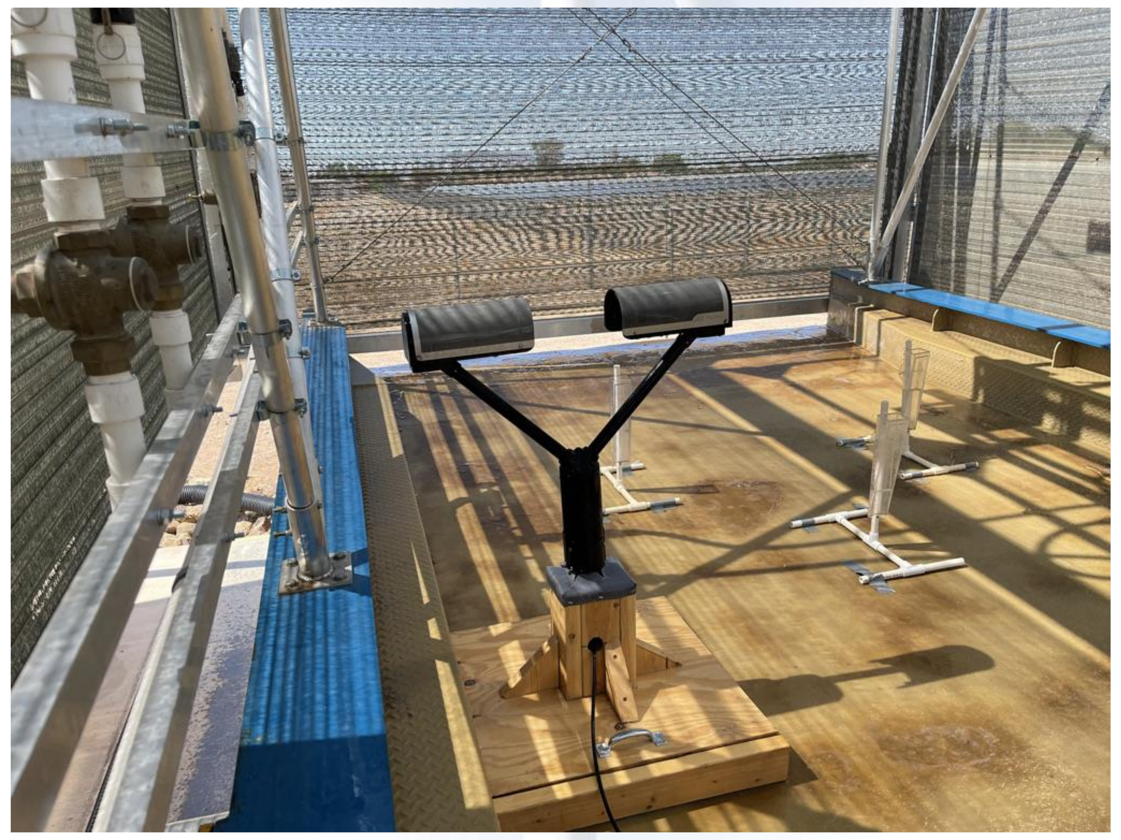
Synthetic Rainfall Calibration Testing

Calibration is required to determine rainfall parameters for comparison to natural rainfall. LORIS rainfall characteristics including drop size, speed, and uniformity are attributed to nozzle type, operating pressure, and system design.

Use standard operating pressure, VeeJet nozzles, and RO water.

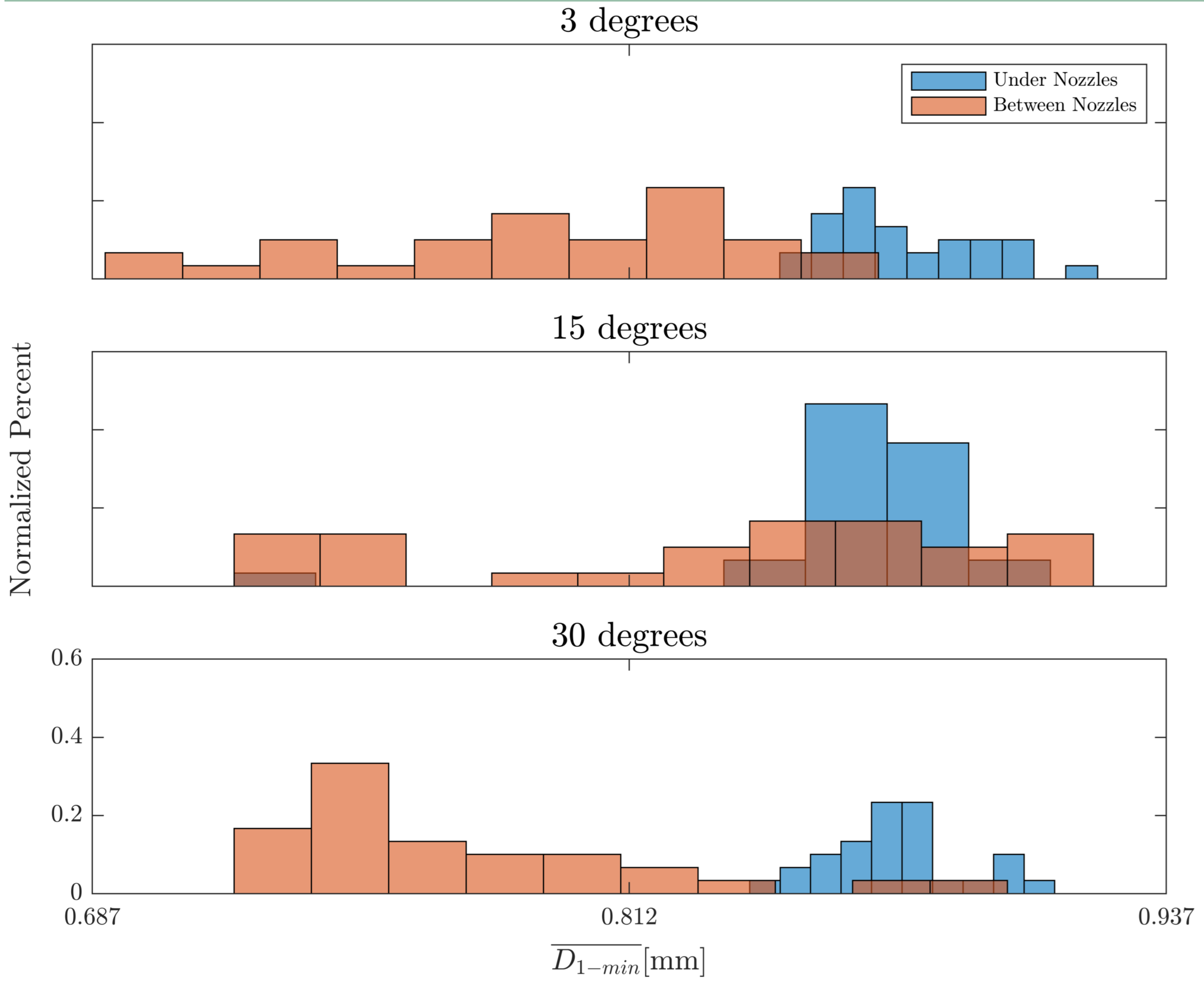
Measure average rainfall intensity, depth, and uniformity with rain gauges.

Collect rainfall characteristics using optical disdrometer.

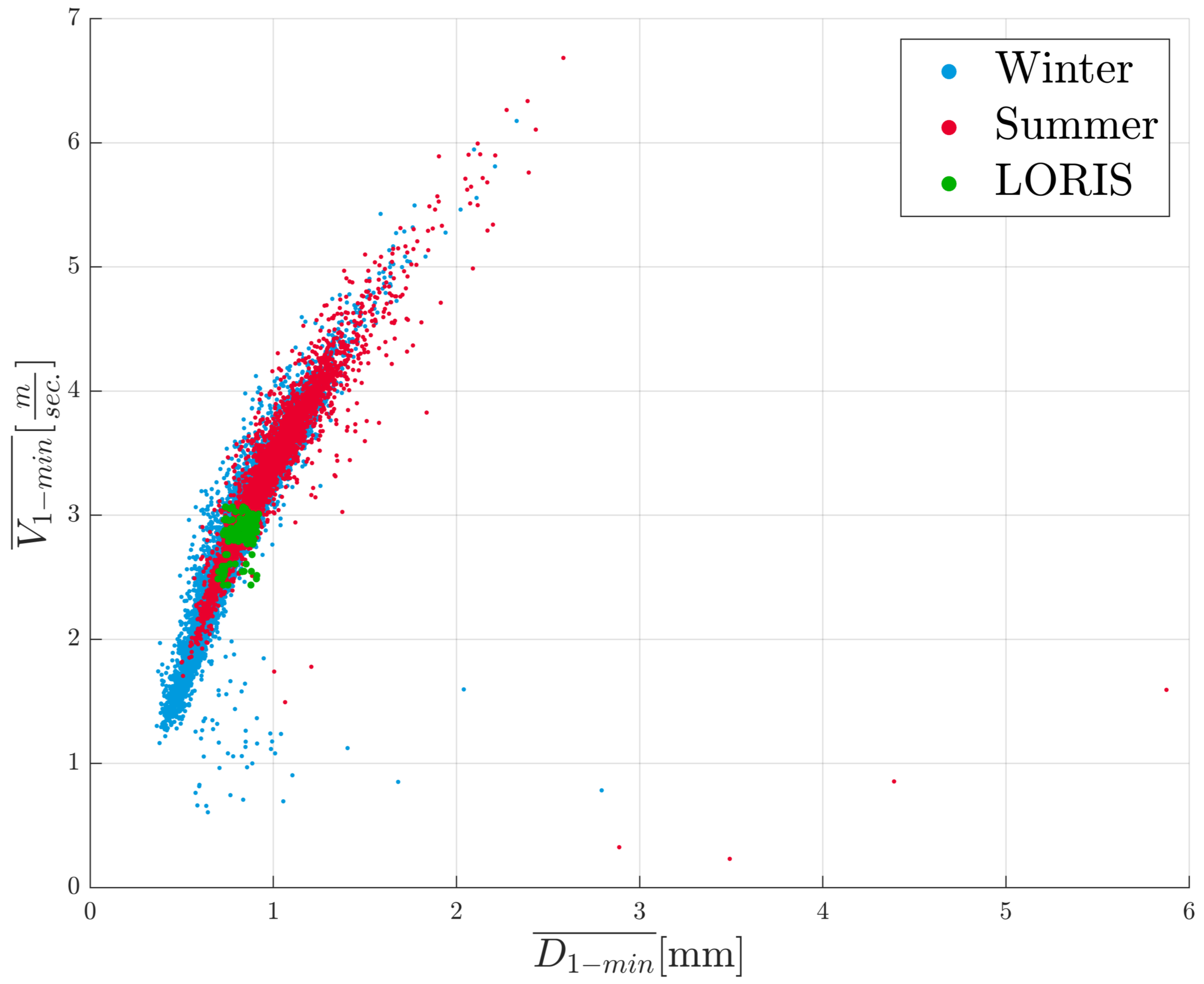


Parsivel[2] disdrometer and rain gauges.

Results



Sampled size distributions from two locations in LORIS.



LORIS size and velocity distributions compared to natural rainfall in Mesa, AZ

- LORIS rainfall is variable in space.
- Intensity does not alter the size distribution.

	Mesa, AZ (SFL)		LORIS	
	Summer	Winter		std. (σ)
D [mm]	0.989	0.802	0.835	0.100
v [m/s]	3.347	2.775	2.788	0.326
KE [J/m^{2}h]	38.278	16.742	263.312	136.565

- LORIS drop D and v resemble mean of natural rainfall.
- Kinetic energy is significantly higher.

Future Work

- Contextualize LORIS rainfall within Arizona's climate regime.
- Complete soil test bed and install soil moisture sensors.
- Investigate erosion and infiltration on bare soil.
- Assess effectiveness of EICP treatment on erosion and infiltration.

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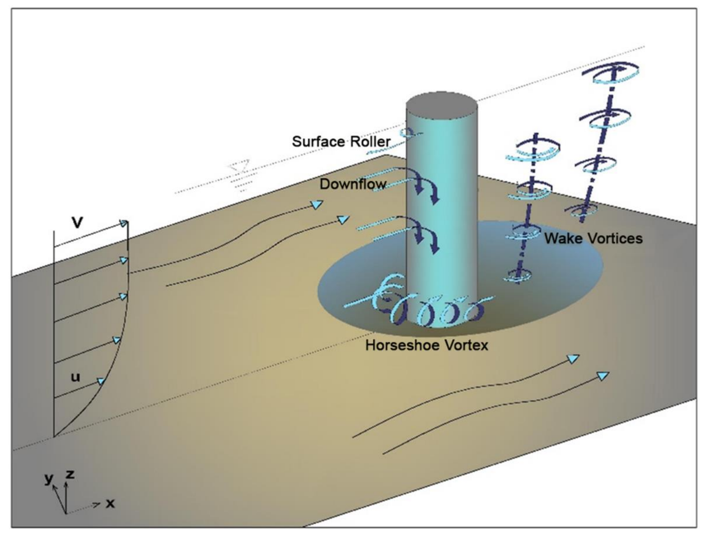
CFD Simulation of Using Mangrove-Inspired Sacrificial Pile Group on Scour Mitigation

Presenter: Xiwei Li Institution: Arizona State University Advisors: Leon van Paassen, Julian Tao

Background & Motivation

- Local scour refers sediment removal around bridge foundation
- Three components: downflow, horseshoe vortex and lee wake.



- Using mangrove-inspired sacrificial pile group to mitigate scour.

Research Objective

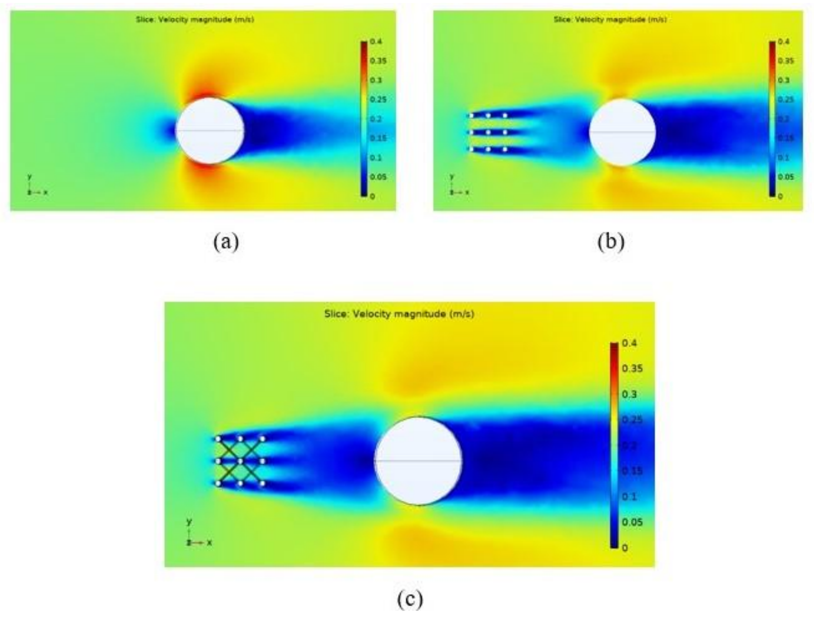
- Extracting key features from the mangrove morphology and ecosystem.
- Software simulation and laboratory test to evaluate the effectiveness of the proposed layout of pile group.
- Developing and evaluating field implementation strategies.
- Compare bed shear stress and critical zone area of different cases

Mangrove Characteristic

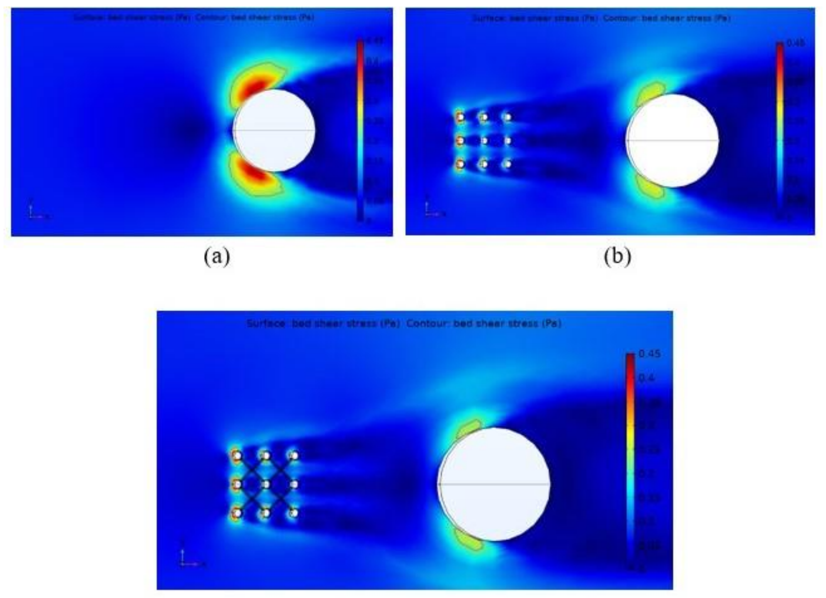
- Mangrove roots are interlaced between trunks.
- Diameter of root is about 1/5 of trunk.
- Dense root system forms barrier and trap sediment

COMSOL Simulation

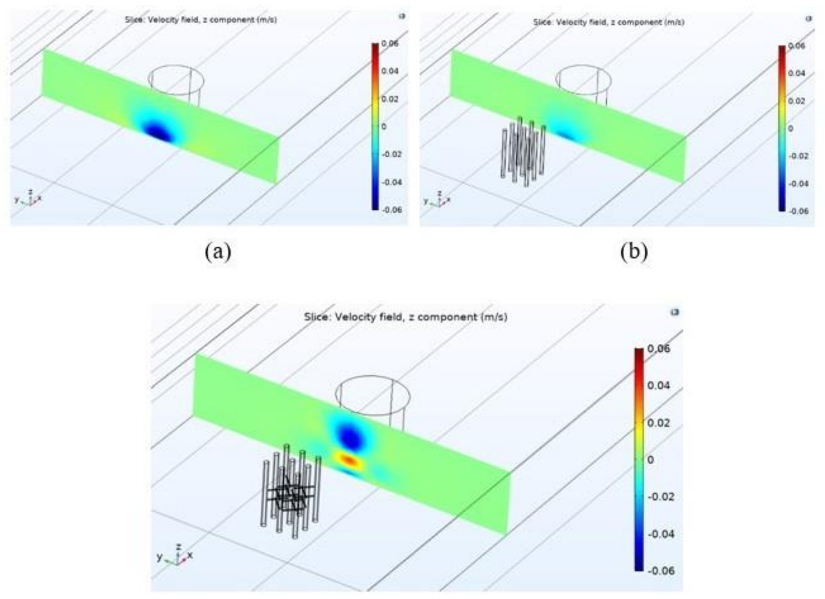
- Mangrove trunk and root are simulated as sacrificial pile and crossbar, respectively.
- Sacrificial piles reduce the velocity in both horizontal and vertical direction.
- Crossbars convert the downflow direction and mitigate strength of HSV.



Horizontal Velocity Distribution

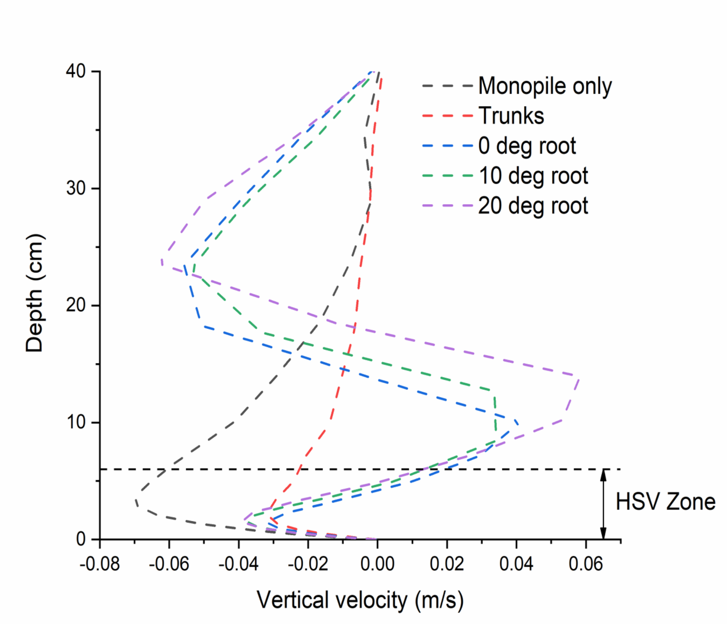


Bed Shear Stress and Critical Zone Area

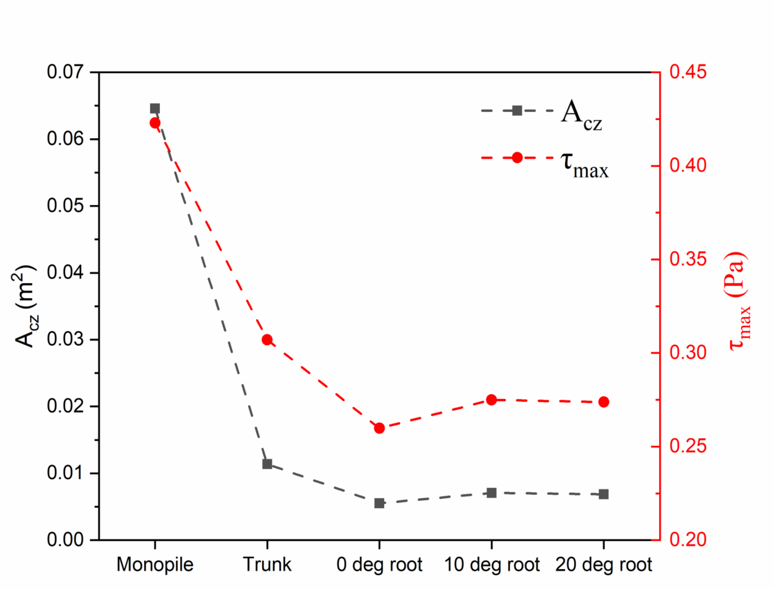


Vertical Velocity Distribution

- Rotate the crossbar to 10 and 20 degree to compare the effect on vertical flow



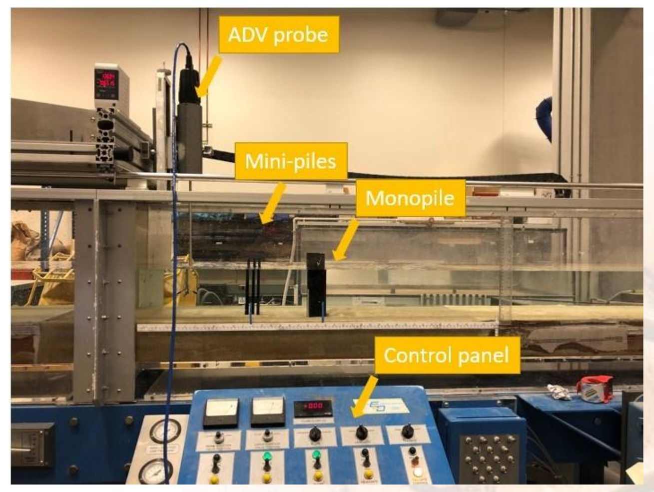
Vertical Flow with Different Inclination Angle

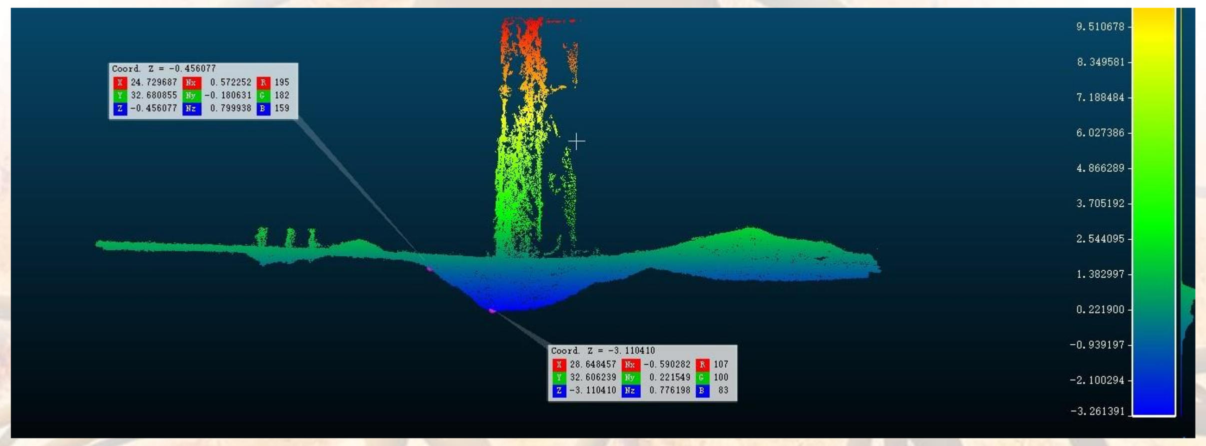


Maximum Shear Stress and Critical Zone Area

Conclusion and Future Work

- Sacrificial pile can reduce the magnitude of both horizontal and vertical velocity but can not change downflow direction.
- Crossbars convert the downward flow to upward and mitigate the strength of HSV.
- Lab Test will be carried out to test different cases.
- 3D-Printed mangrove-inspired sacrificial pile group model will be used in the lab-scale test.
- Acoustic Doppler Velocimeter (ADV) will be used to measure horizontal and vertical velocity and calculate the vorticity.
- Investigate the change of scour hole volume and slope angle in different sacrificial pile height .





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Bio-Cementation for Dust Mitigation in Salton Sea

Presenter: Farideh Ehsasi **Advisor: Leon van Paassen, Ed Kavazanjian** **Institution: ASU** **CBBG Industry Partner: BoR**

Background

Salton Sea (largest inland lake in California) formed in 1905

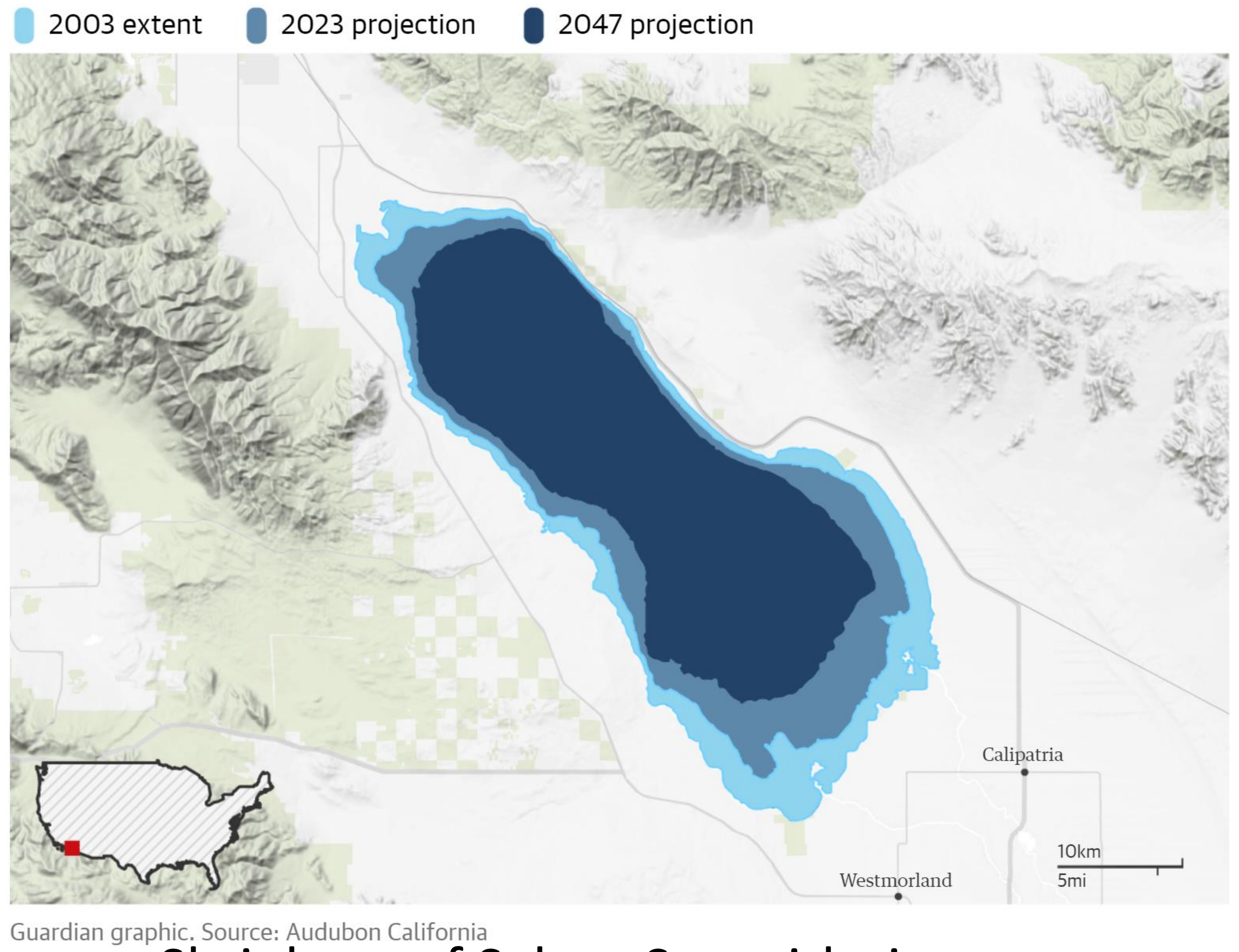
- All American canal from Colorado River breached
- Lake level sustained by agricultural runoff until 21st Century

Lake has been shrinking due to more efficient agricultural, drought

- Exposes dust susceptible sediment impacted by agricultural runoff (herbicides, pesticides)
- Projected to shrink more

Impacted dust blamed for increased asthma, other respiratory diseases downwind

- BoR (lead) and Cal EPA under mandate to address health and environmental issues.



Shrinkage of Salton Sea with time

Research Objective

Evaluate the effectiveness and feasibility of biocementation through EICP/MICP for mitigating the dust problem in Salton Sea.

Work Plan

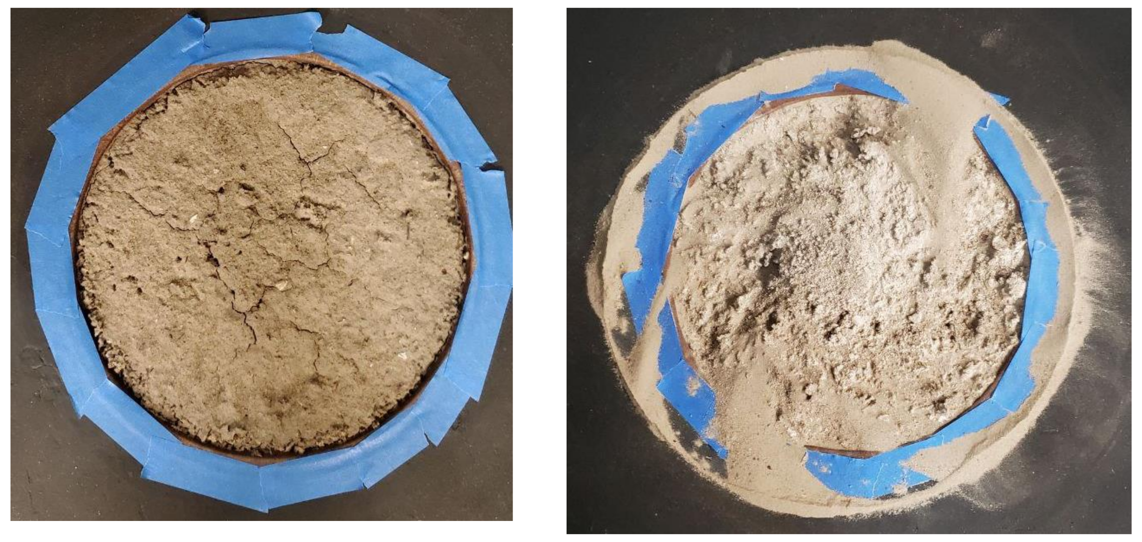
- Further Characterization tests
  - XRF and XRD for elemental and mineralogical composition
  - SEM on the natural crust
  - Leachate testing on the soil
  - Salinity groundwater composition
- Further evaluation of the effectiveness of biocementation in lab scale using different methods:
  - PI-SWERL
  - Air jet
  - Penetration test
- Evaluate the role of evaporation and rainfall on treatment performance and crust durability
- Field test using MICP and EICP
- Performing a LCSA on application of MICP/EICP for dust suppression in Salton Sea

Work to date

- Site visit
- Soil Characterization
  - Grain size distribution
  - Carbonate content
  - Soil water retention characteristics

Sampling location during site visit

- Preliminary bio-cementation treatment in the lab with varying treatment methods
- PI-SWERL testing in the lab



Treated (using MICP 0.5 M urea + CaCl2) vs. untreated sample after testing with PI-SWERL

Running Pi-SWERL in the pan specimens in the lab

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