Center for Integration of Composites into Infrastructure

Application of Geofoam in Thermal Encapsulation of Foundations

Project (Leader): Surya Sarat Chandra Congress
Senior Research Engineer

Team: Hiramani Chimauriya, Nripojyoti Biswas, Clay Caldwell

PI: Anand J. Puppala
Professor | A.P. and Florence Wiley Chair
Associate Director – Center for Infrastructure Renewal

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May 26, 2021

ThermaFoam LLC

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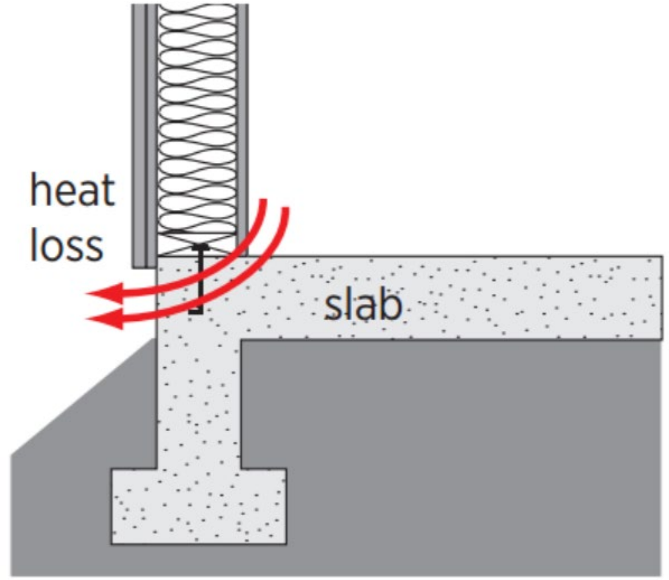
Zachry Department of Civil & Environmental Engineering

Presentation Outline

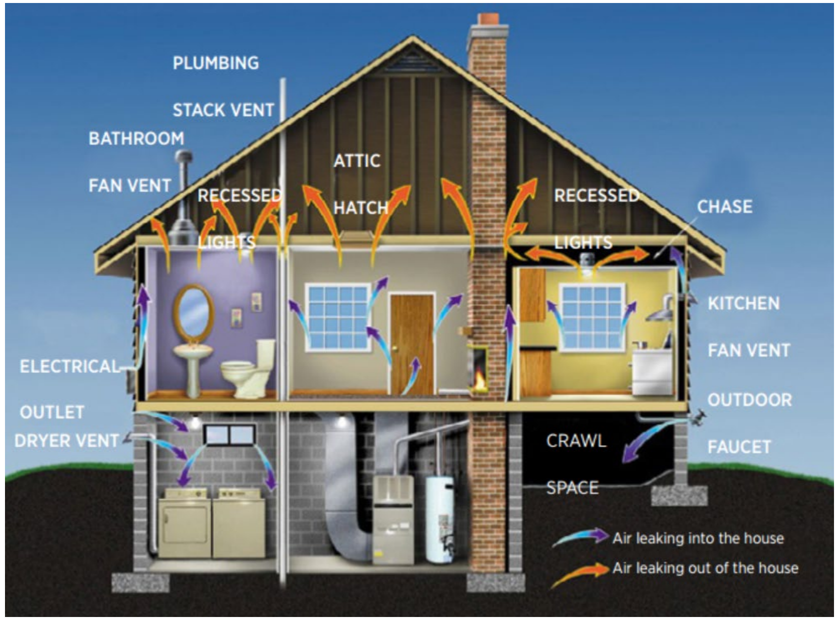
- Introduction
- Thermal Conductivity Test
- Thermal Encapsulation using Geofoam
  - Research Plan
  - Test Setup
  - Laboratory Testing Setups
  - Preliminary Simulations
- Future Work

Introduction

- Temperature fluctuations inside the dwellings typically occur from advection, diffusion and radiation at foundation superstructure joints
- About 15% of all heat loss in a home is through floors or basements
- Thermal Encapsulation using Geofoam
  - Research Plan
  - Laboratory Testing Setups



Heat loss



The stack effect

Source: EPA, US DOE (2011, 2012)

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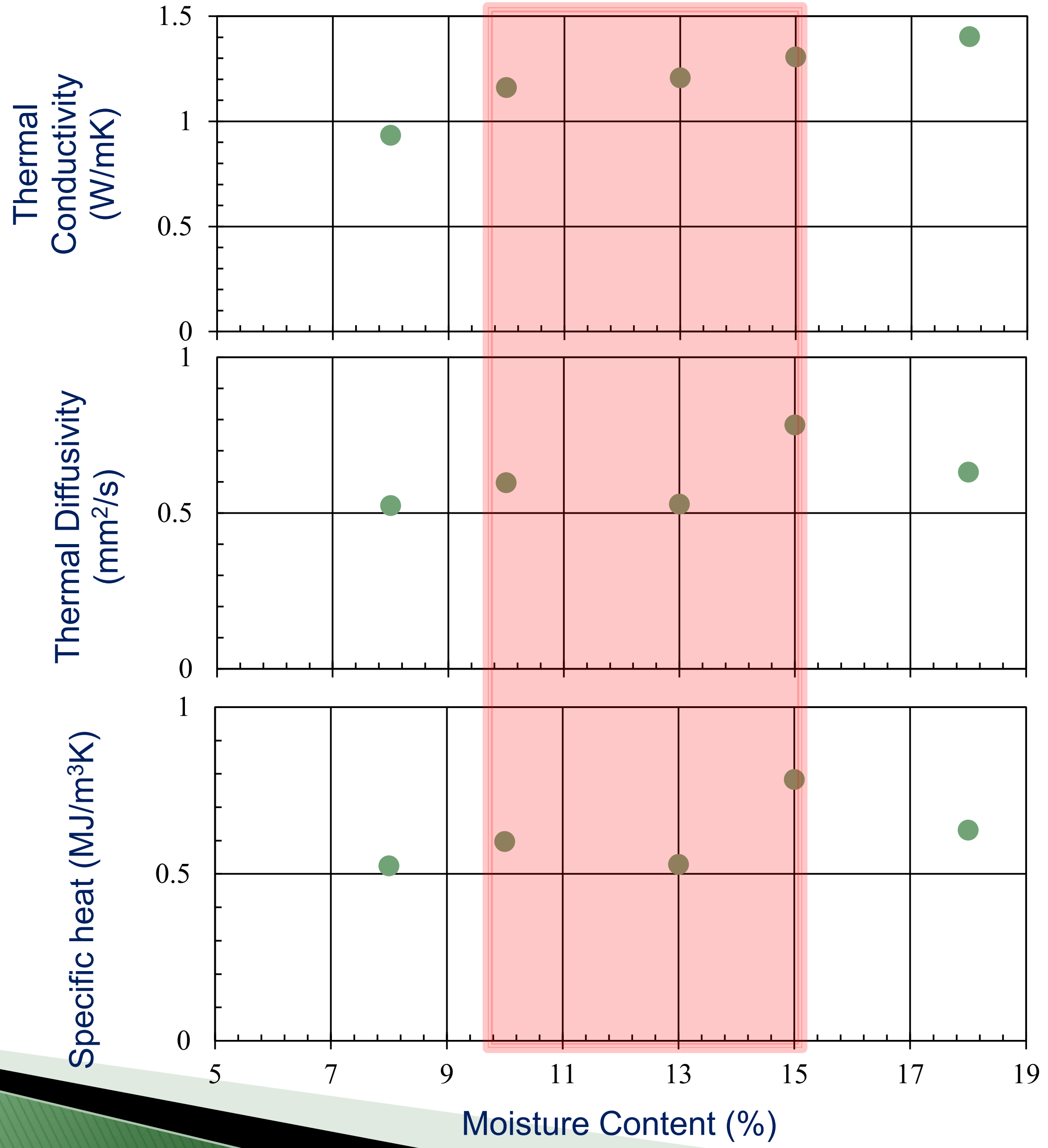
Thermal Conductivity Test



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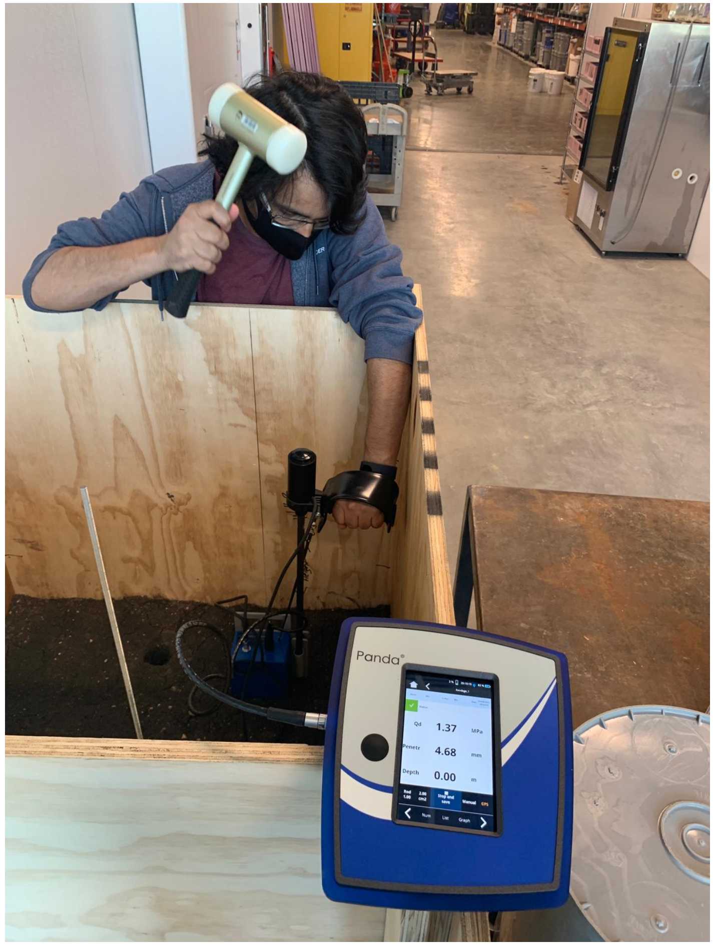
Compaction

- Soil being compacted at OMC and 90% of MDD.
- 4” (compacted) lifts.
- PANDA dynamic penetrometer used for compaction control.
  - Data collected for each blow.
  - Monitor compaction throughout the layer.



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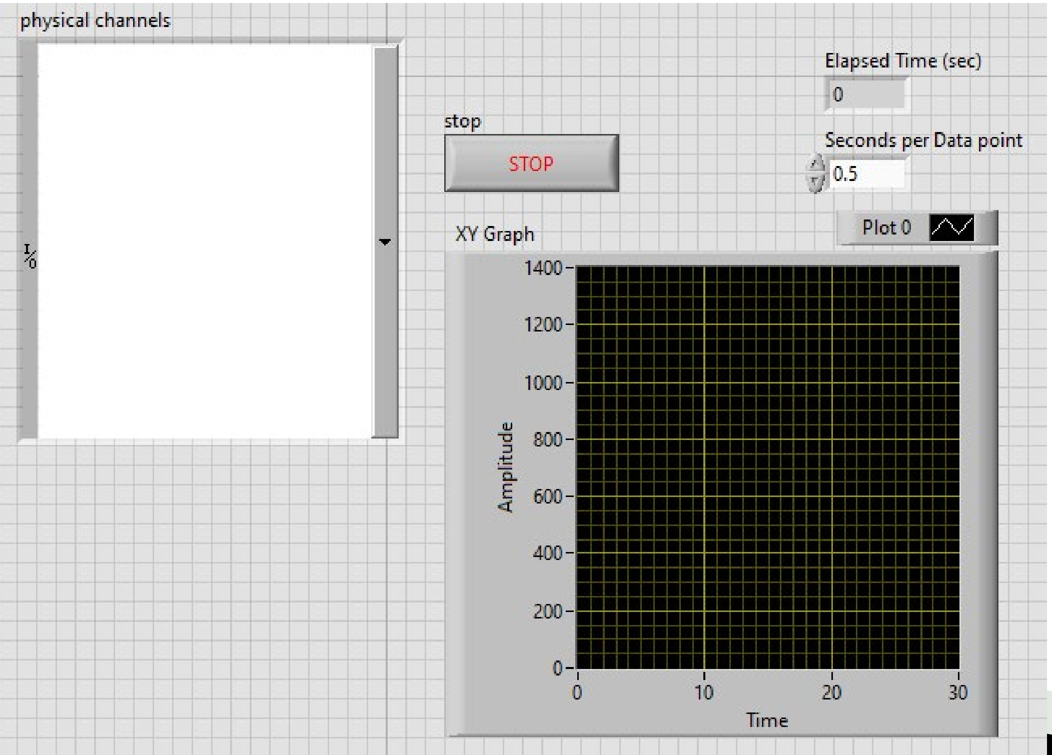
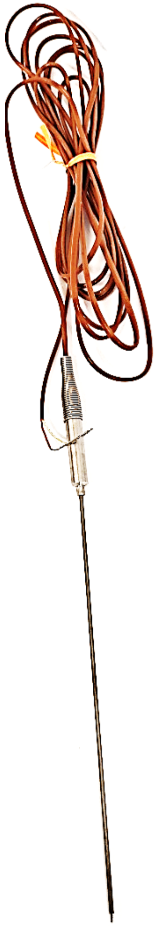
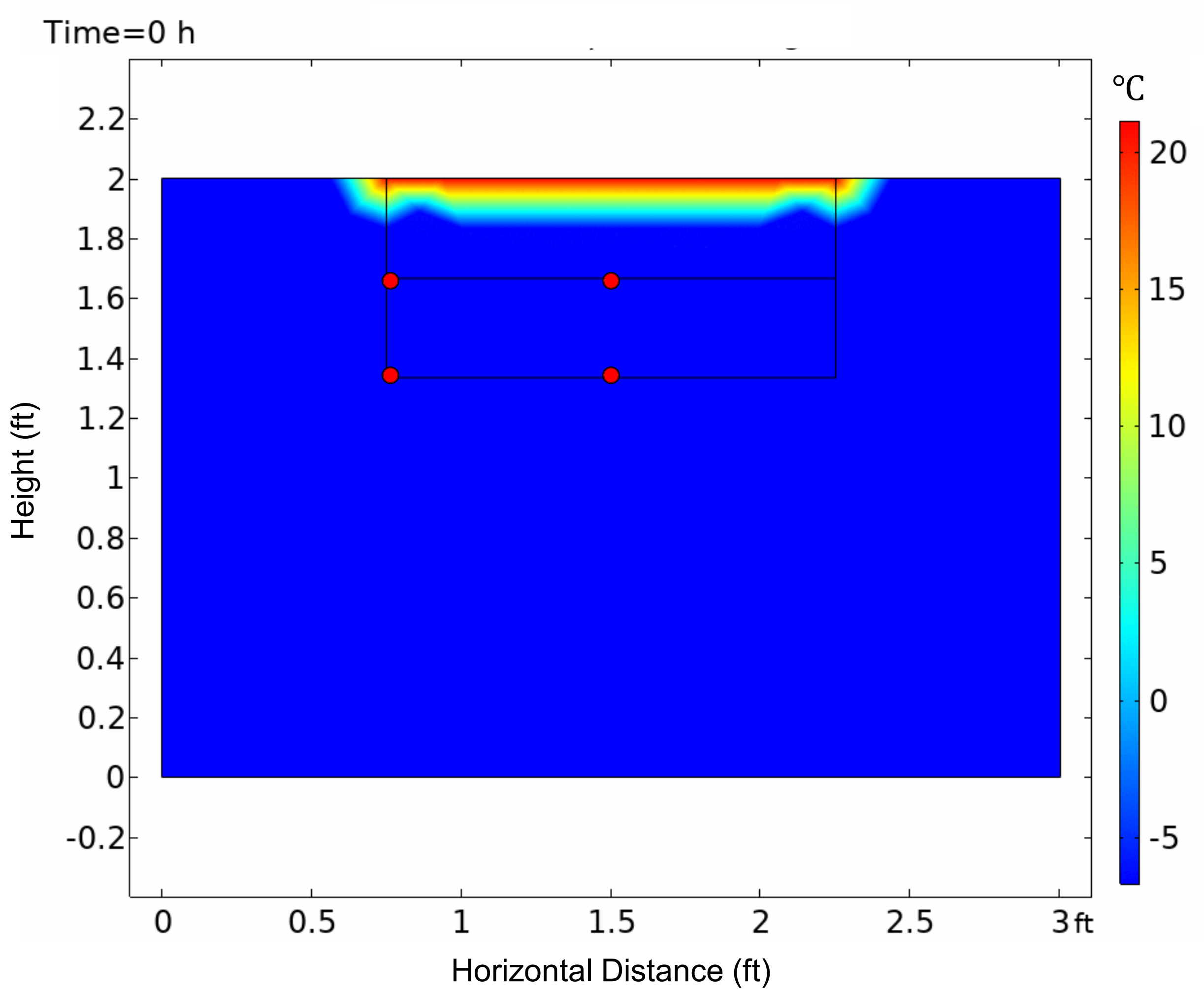
Instrumentation

- Thermocouples
- Data Acquisition system
  - NI-9233 (Thermocouple card)
  - cDAQ-9184 (Ethernet DAQ chassis)

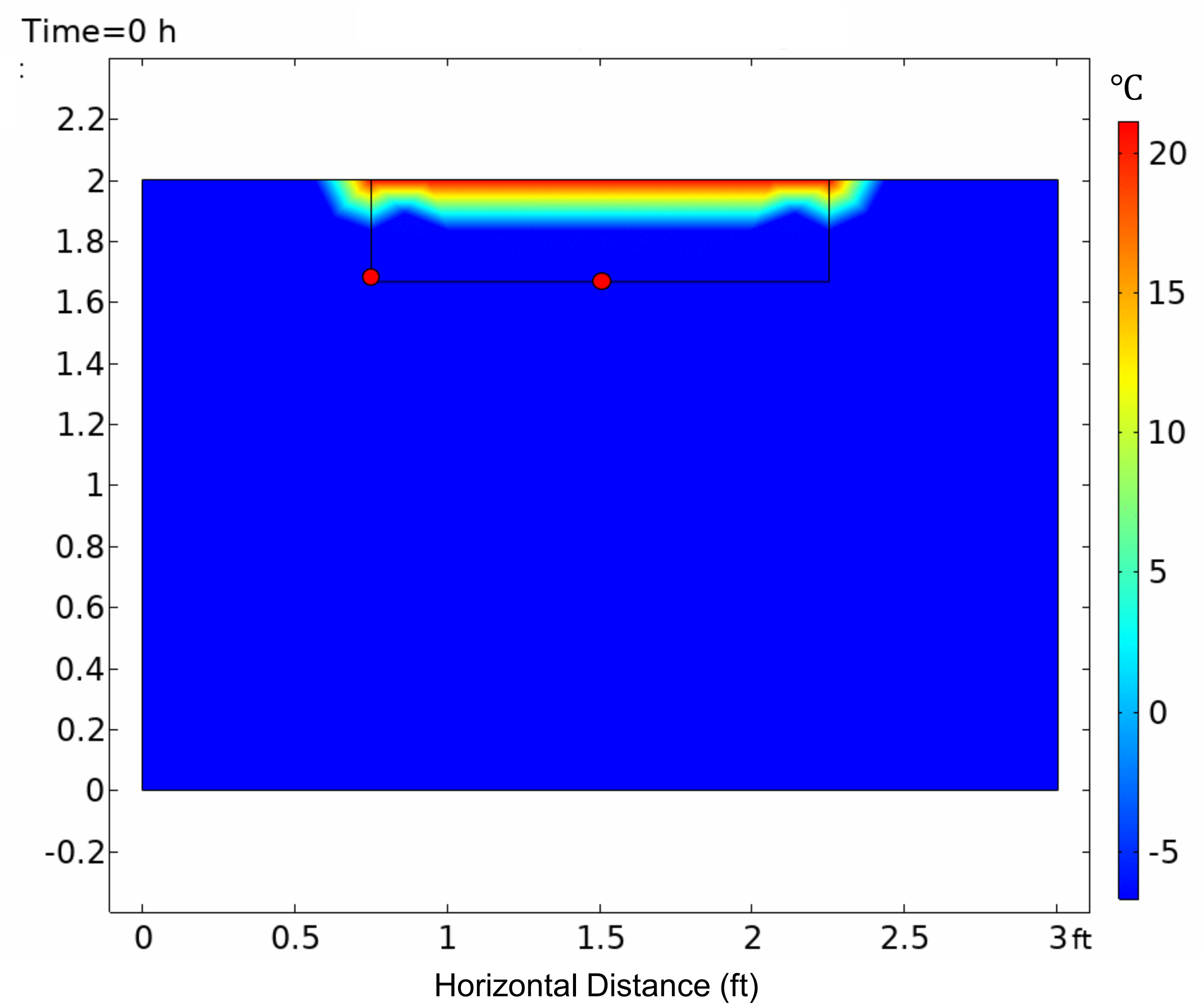




Example Simulation: Temperature Distribution

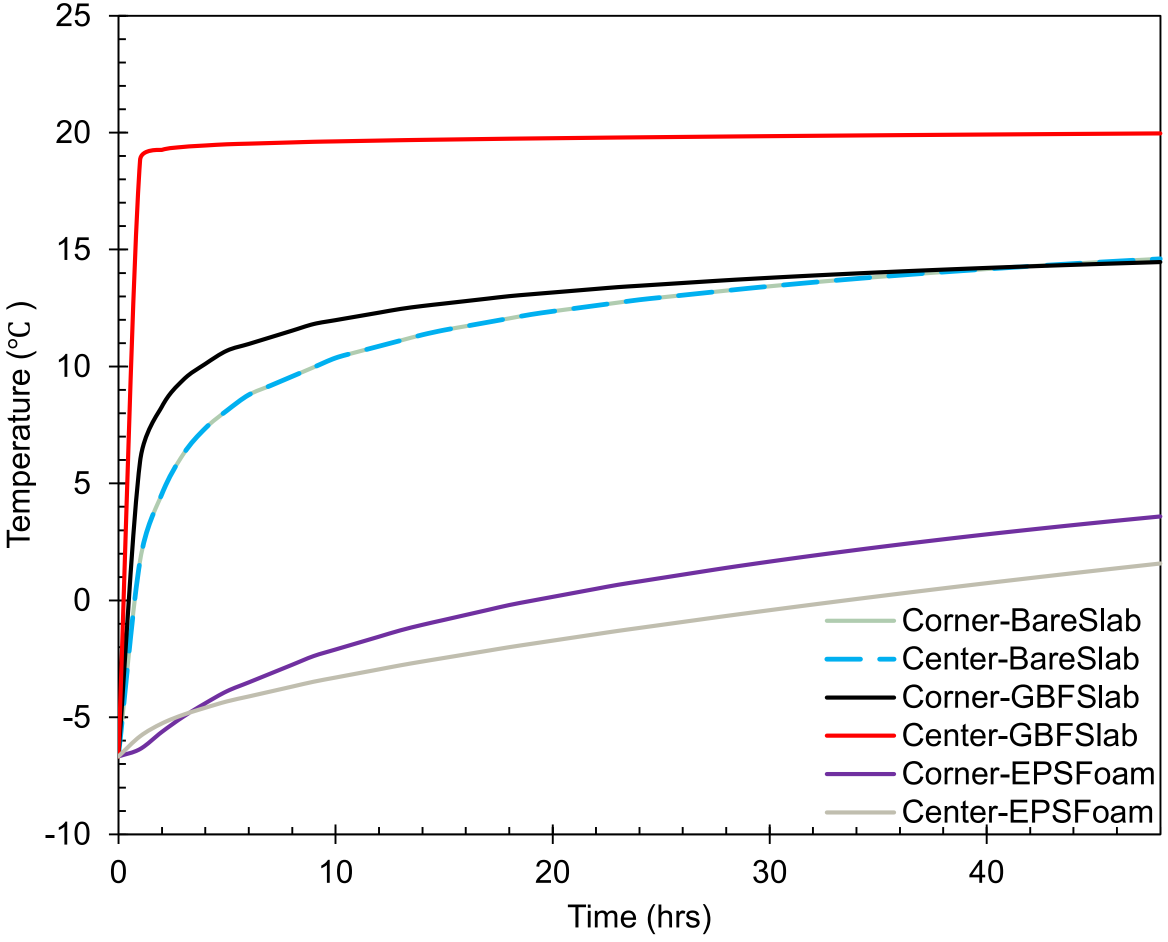


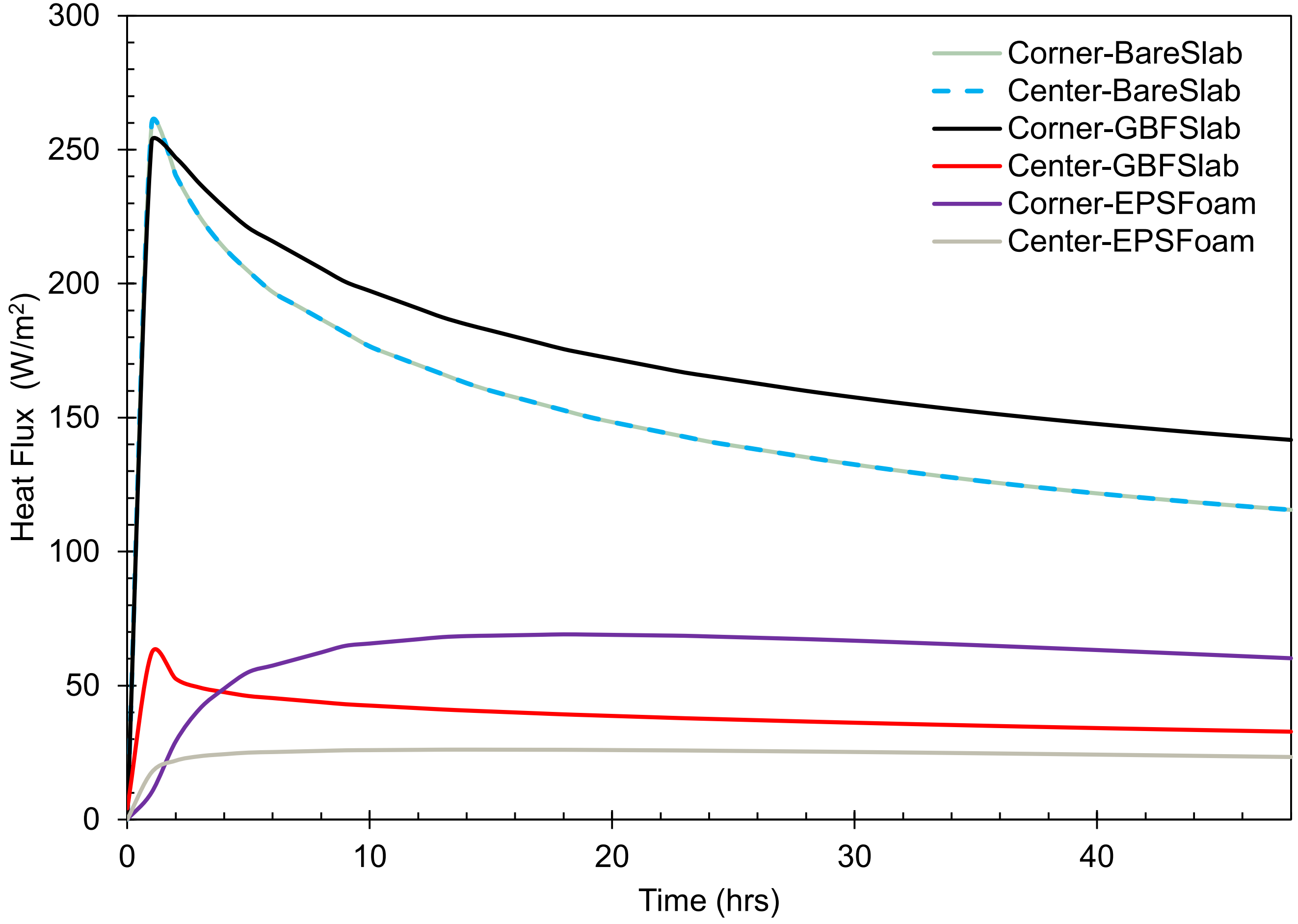
With Geofoam



Without Geofoam

Example Simulation: Distribution With Time





Temperature Distribution

Flux Distribution

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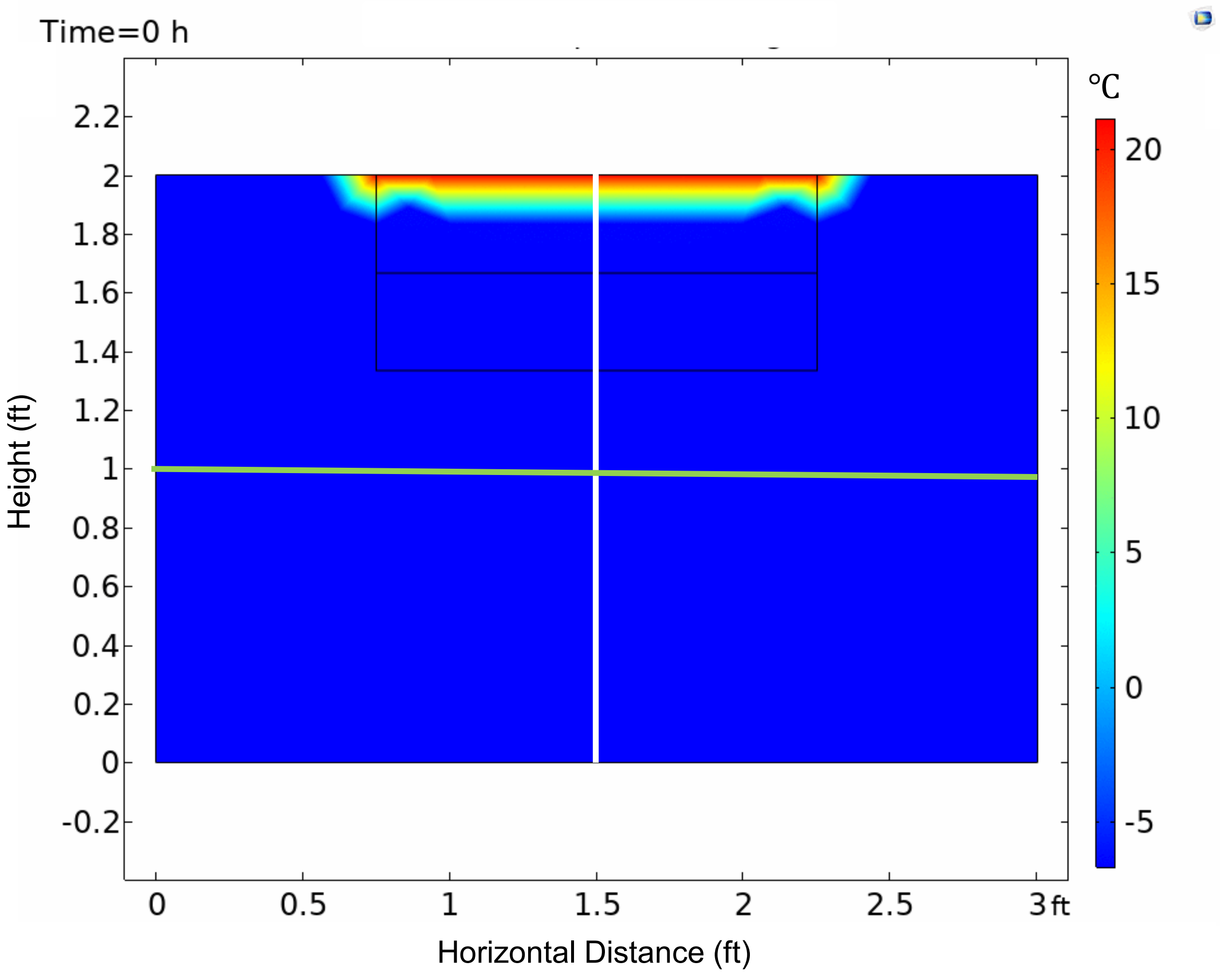
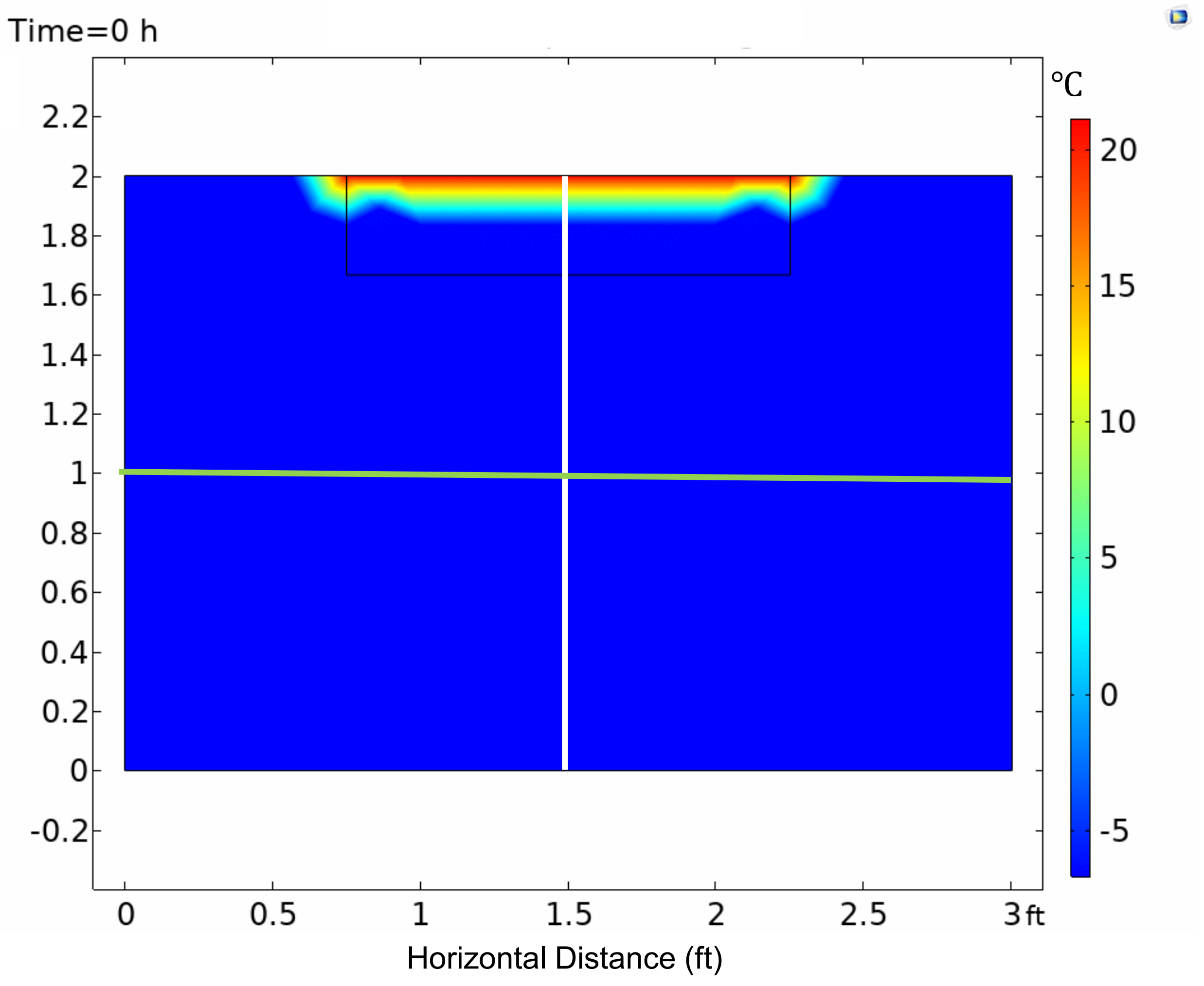
Example Simulation: Temperature Distribution



With Geofoam



Without Geofoam

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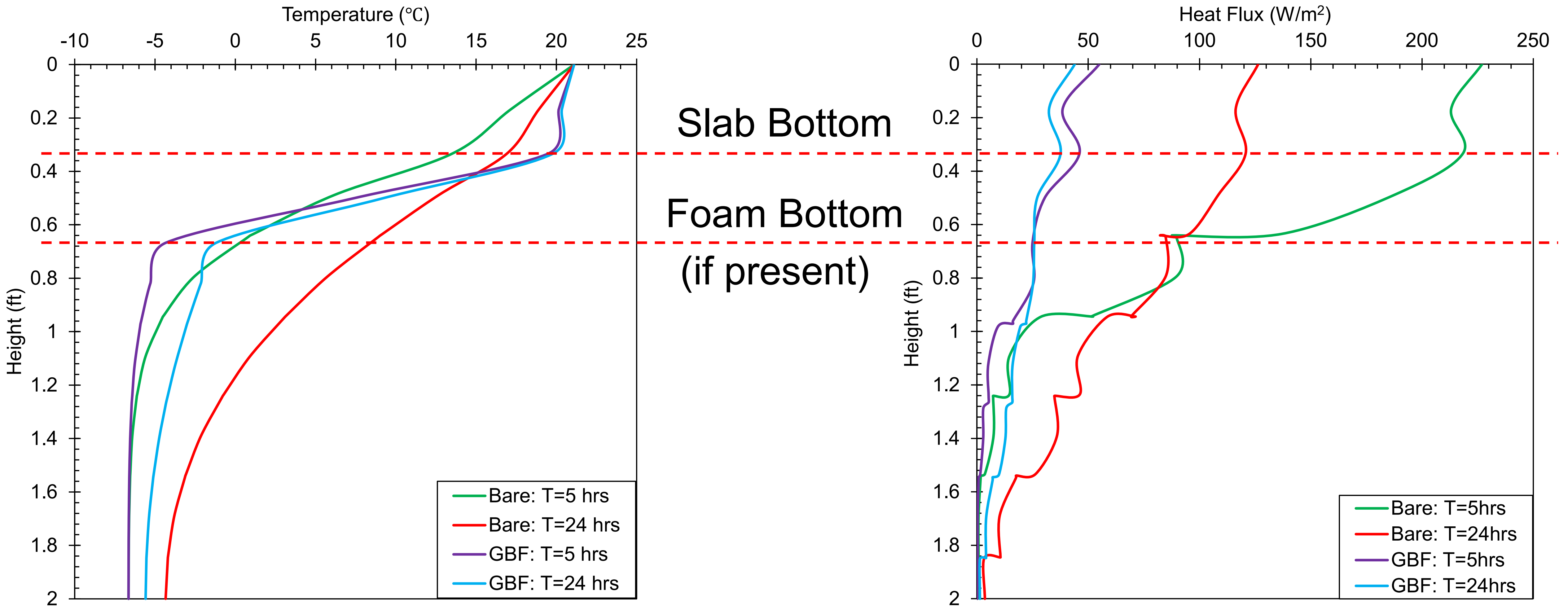
Example Simulation: Vertical Distribution Along Slab Centerline



Temperature Distribution

Flux Distribution

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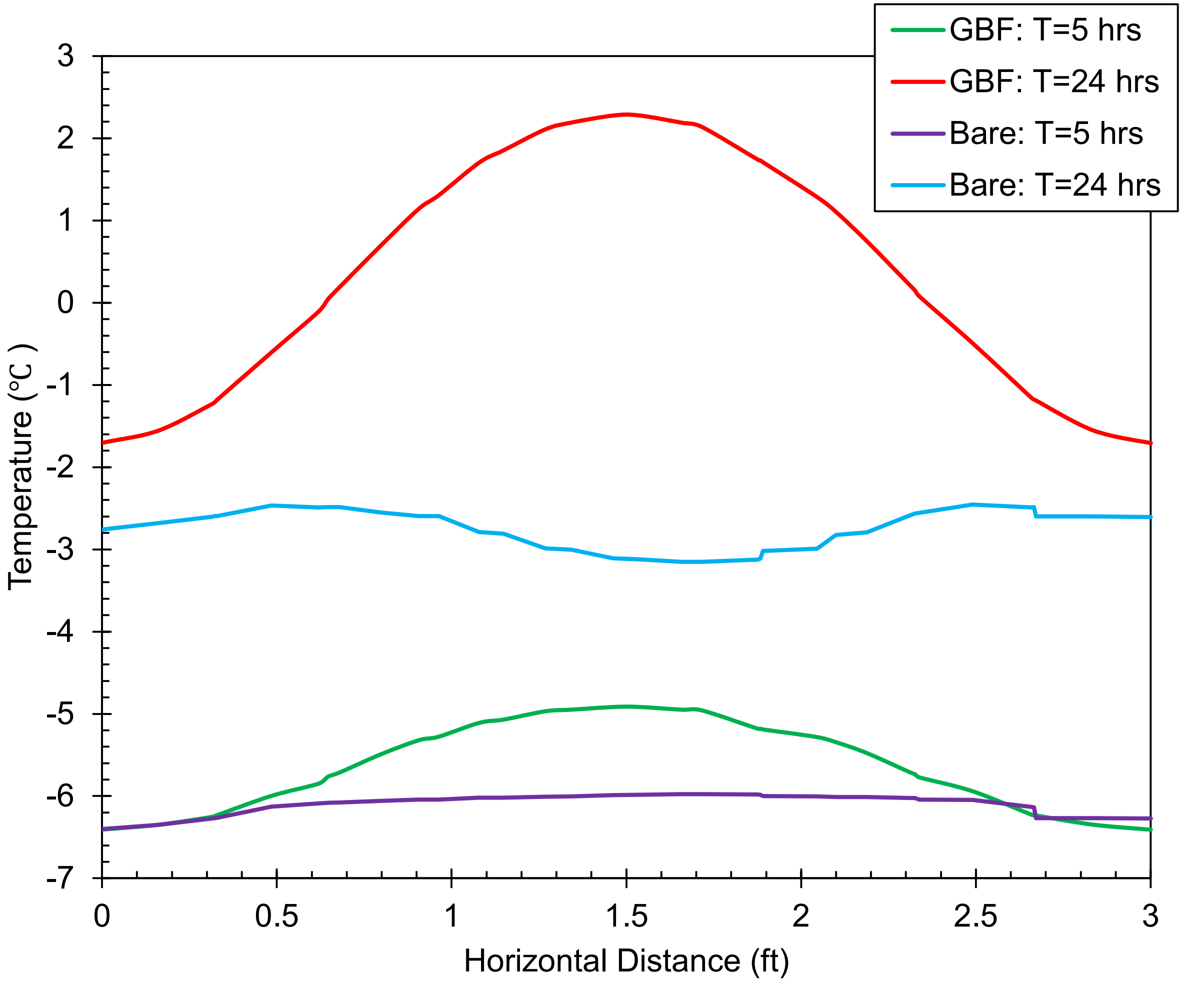
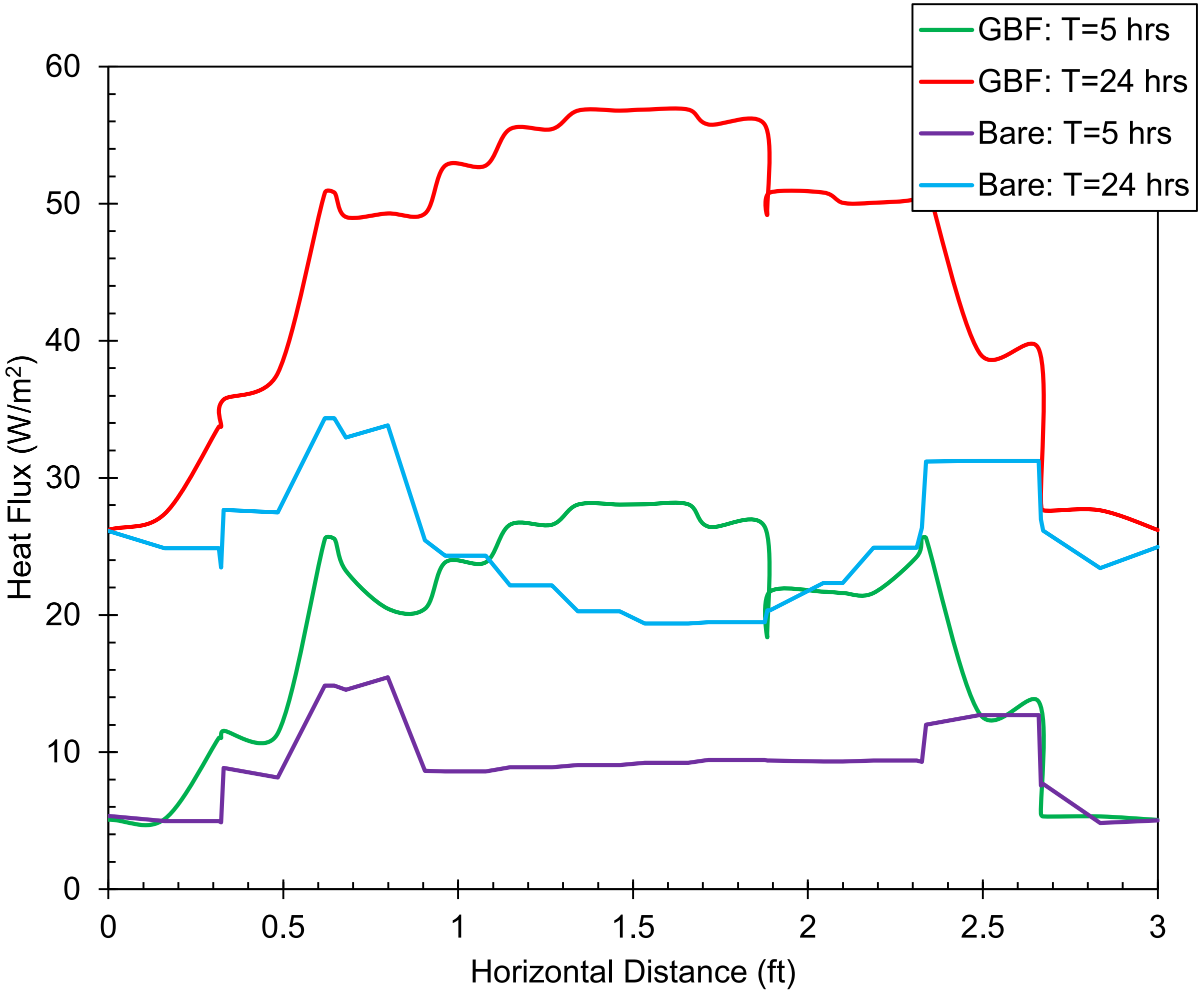
Example Simulation: Horizontal Distribution At Mid-Height



Temperature Distribution



Flux Distribution

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Future work

- Complete test setups
- Performance Monitoring
- Numerical Simulation
- Small Scale Cost Benefit Analysis

LIFE FORMS

Project: Application of Geofoam in Thermal Encapsulation of Foundations

Number: 1

Center for Integration of Composites into Infrastructure

Design and Testing of IFI Geosynthetic Products

Graduate Student: Md Ashrafuzzaman Khan

Team: Nripojyoti Biswas & Surya S.C. Congress

PI: Anand J. Puppala

Professor | A.P. and Florence Wiley Chair

Associate Director – Center for Infrastructure Renewal

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May 26, 2021

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Background and Objectives

Background

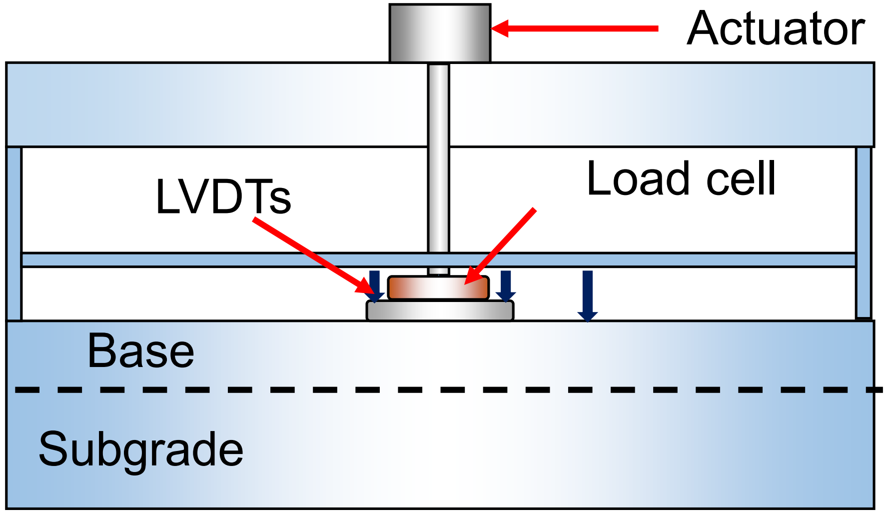
- HDPE geosynthetic products may provide sustainable and economic solution

- There is a lack of knowledge about the performance under control environment

FabGrid™ is a next generation composite
https://ind-fab.com/geogrids/

Objective

Performing repeated load tests on geosynthetic reinforced base layers built on different weak subgrades to calibrate design parameters based on Giroud-Han (G-H) method



Large-scale box size: 6’x6’x2.5’

Progress of Work

Task List

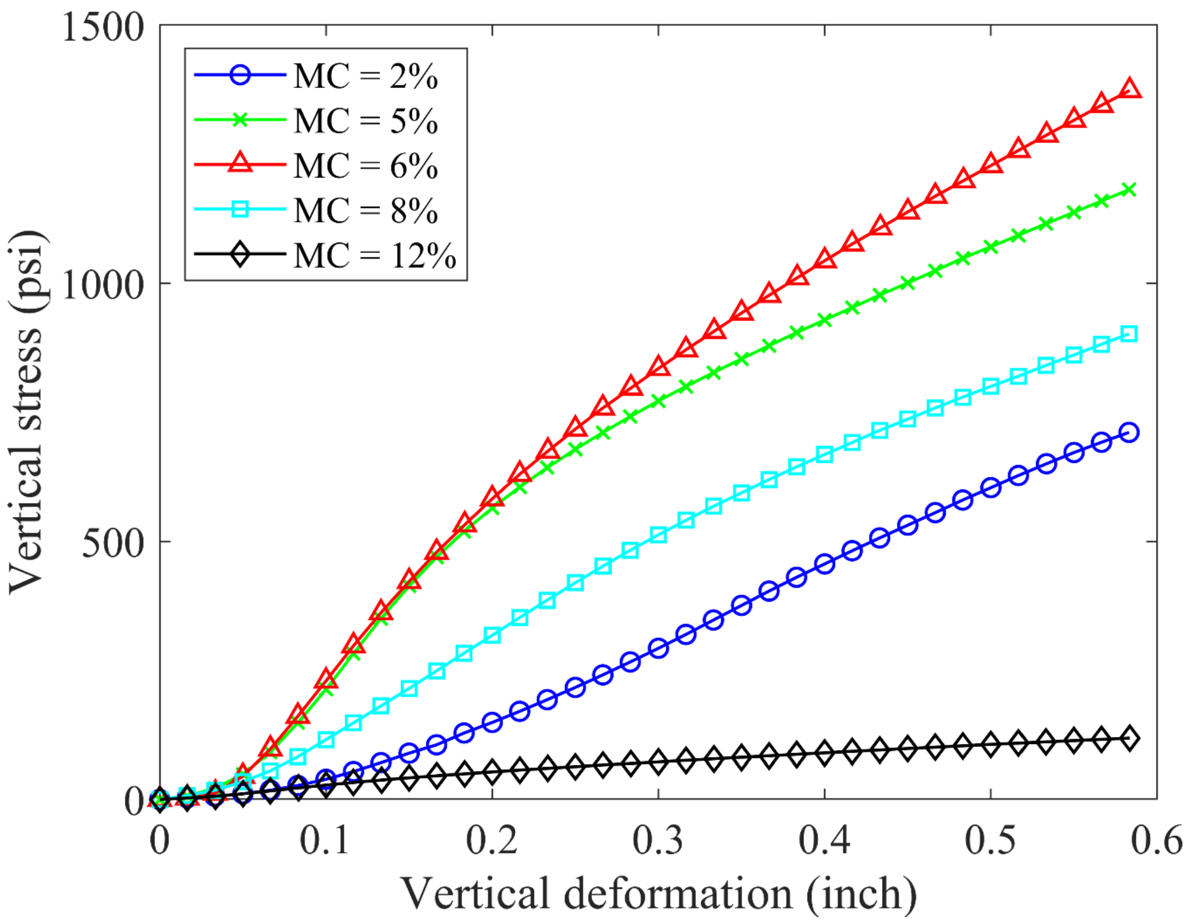
- ❑ **Characterization of subgrade material** → Presented on IUCRC meeting 2nd December 2020
- ❑ **Characterization of base material**
- ❑ **Construction of large-scale test section**
- ❑ **Large-scale repeated load testing (RLT)***

(Characterization of base material, Construction of large-scale test section, Large-scale repeated load testing (RLT)* → IUCRC meeting 26th May 2021)

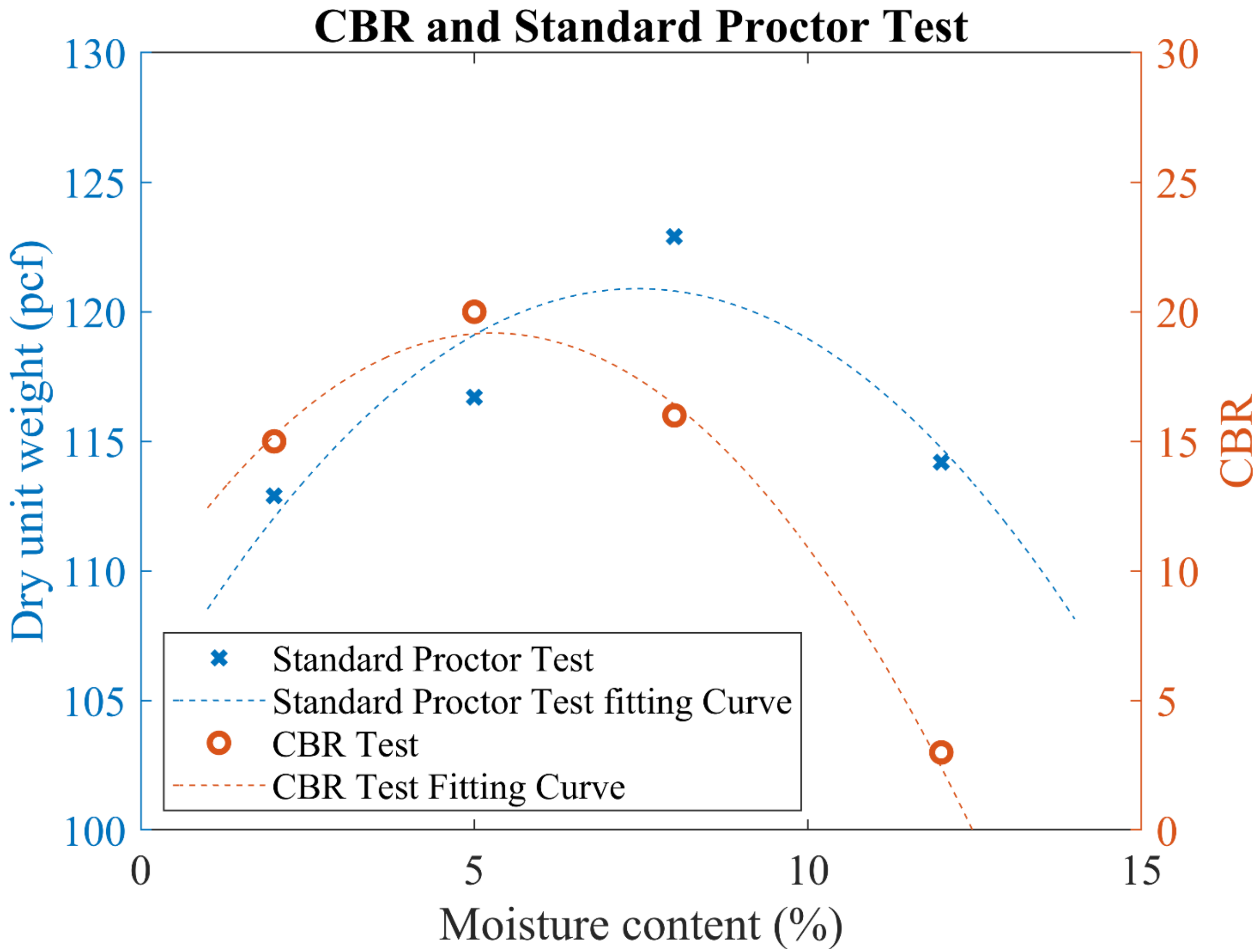
- ❑ **Data analysis and calibration of G-H parameters**
- ❑ **Development of design charts**

*1 test completed till 26th May 2021

Characterization of Base Materials

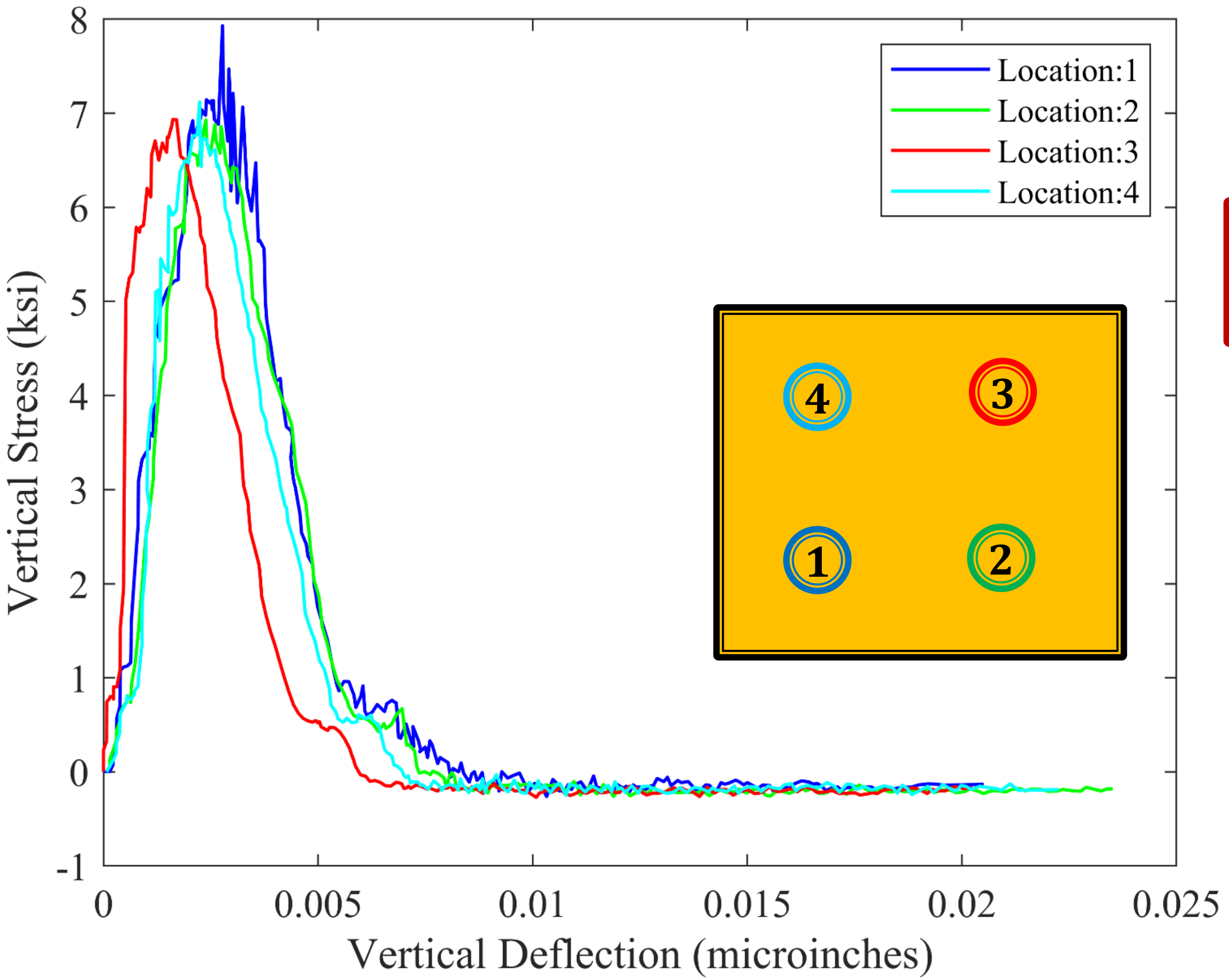


Trend of CBR was not the same as subgrade- maximum CBR observed near to the optimum moisture



Maximum CBR occurred when the dry density was lower than the optimum moisture content

Construction of large-scale test section

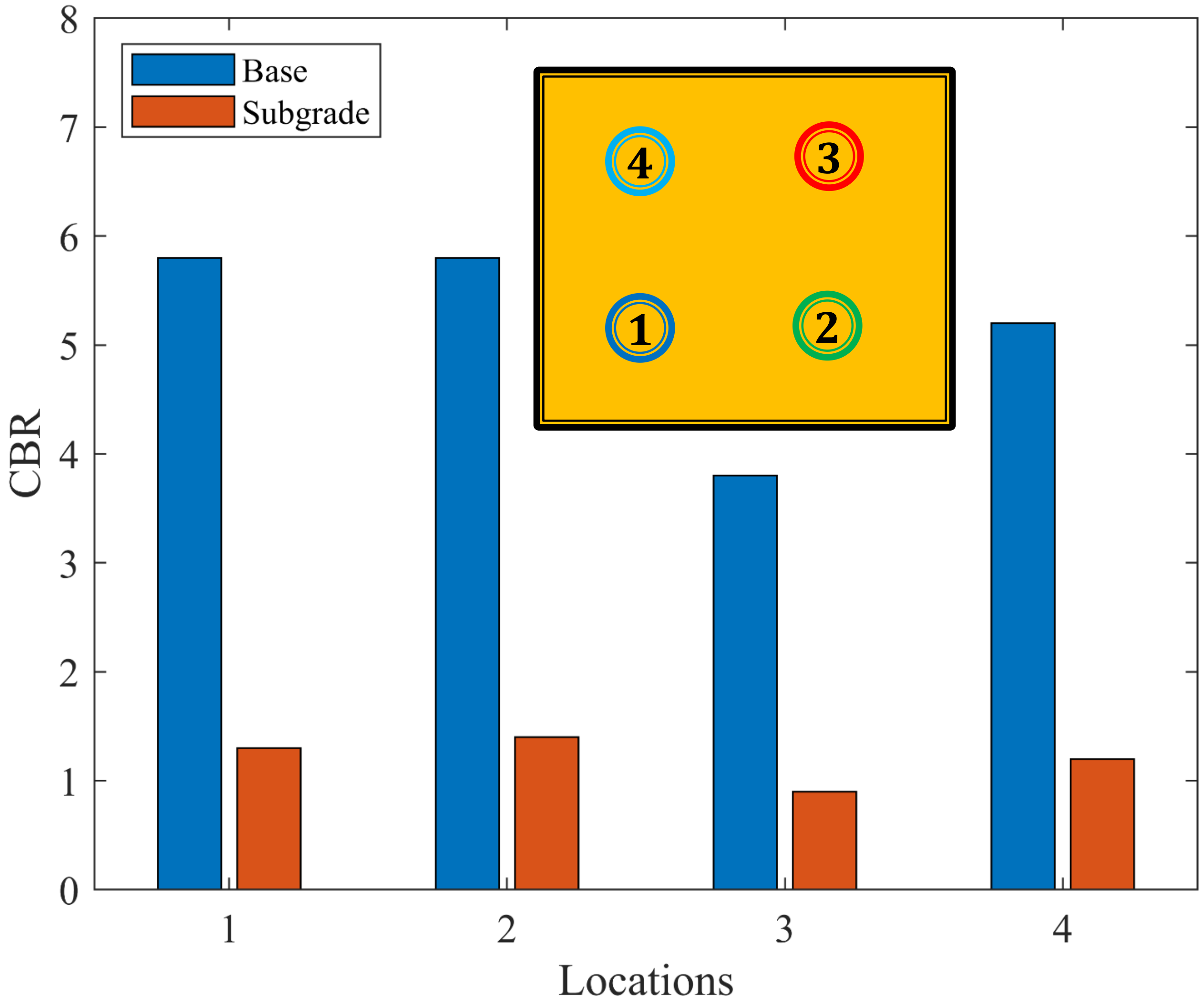


Top of Subgrade

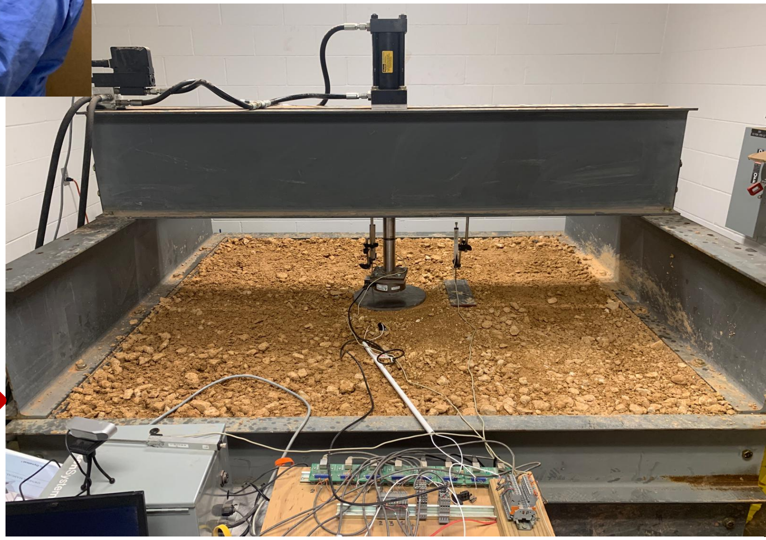
Light Weight Deflectometer (LWD)

- **LWD tests were performed at 4 locations**
- **Stress-deflection plots had the similar pattern**
- **Confirmed the consistency**

Construction of large-scale test section



Dynamic Cone Penetrometer (DCP) Testing

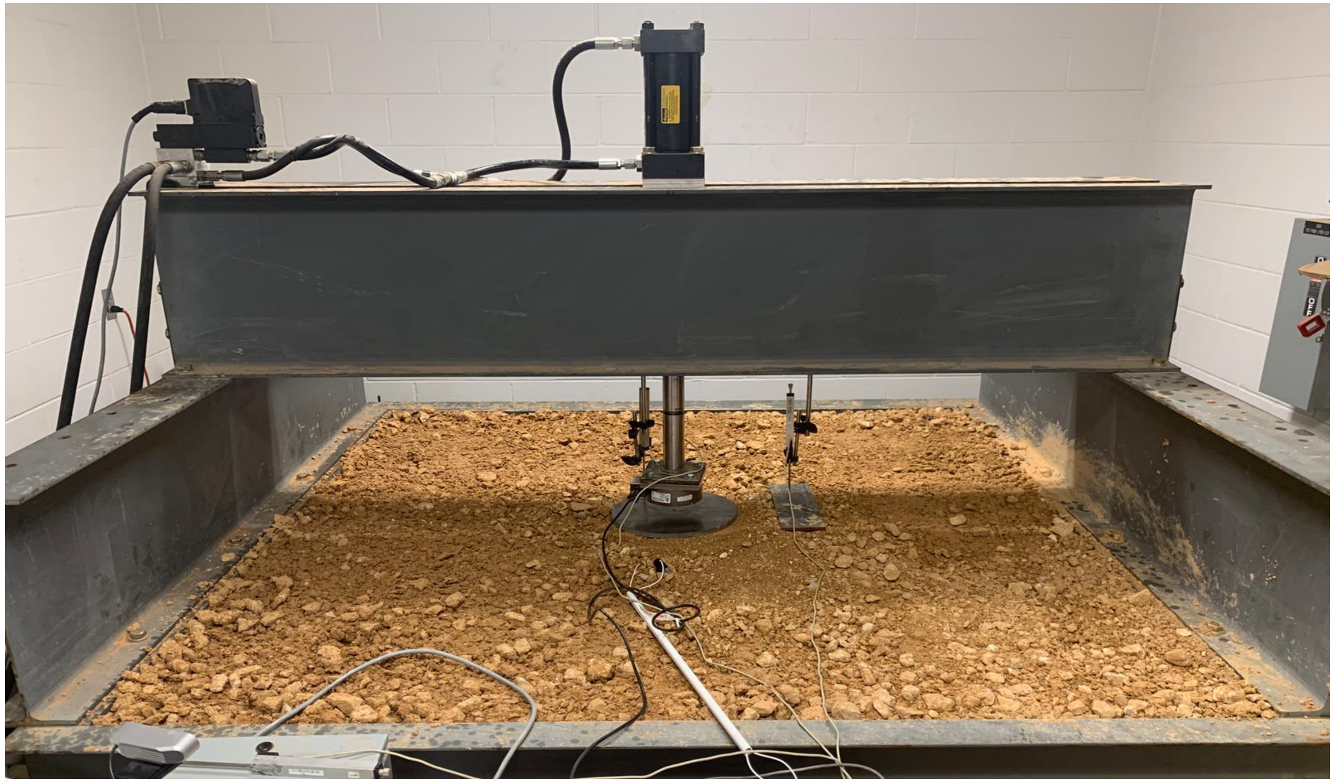


Before RLT

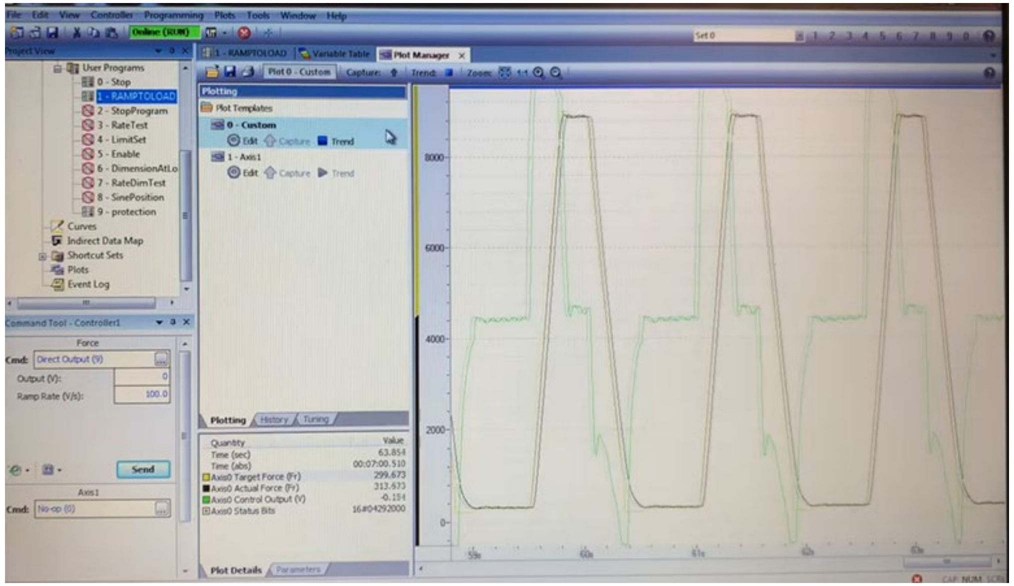
18-inch subgrade + 12-inch base

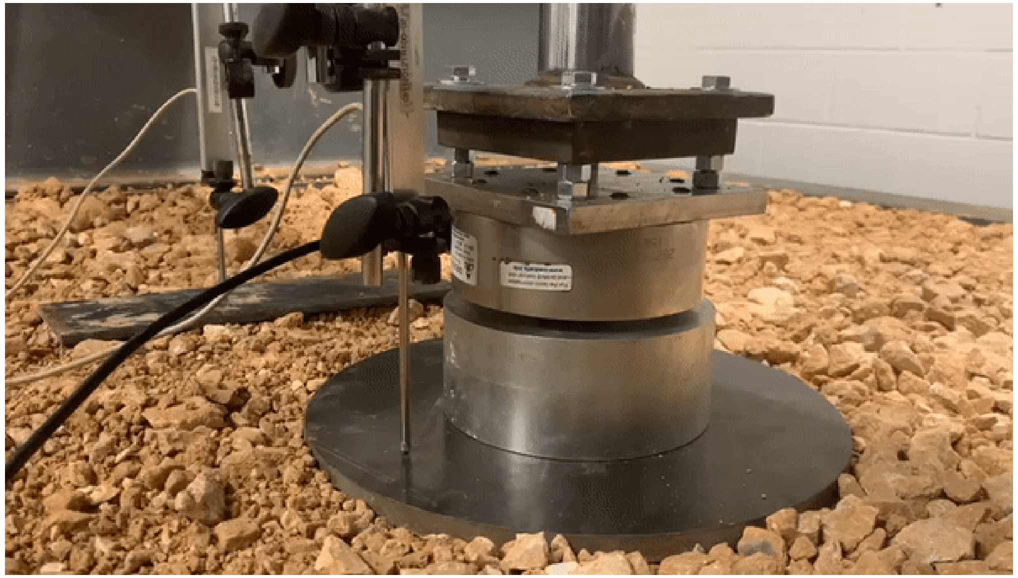
- **DCP tests were performed at 4 locations**
- **Base/Subgrade CBR ratios were between 4 to 5**
- **Confirmed the consistency (Target CBR = 1)**

Large-scale repeated load testing



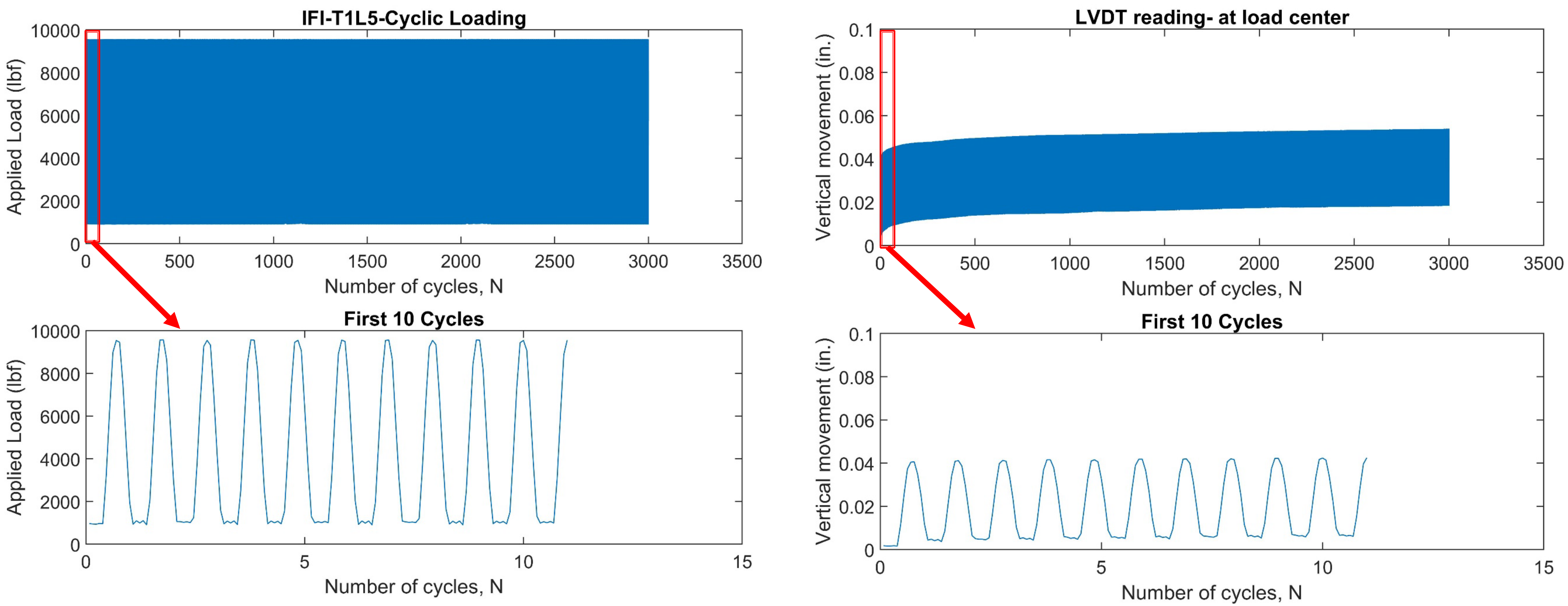
Unreinforced Test Section
(18-inch subgrade + 12-inch base)





- **Frequency of loading: 0.77 Hz**
- **Peak load: 9000 lbf (Target 80 psi)**
- **Loading plate diameter: 12 inch**
- **Data: 1 Load cell, 2 force sensors and 2 LVDTs**

Large-scale repeated load testing



- First test was conducted for 3000 cycles
- The applied load was equivalent to single-wheel load
- The vertical deformation data obtained from the LVDTs will be used to determine the elastic deformation and permanent deformation with the number of loading cycle

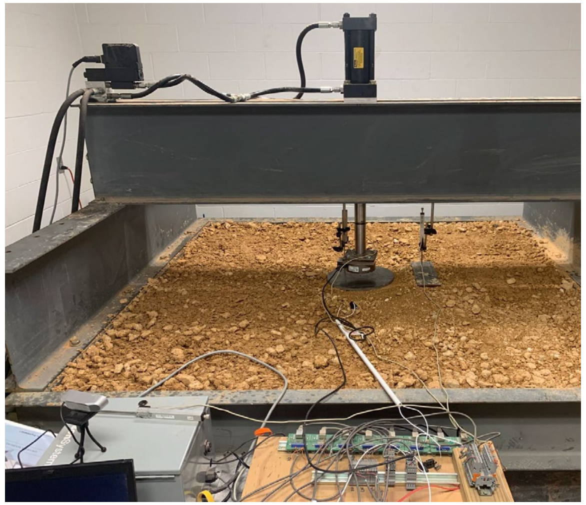
Summary

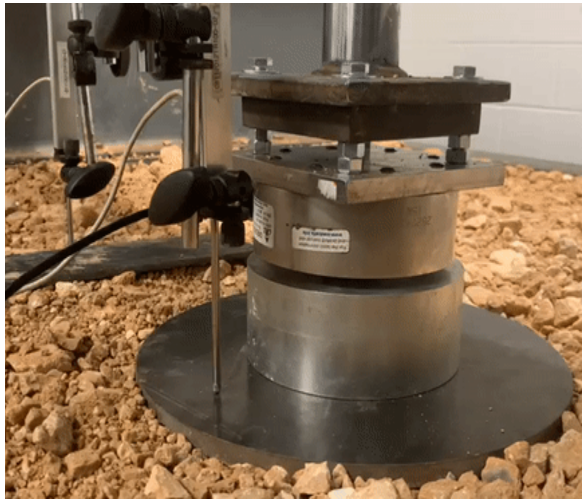
Completed the characterization of base and subgrade materials

First test section was constructed with 18-inch subgrade and 12-inch base layer

LWD, DCP and other in-situ tests were performed to check the test section quality during construction

Completed the first repeated load testing for the unreinforced section with subgrade CBR = 1





LIFE FORMS

Project: Design and Testing of IFI Geosynthetic Products

Number: 2

Center for Integration of Composites into Infrastructure

Performance of pavement sections with H_2Ri geosynthetics

Graduate Student: Nripojyoti Biswas

Team members: Md Ashrafuzzaman Khan, and Surya Sarat Chandra Congress

PI: Anand J. Puppala

Professor | A.P. and Florence Wiley Chair

Associate Director – Center for Infrastructure Renewal

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Texas Department of Transportation

TENCATE

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Zachry Department of Civil & Environmental Engineering

Introduction

❖ **Objective**

- ❑ **To address the feasibility/efficiency of H_2Ri geosynthetic drainage and strengthening layer to improve the performance of pavement sections built on high-PI soil**

❖ **Single wicking geotextile layer - serves various functions**

- ❑ **Wicking action**
- ❑ **Drainage through capillary action**
- ❑ **Reinforcement**
- ❑ **Separation**

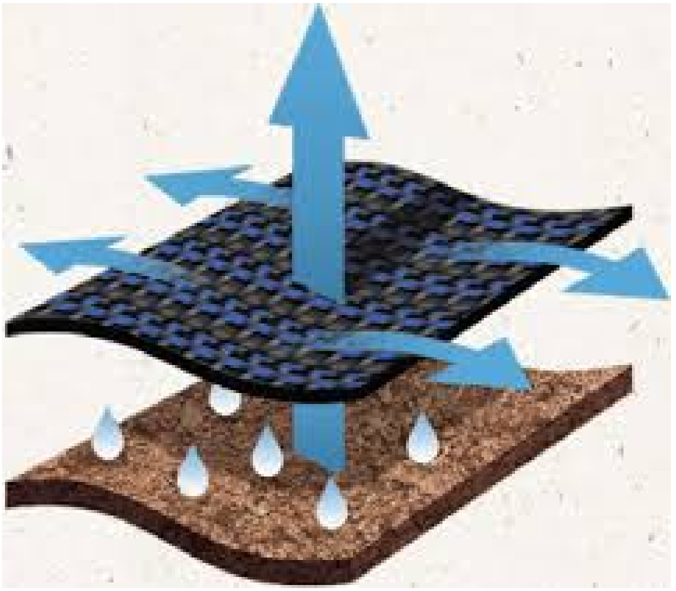
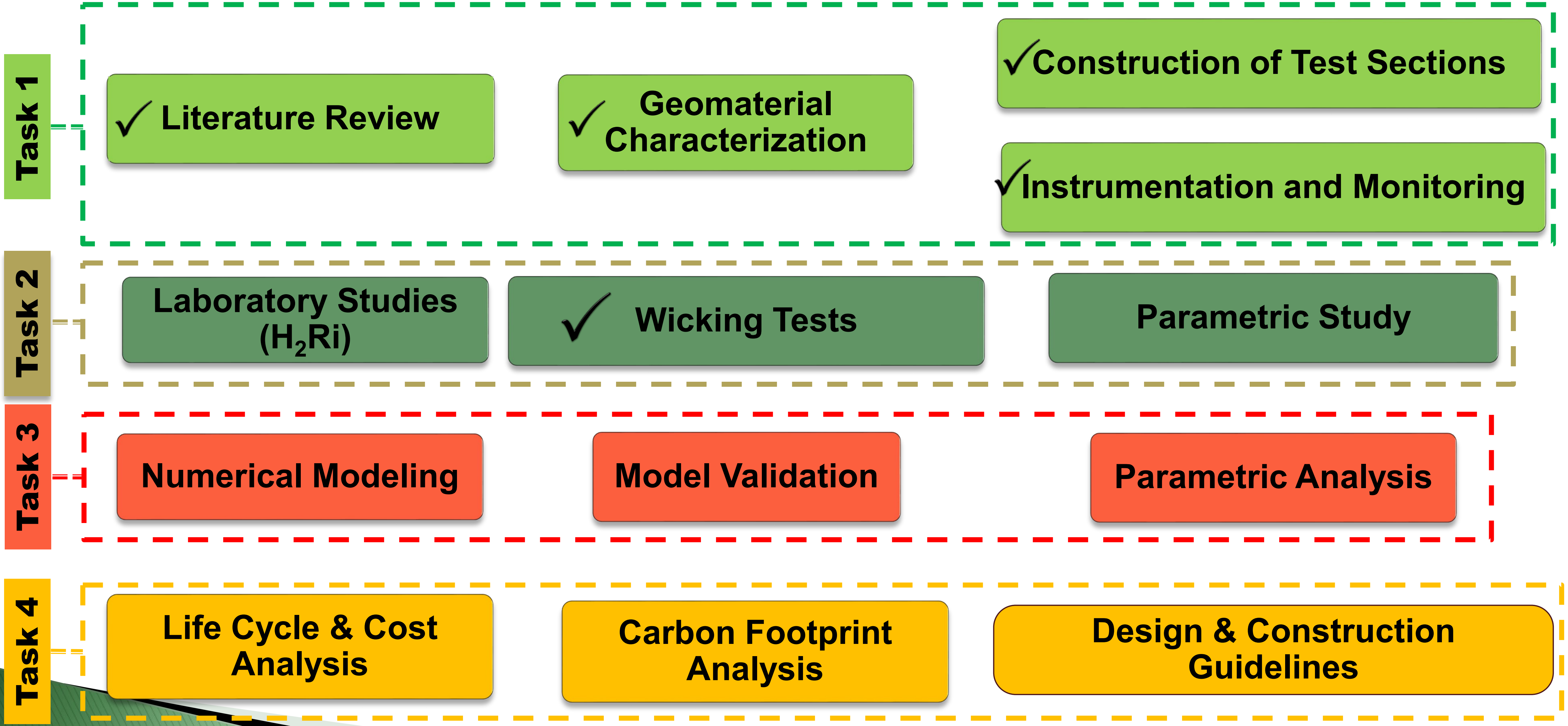
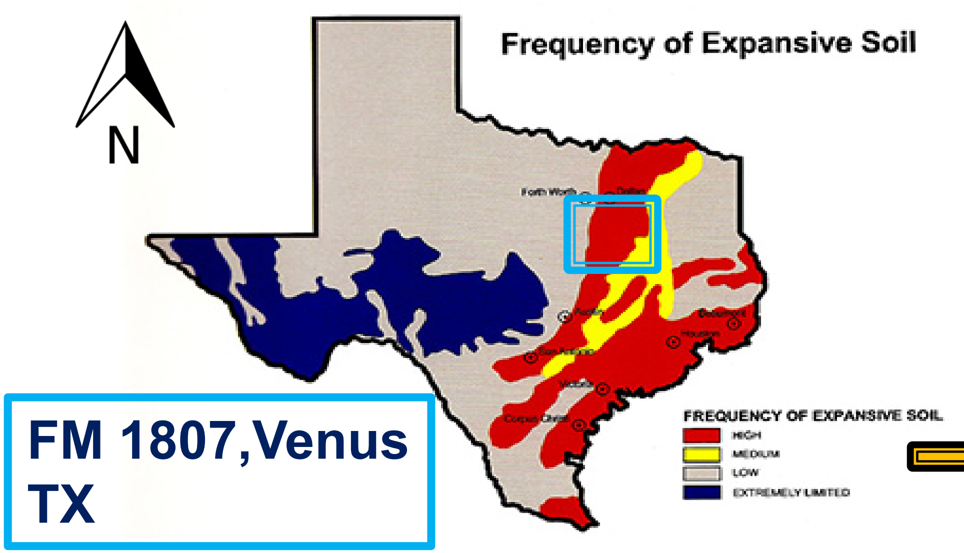


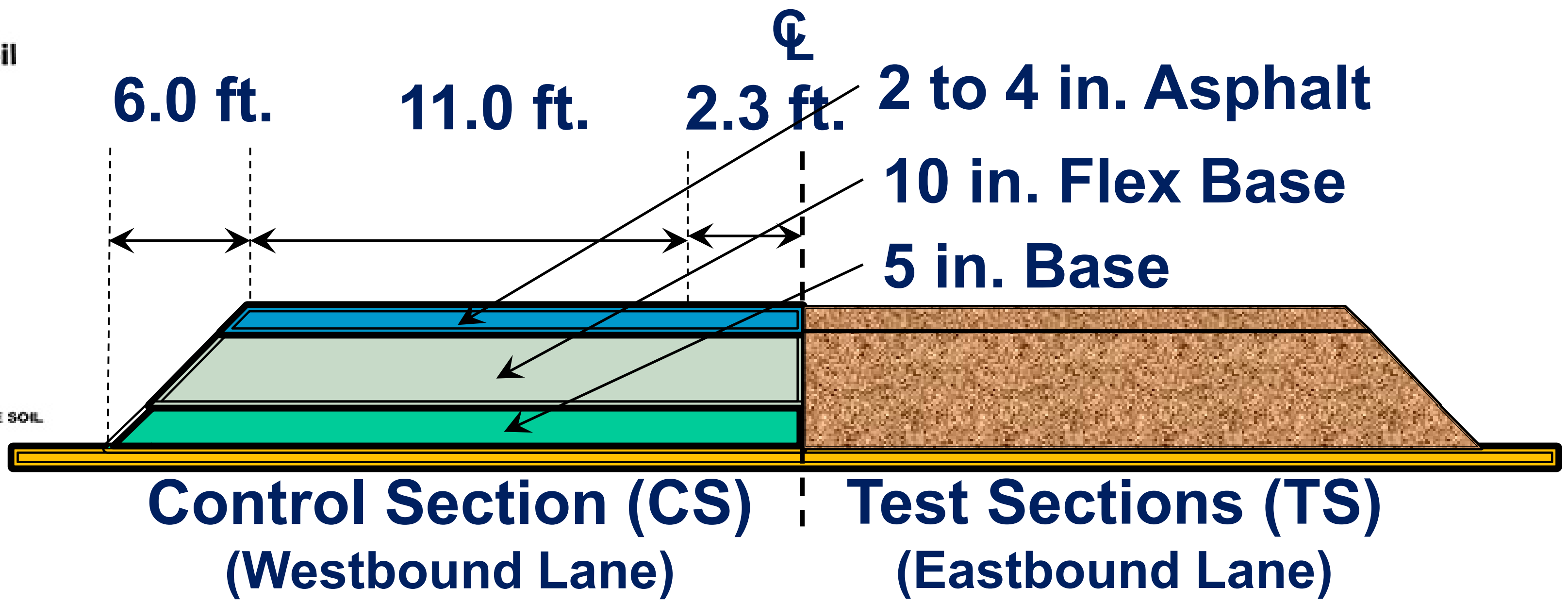
Figure-TenCate, Inc.

Task Plan


Task 1
✓ Literature Review
✓ Geomaterial Characterization
✓Construction of Test Sections
✓Instrumentation and Monitoring
Task 2
Laboratory Studies (H_2Ri)
✓ Wicking Tests
Parametric Study
Task 3
Numerical Modeling
Model Validation
Parametric Analysis
Task 4
Life Cycle & Cost Analysis
Carbon Footprint Analysis
Design & Construction Guidelines

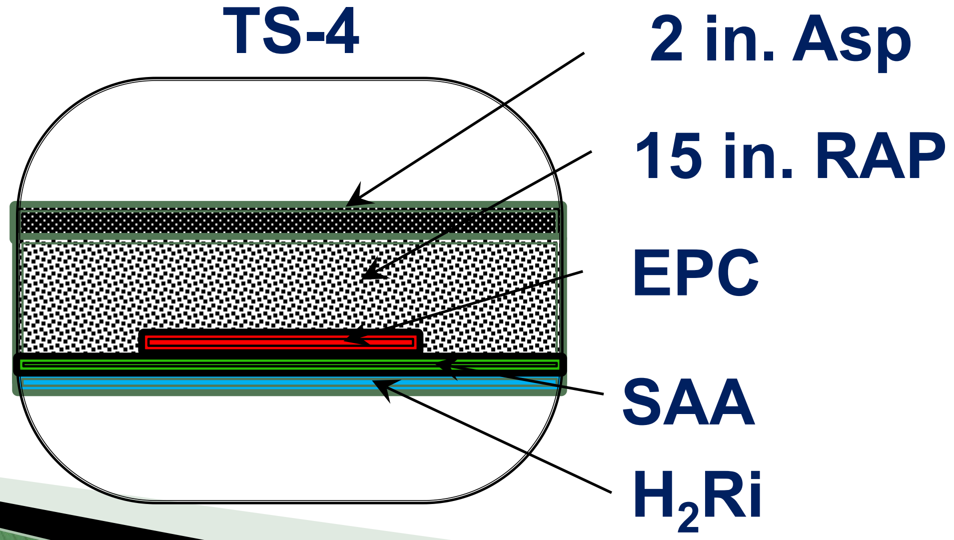
Project Location and Section Details

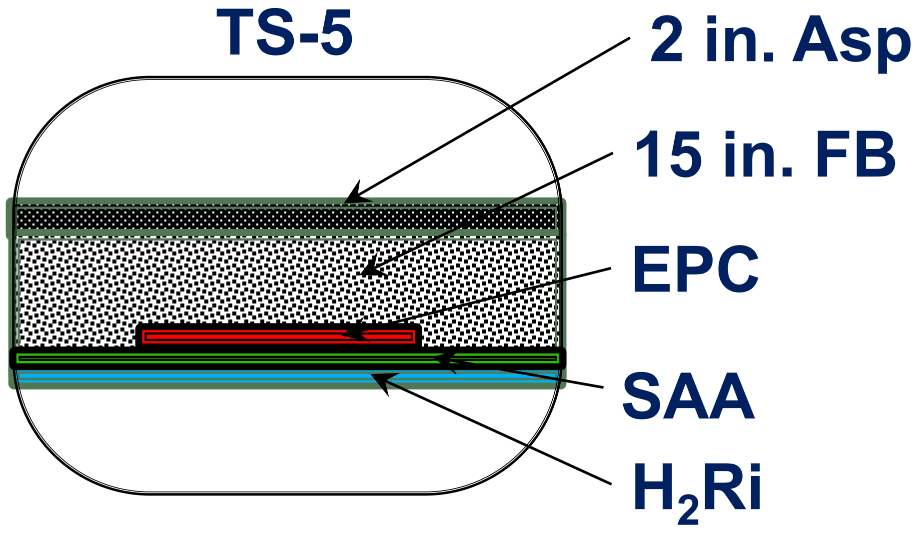




Asp – Asphalt Course
RAP - Reclaimed Asphalt Pavement Aggregates
FB - Flex Base

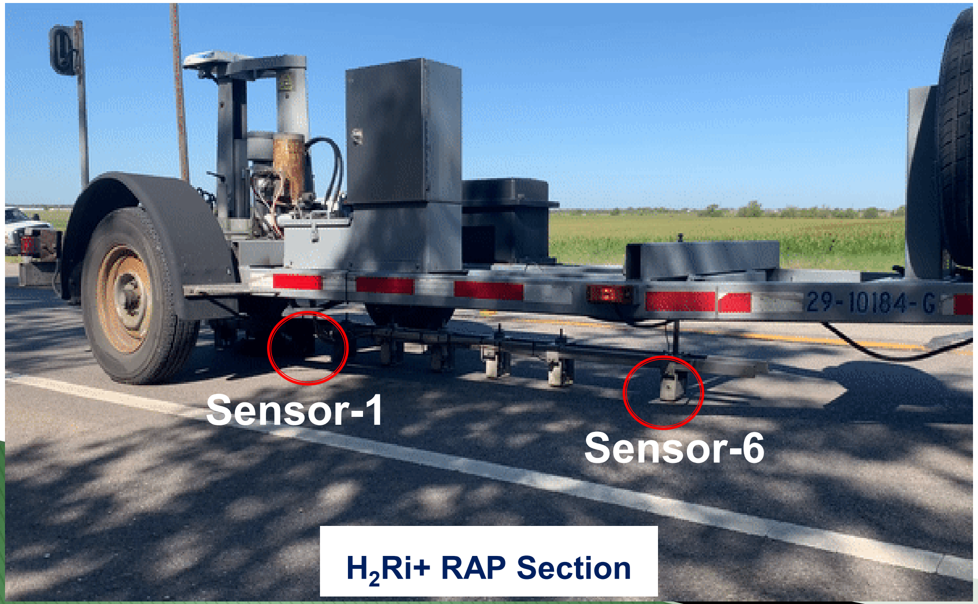
EPC - Earth Pressure Cells
SAA - Shape Array Sensors

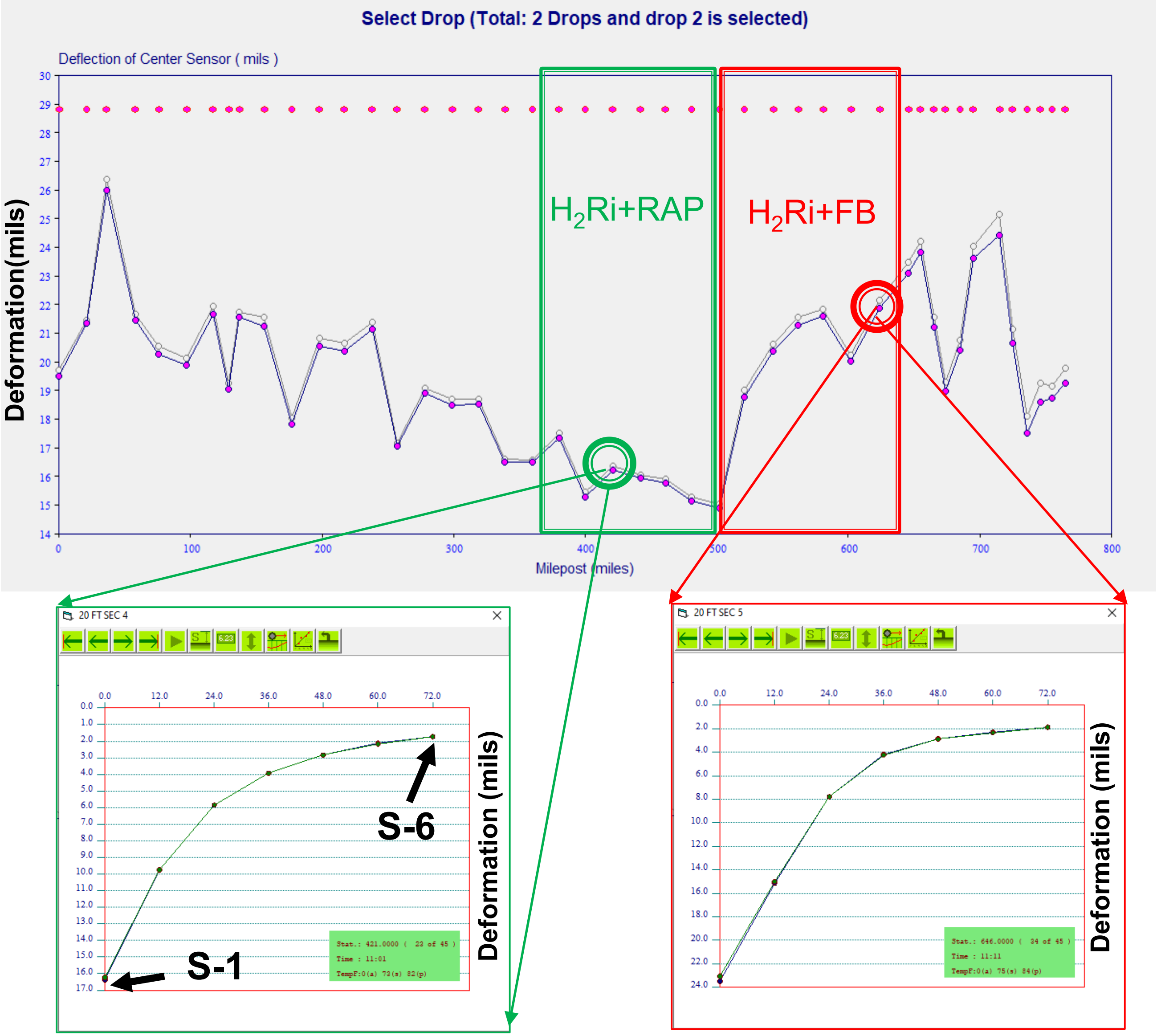




Falling Weight Deflectometer (FWD) Test

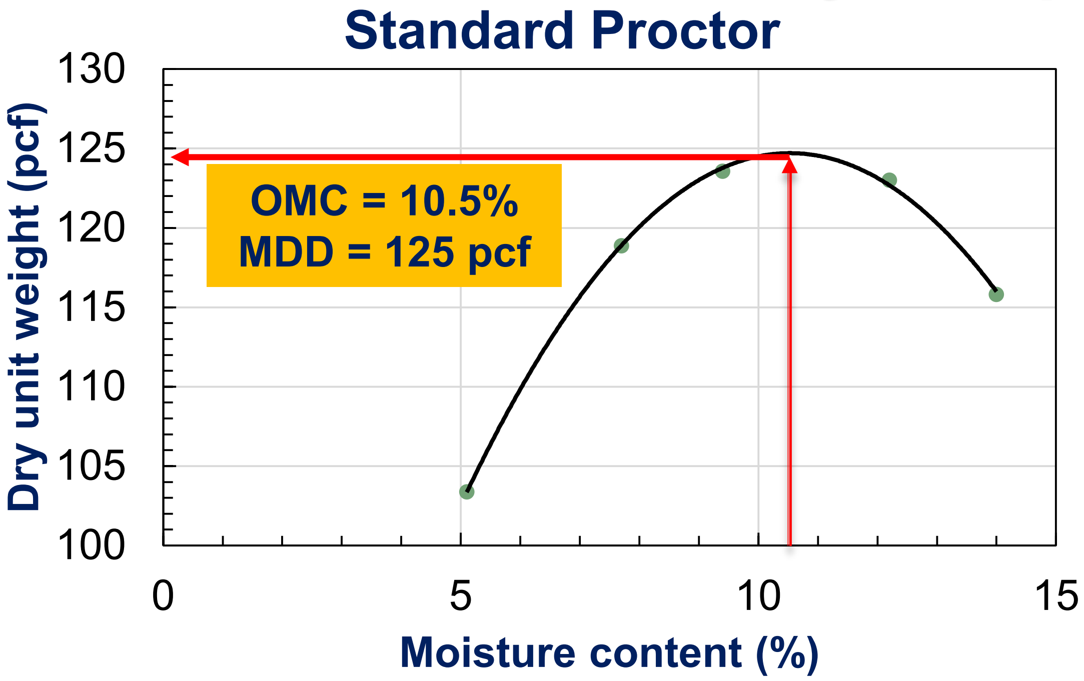
1 mils = 0.001 in.





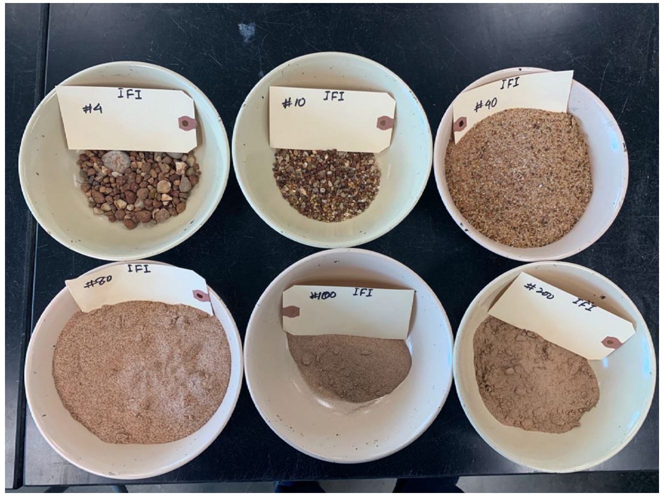
❖ **Deformation of RAP section was lower than FB section**

Laboratory setup – Material Characterization

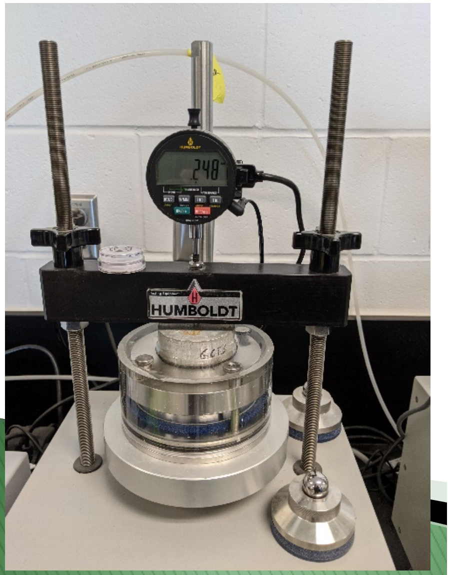


Particle size analyzer

Sieve Analysis (ASTM D6913)



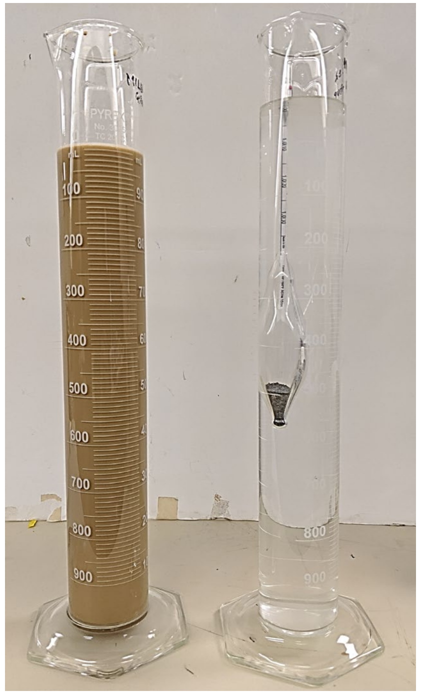
Liquid Limit (ASTM D4546)



Liquid Limit (ASTM D4318)

Wet Sieve Analysis (ASTM D1140)

Hydrometer Analysis (ASTM D7928)



Laboratory setup – Construction of Unreinforced Section

Laying subgrade soil

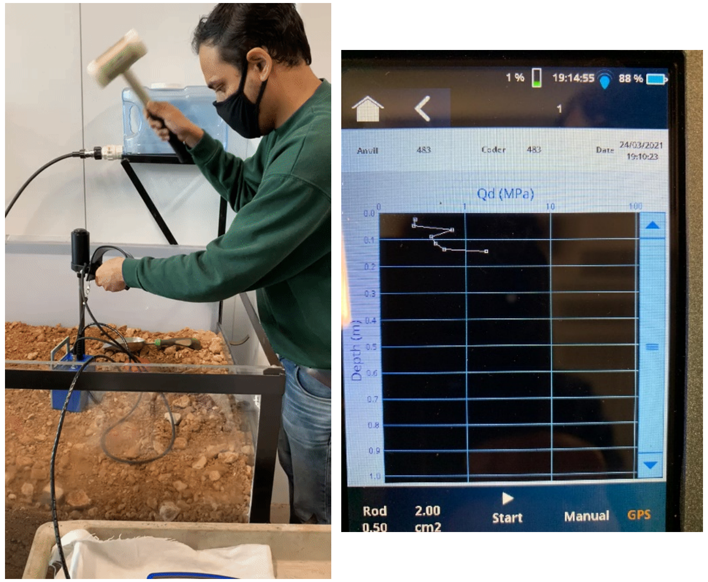
Compaction of layers

Subgrade after compaction

Base layer after compaction

Dynamic Cone Penetrometer test

DCP test in progress



Future Studies

- Monitoring of the Control Section

  Moisture Box
- Construction of Reinforced Section
- Life Cycle Cost Analysis
- Numerical model

LIFE FORMS

Project: Performance of pavement sections with H2Ri geosynthetics

Number: 3

Mitigating Sulfate Heaving Using Novel Admixtures

Center for Integration of Composites into Infrastructure

Project Leader: Nripojyoti Biswas

Team Members: Jungyeon Jang, and Surya Sarat Chandra Congress

PI: Anand J. Puppala

Professor | A.P. and Florence Wiley Chair

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Terracon

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Research Need: Mitigating Sulfate Heaving Using Novel Admixtures

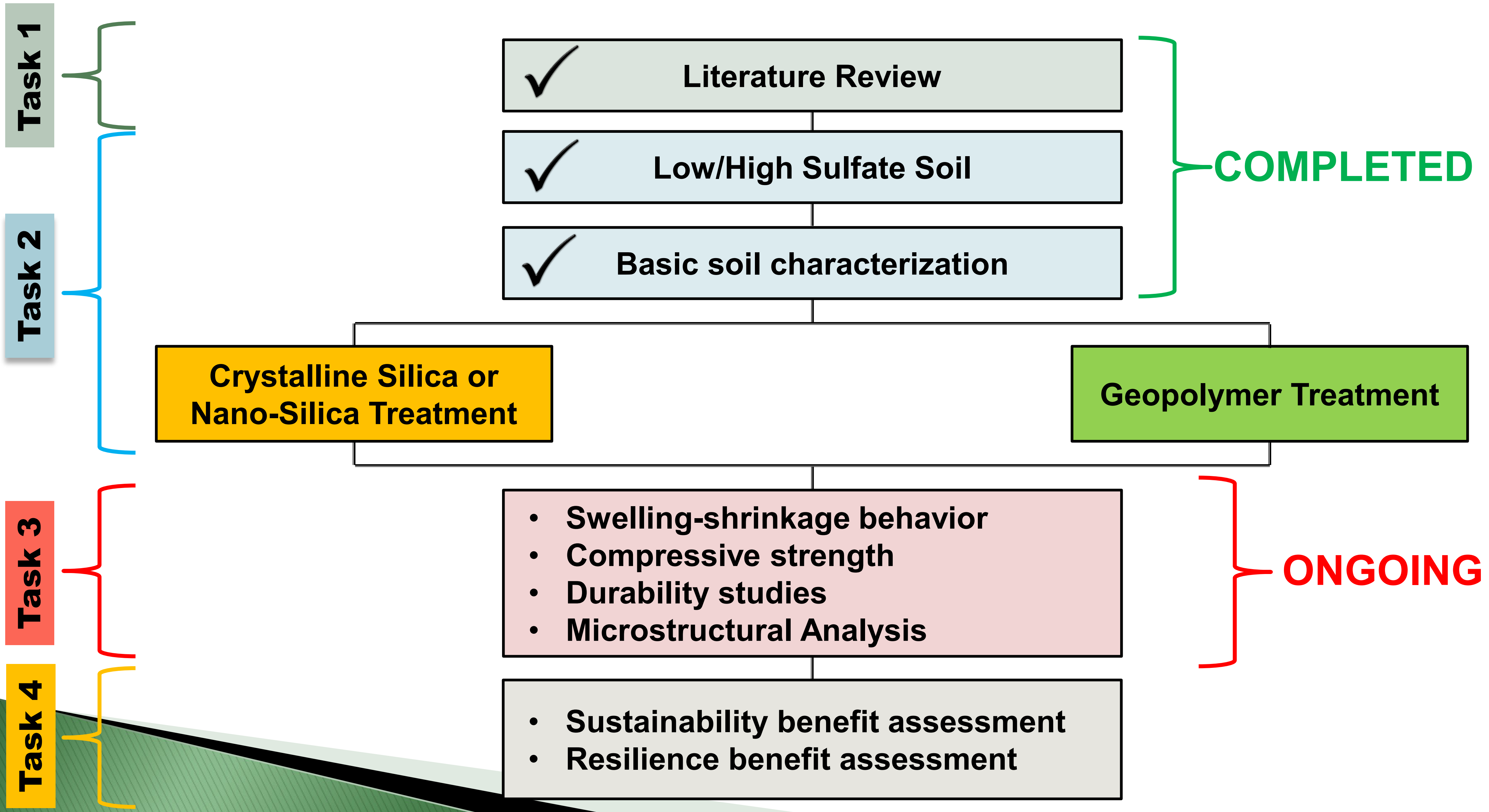
- **Problem**
  - Sulfate heaving has a detrimental impact on overlying infrastructure
- **Objective**
  - Study alternate sustainable co-additives for stabilizing sulfate-rich soils
- **Co-additive studied**
  - Silica admixture
    - Quarry Fines
    - Laboratory grade Nano-Silica
  - Geopolymers (GPs)

Heaving on Joe Pool Lake Road, Grand Prairie, Texas

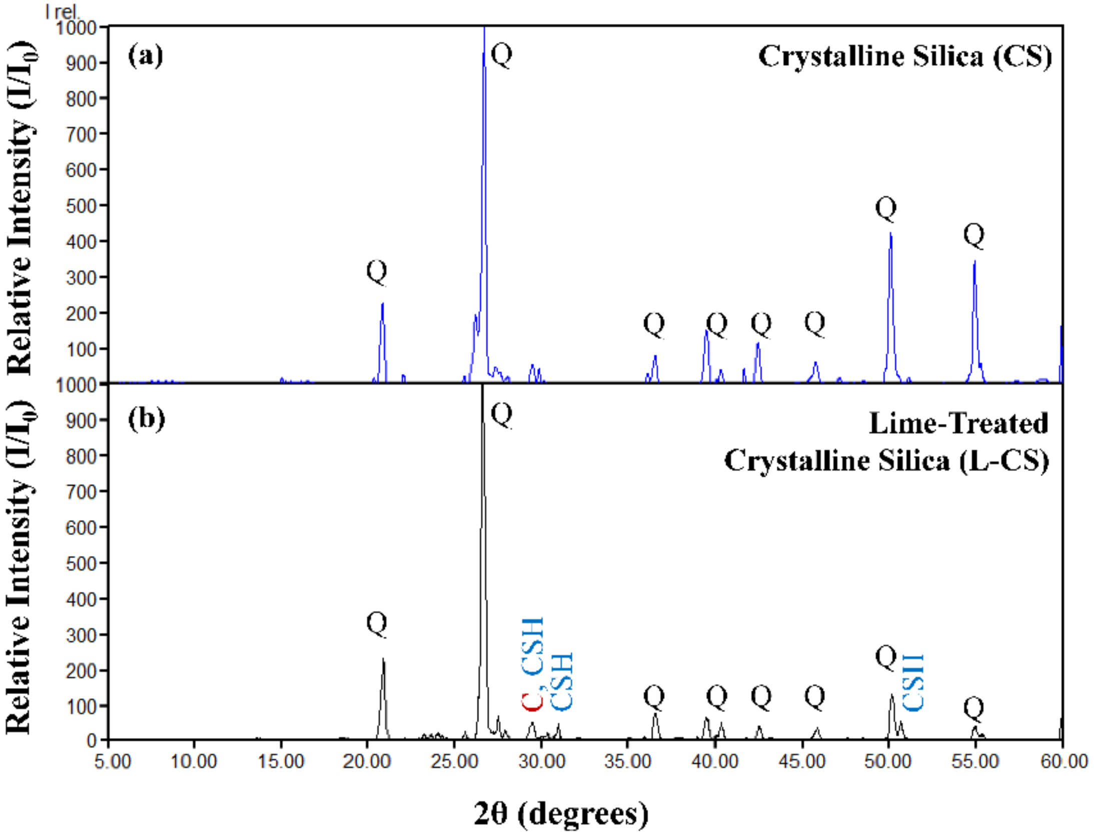
Source: Les Perrin, USACE

Joe Pool Lake (Les Perrin, USACE)

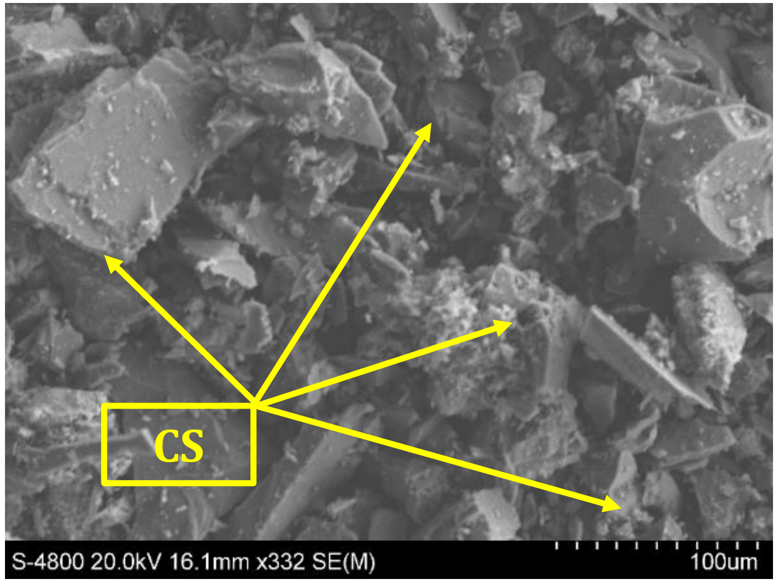
Research Plan: Mitigating Sulfate Heaving Using Novel Admixtures

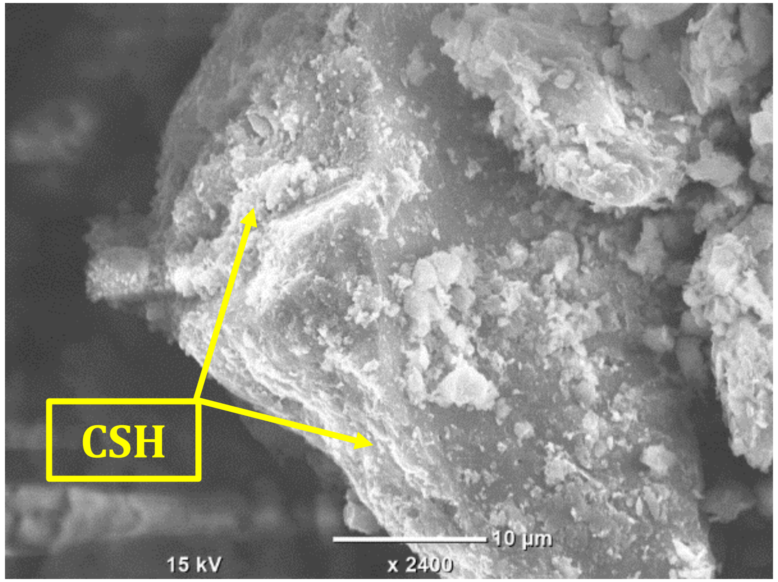


Test Results: Crystalline Silica treatment



C: Calcite (Calcium carbonate); Q: Quartz; CSH: Calcium silicate hydrate

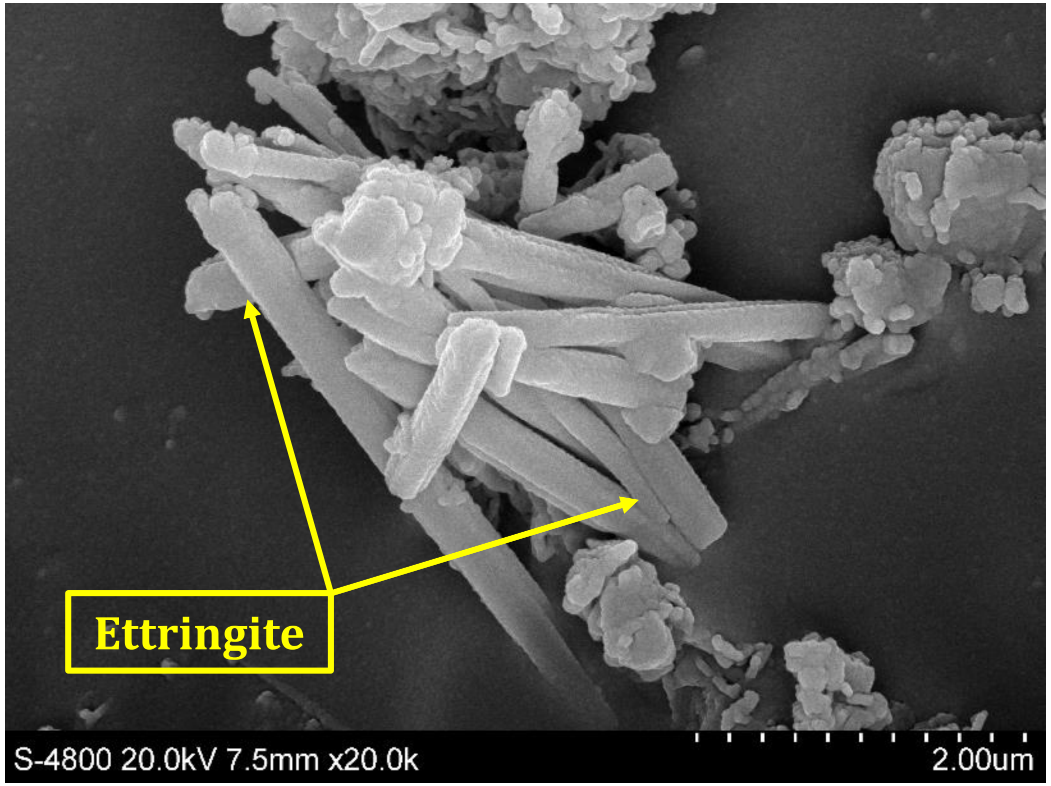




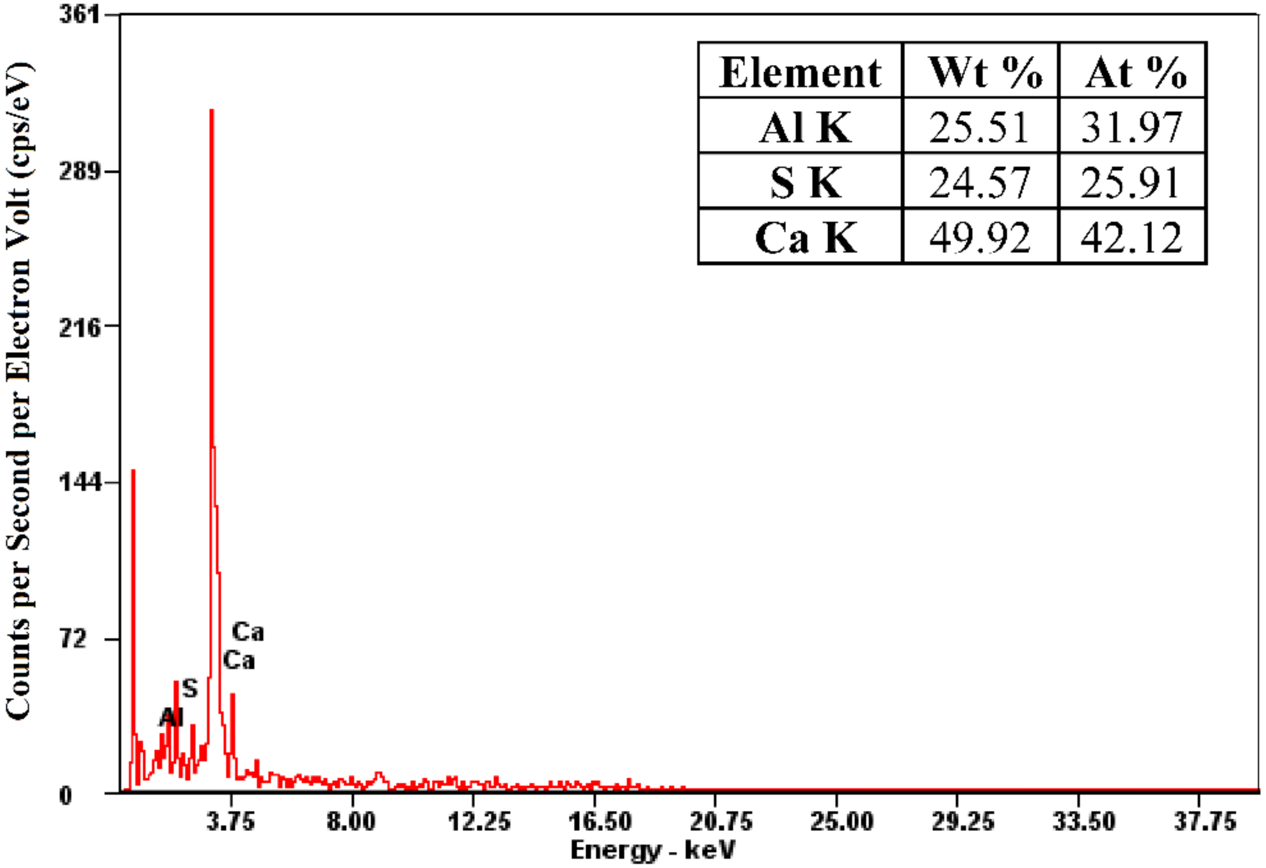
❖ **Crystalline silica fines participated in chemical reaction**

Test Results: Field Emission Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy

Lime-Treated High Sulfate Soil



Lime-treated high-sulfate soil



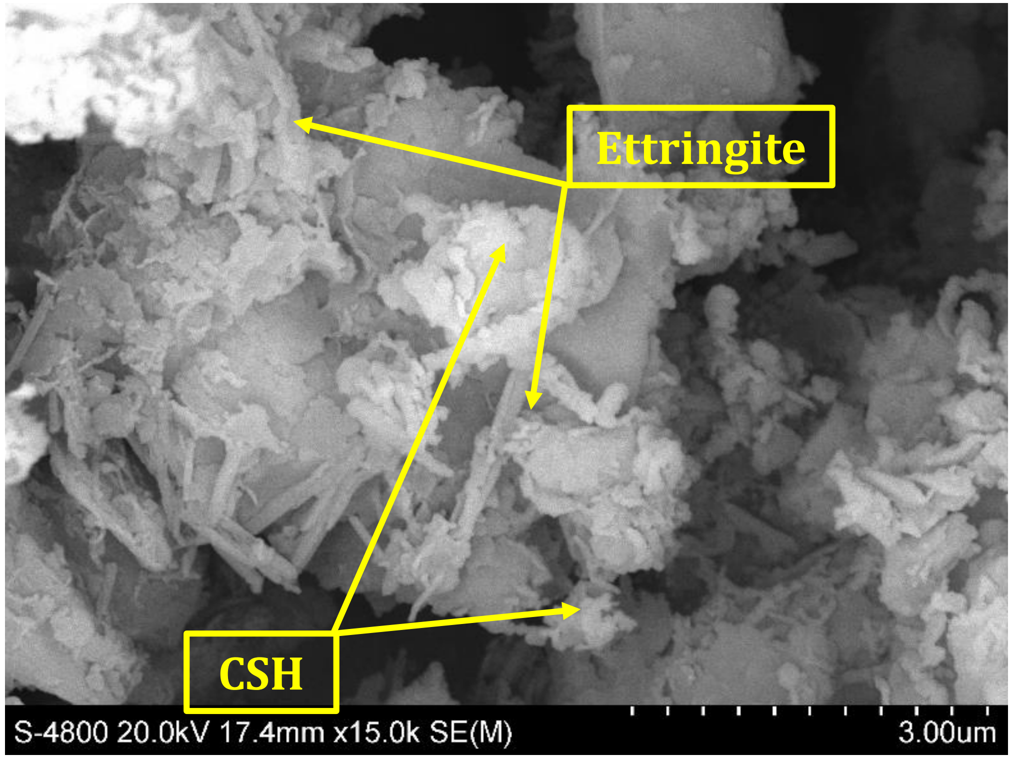
Element	Wt %	At %
Al K	25.51	31.97
S K	24.57	25.91
Ca K	49.92	42.12

Note: The strongest peak corresponds to silver (Ag) since the specimens were sputter coated with Ag

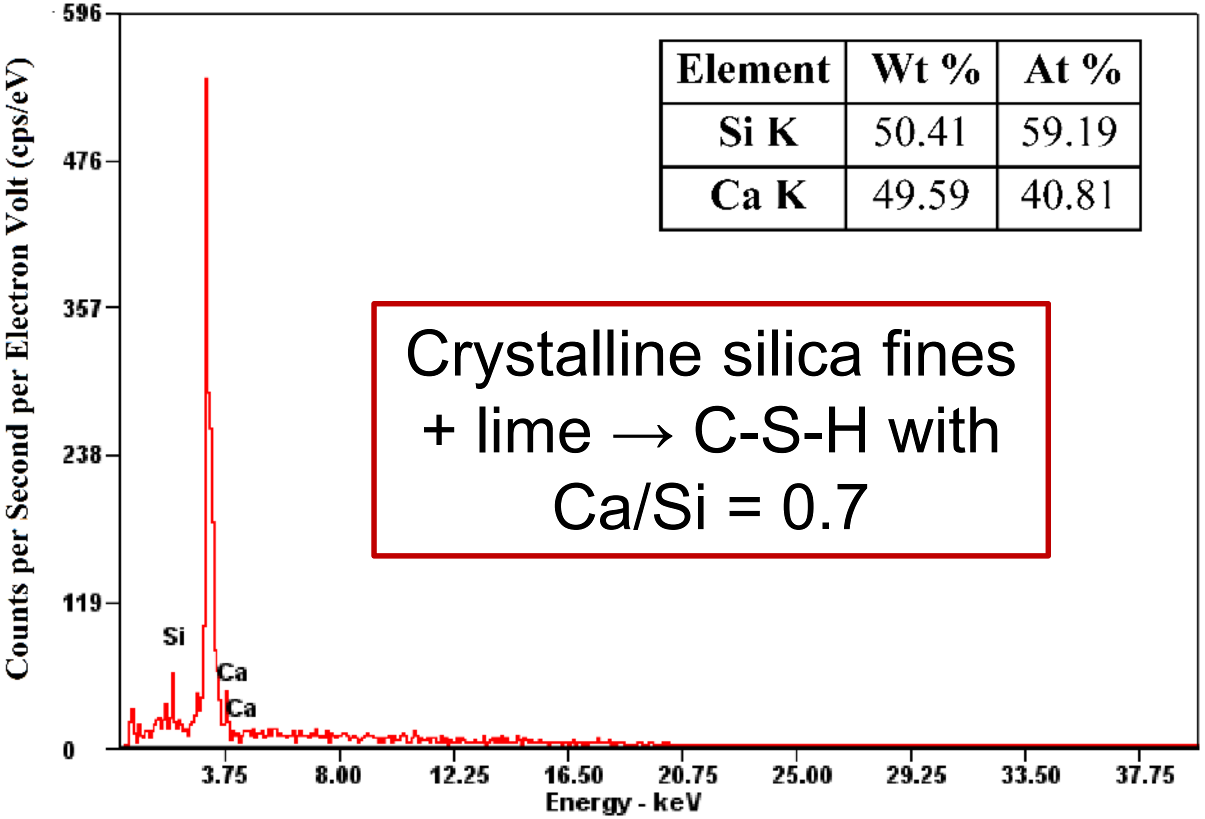
- ❖ Lime treatment → ineffective for high-sulfate soil
- ❖ Ettringite Crystals formed due to lime addition

Test Results: Field Emission Scanning Electron Microscopy and Energy Dispersive X-ray Spectroscopy

Lime-Treated High-Sulfate Soil with Crystalline Silica



Lime-treated high-sulfate soil with 30%CS



Element	Wt %	At %
Si K	50.41	59.19
Ca K	49.59	40.81

Crystalline silica fines + lime → C-S-H with Ca/Si = 0.7

Note: The strongest peak corresponds to silver (Ag) since the specimens were sputter coated with Ag

- ❖ **Crystalline silica fines participated in chemical reaction**

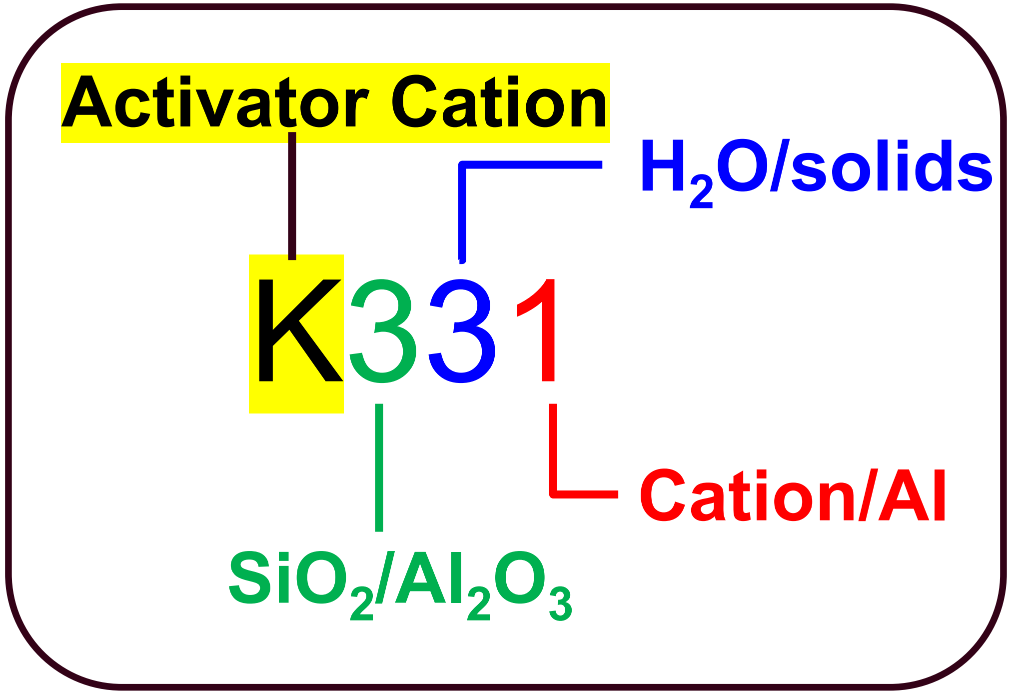
Geopolymer Treatment

Geopolymer Development and Characterization

- $M_n(-(SiO_2)_z-AlO_2) \cdot wH_2O$
  - M is a monovalent cation (K, Na, etc.)
  - z is the molar ratio SiO_2/Al_2O_3
  - n is a molar ratio M/Al
  - w is water molar amount ($H_2O/(SiO_2+Al_2O_3)$)

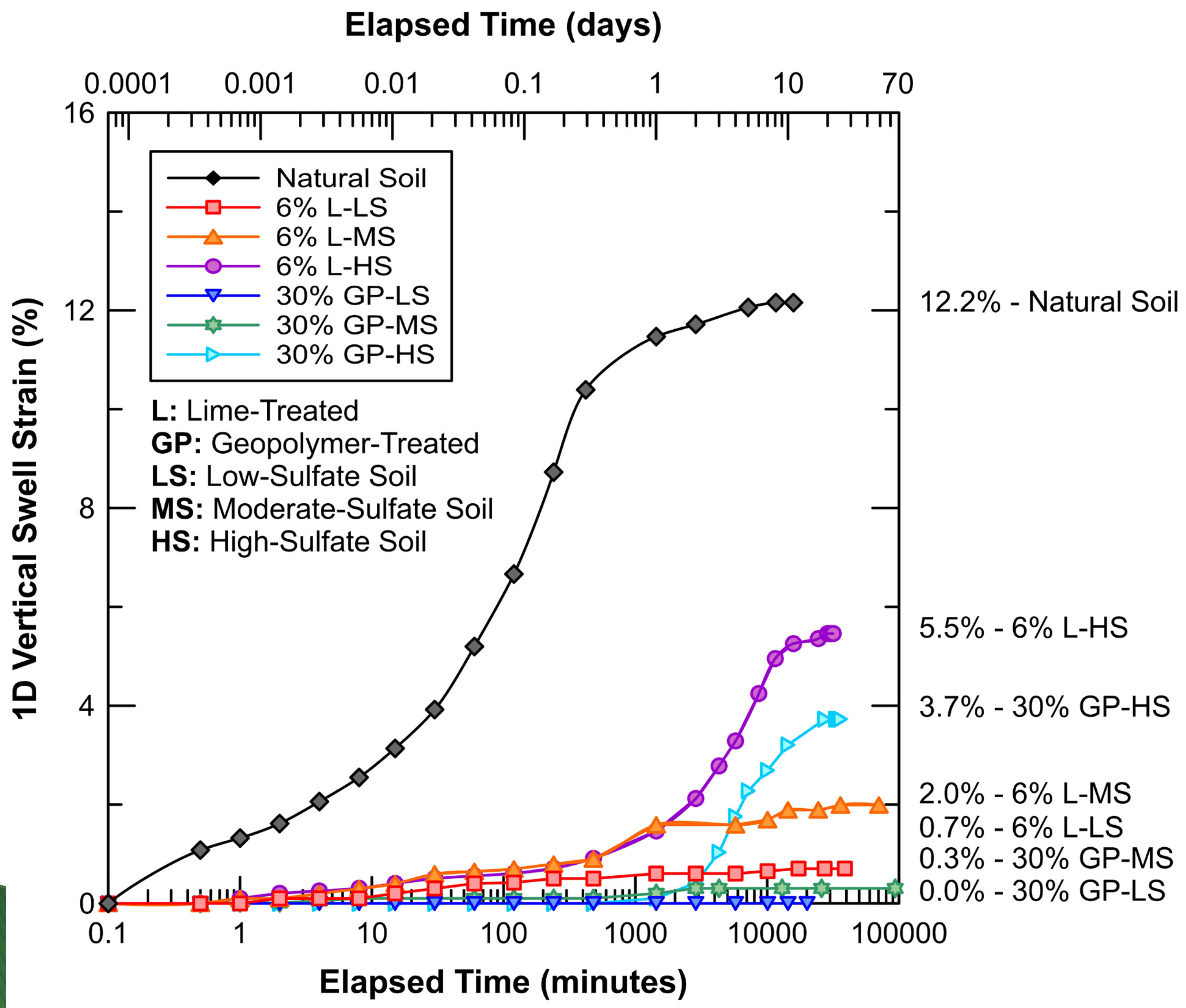
- Utilization of metakaolin as a pure source of aluminosilicate for better control of different parameters

- Instead of fly ash which is inconsistent and becoming more expensive



Test Results: Swell Test

Lime-Treated High-Sulfate Soil with Metakaolin-based Geopolymer



- **Immediate swelling**
  - **Natural soil → Clay mineral swelling**
  - **Lime and GP treatment reduced clay mineral swelling**
- **Swelling after 1 day of soaking**
  - **Ettringite-induced swelling in lime-treated high-sulfate soil**
  - **Swelling after GP-treatment < lime treatment**

Metakaolin-based Geopolymer is effective in reducing sulfate heaving

Future Studies

- **Exploring collaborating opportunities with University of Miami researchers**
- **Unsaturated behavior and other remaining engineering tests**
- **Mineralogical and microstructural analyses**
- **Sustainability and resiliency studies**

LIFE FORMS

Project: Mitigating Sulfate Heaving Using Novel Admixtures

Number: 4