Center for Integration of Composites into Infrastructure

Application of Geofoam in Thermal Encapsulation of Foundations

Project (Leader): Surya Sarat Chandra Congress
Associate Research Scientist

Team: Amit Gajurel, Doctoral Student

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

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NSF IUCRC CICI - IAB Spring 2020 Virtual Meeting

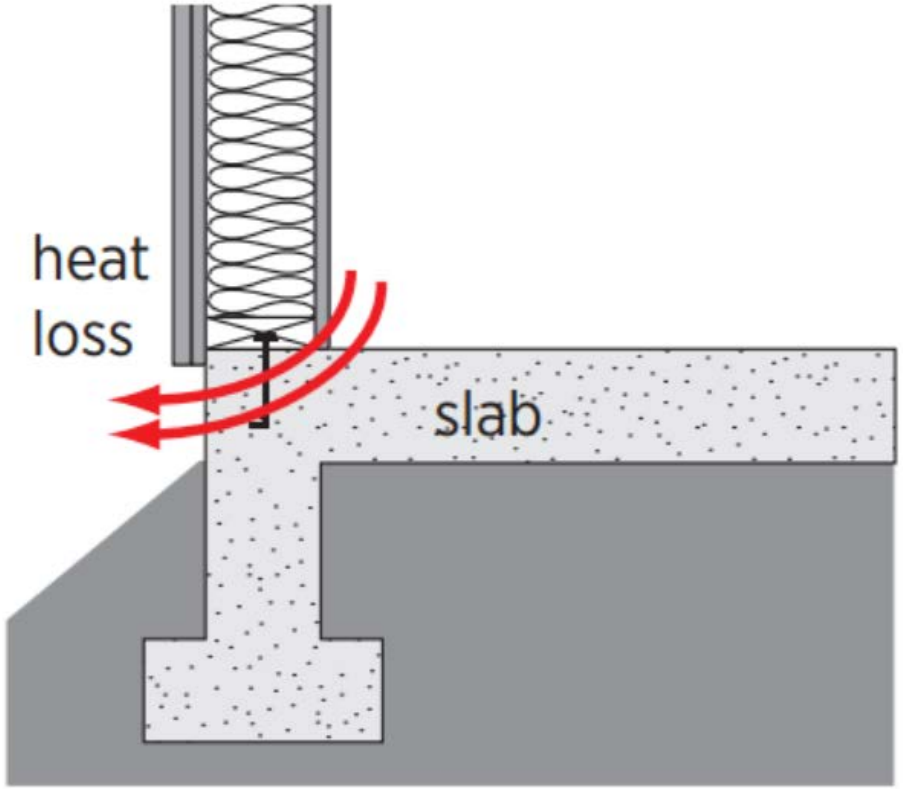
June 16, 2020

ThermaFoam LLC

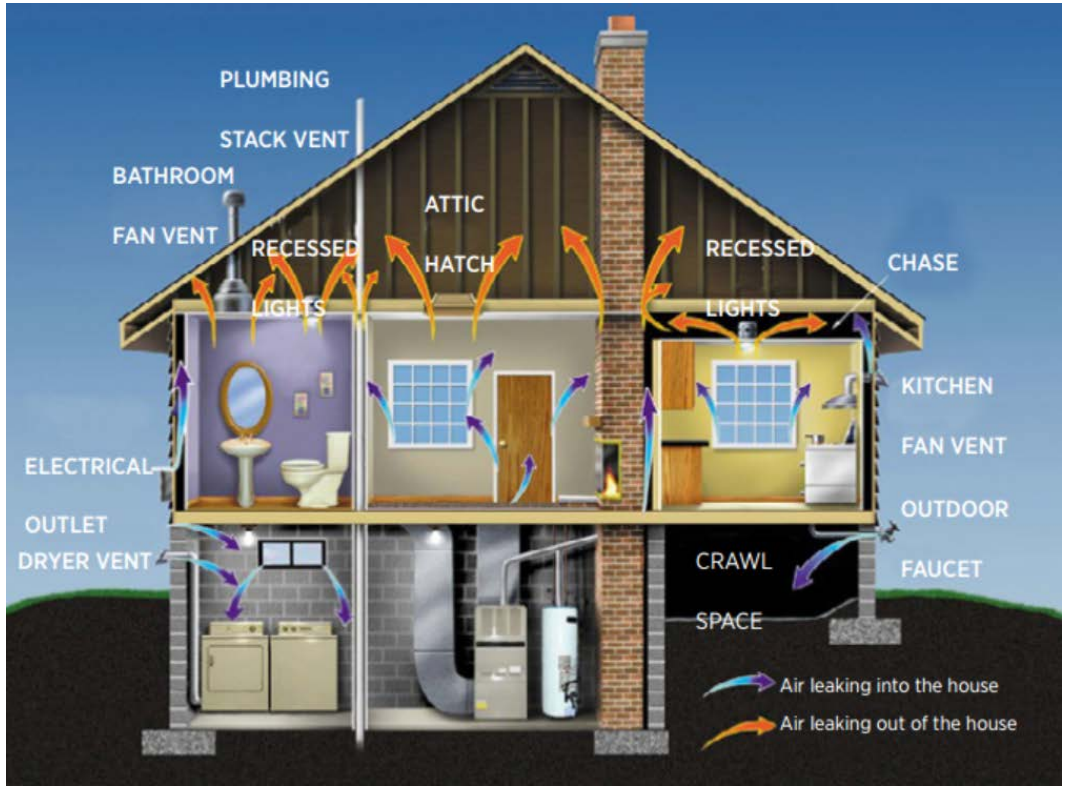
TEXAS A&M UNIVERSITY
Zachry Department of Civil & Environmental Engineering

Requirement for Thermal Insulation

❖ **Study:** Effect of insulating the foundations using Geofoam



Heat loss

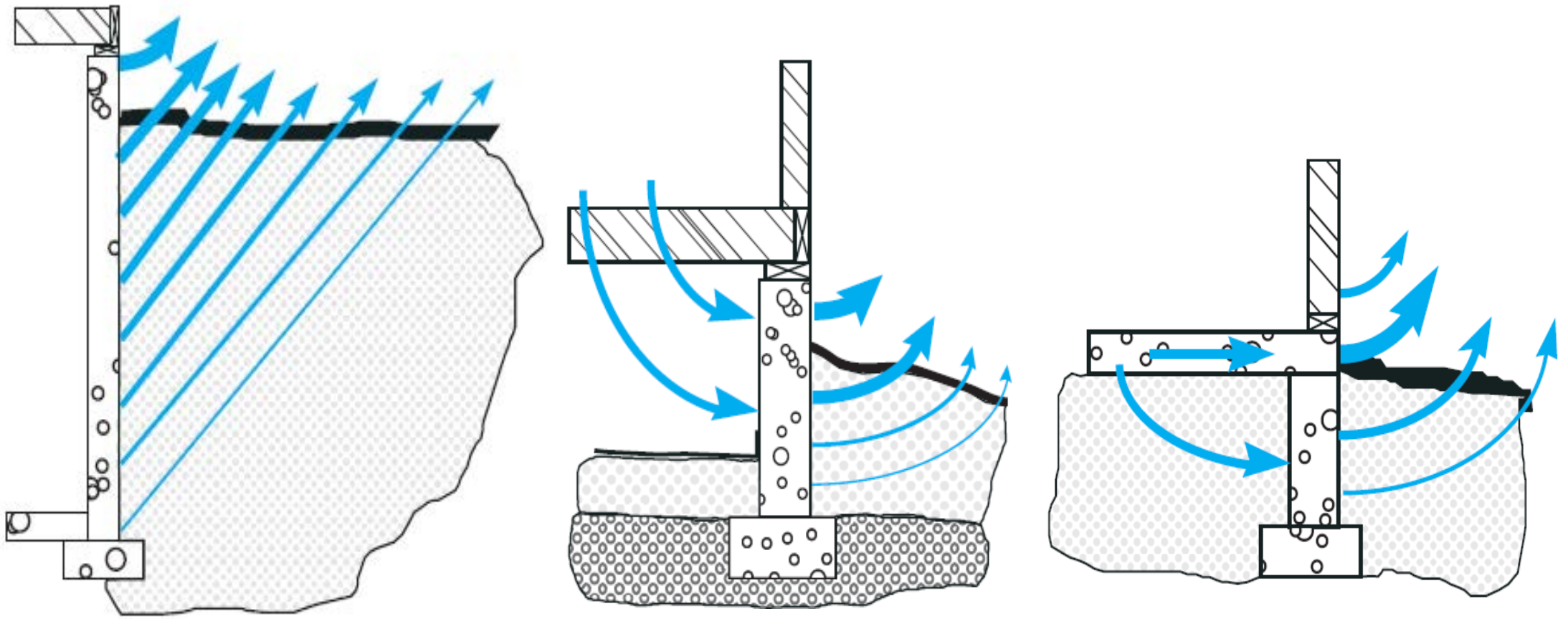


The stack effect

- Concrete slabs primarily lose heat outward and through the edge of the slab
- In cold climates, insulating the slab perimeter can **reduce** heating bills by **upto 20%**

Source: EPA, US DOE (2011, 2012)

Heat Loss through Foundation

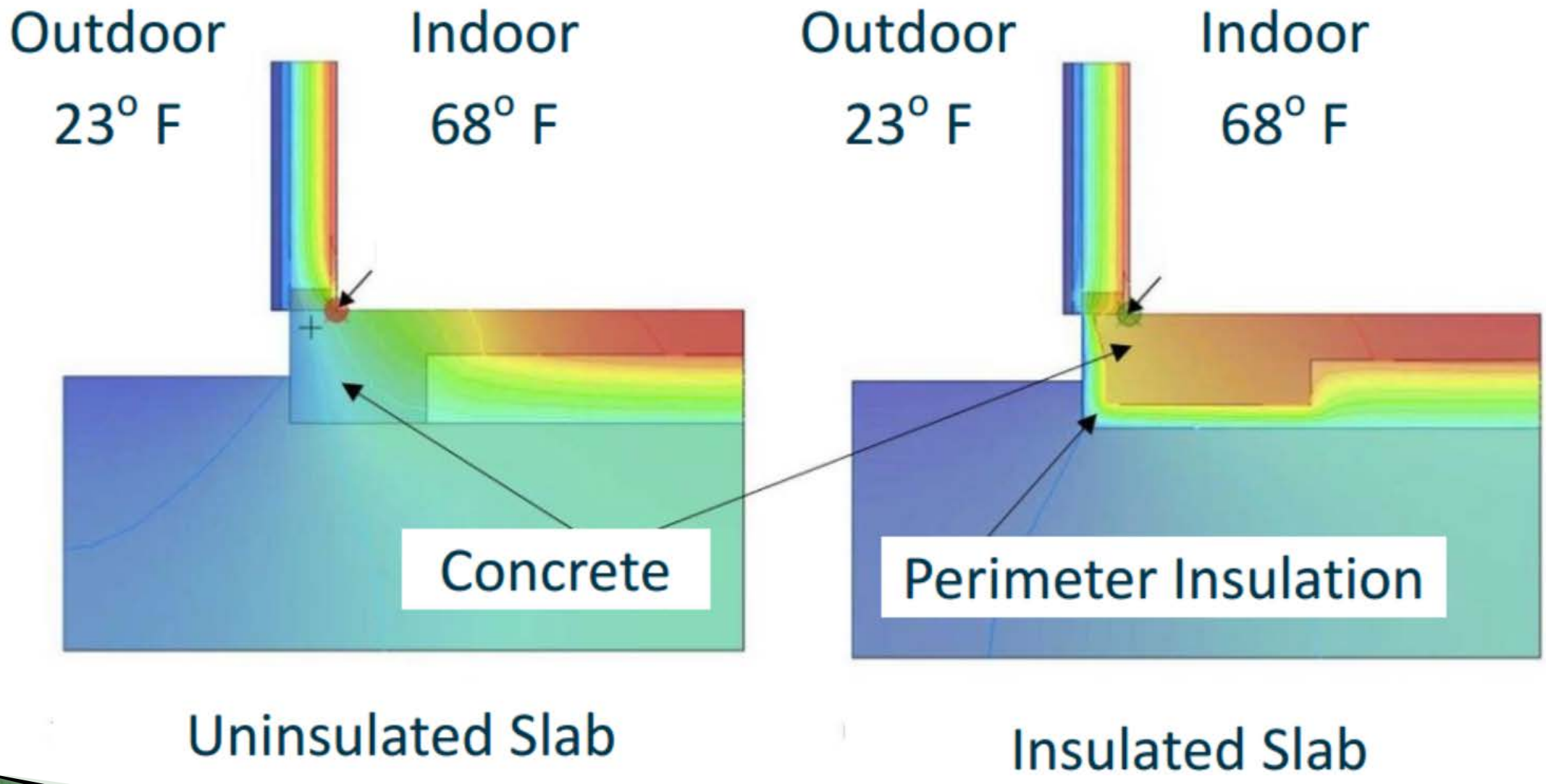


(a) (b) (c)

Types of foundation and heat loss for residential dwellings (a) full basement; (b) crawl space; and (c) slab-on grade

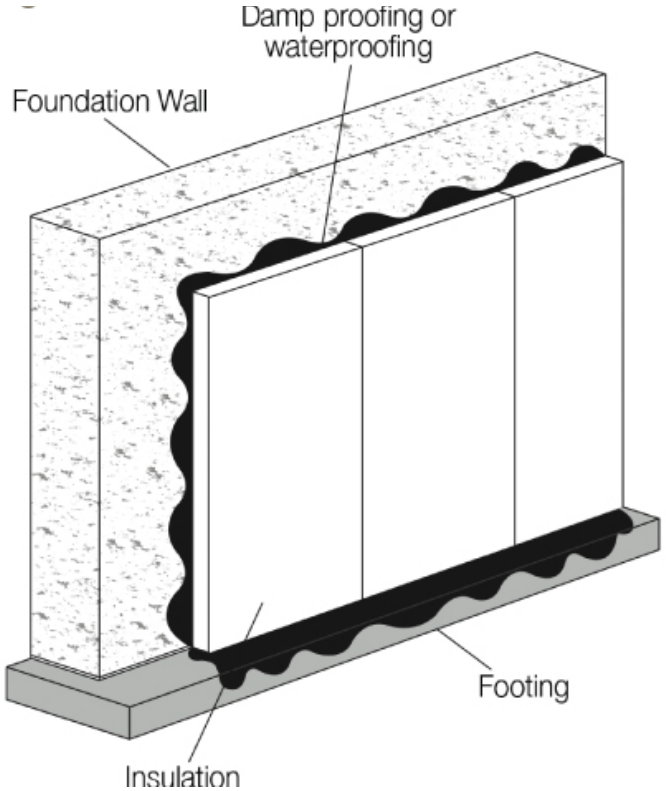
Source: Labs et al. (1988)

Why is Slab Perimeter Insulation Important?



Source: US DOE

Thermal Encapsulation using Geofoam



- Good Insulation Properties
- Cost-effective dwelling
- Substantial energy savings

- Construction Friendly
- Limited Water Absorption
- Being Inert in Long-term Buried Conditions

Source: ACH Foam (2011) (Left)
ConstructionSpecifier
(2013) (Middle)
Insulfoam (2014) (Right)

Research Plan: Thermal Encapsulation using Geofoam

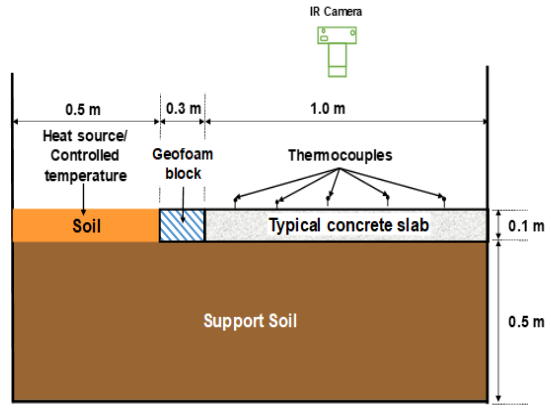
- **Study:** Effect of insulating the foundations using Geofoam
- **Problem Identification: No Insulation of Foundations**
  - Summer: Hot climate → Hot air enters through gaps & heat enters by conduction
  - Winter: Cold climate → Cold air enters through gaps & heat escapes by conduction
  - Thermal conductivity of soil is 40-50 times higher than that of air
- **Small Scale Building Models in Region 3 climate**
  - Lab scale study: Foundation wall insulation solutions using Geofoam
- **Temperature Monitoring**
  - Infrared (IR) imaging - Monitor temperature variation and potential leakages
  - Comparison with control section
- **Potential Outcomes:** Guidelines for insulation using Geofoam

Research Plan: Thermal Encapsulation using Geofoam

Lab Scale Study Prototypes

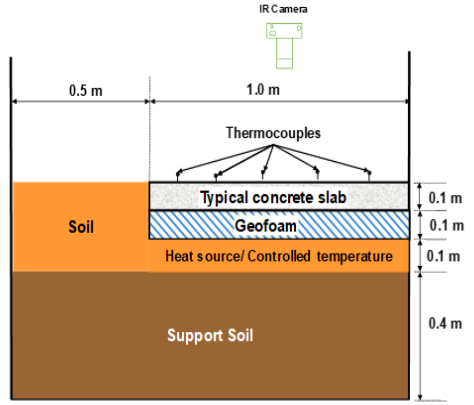
- Geofoam blocks attached around the periphery of foundation ~ at grade foundation systems (GAF system)
- Geofoam slab placed underneath the foundation system ~ crawl-space foundation systems (GBF system)

Laboratory Setup I: Thermal Encapsulation using Geofoam



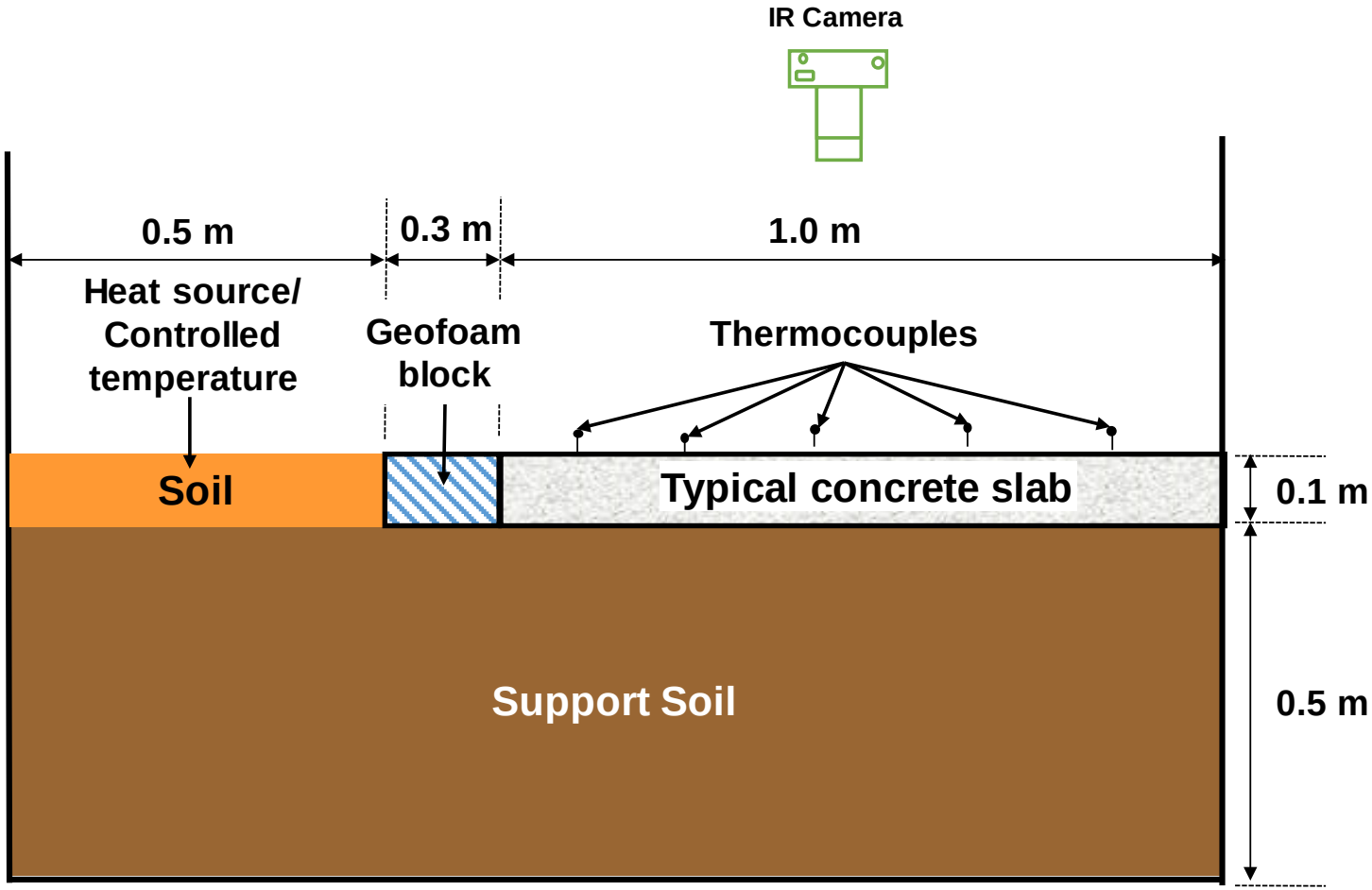
Laboratory setup to evaluate the performance of GAF slab

Laboratory Setup II: Thermal Encapsulation using Geofoam



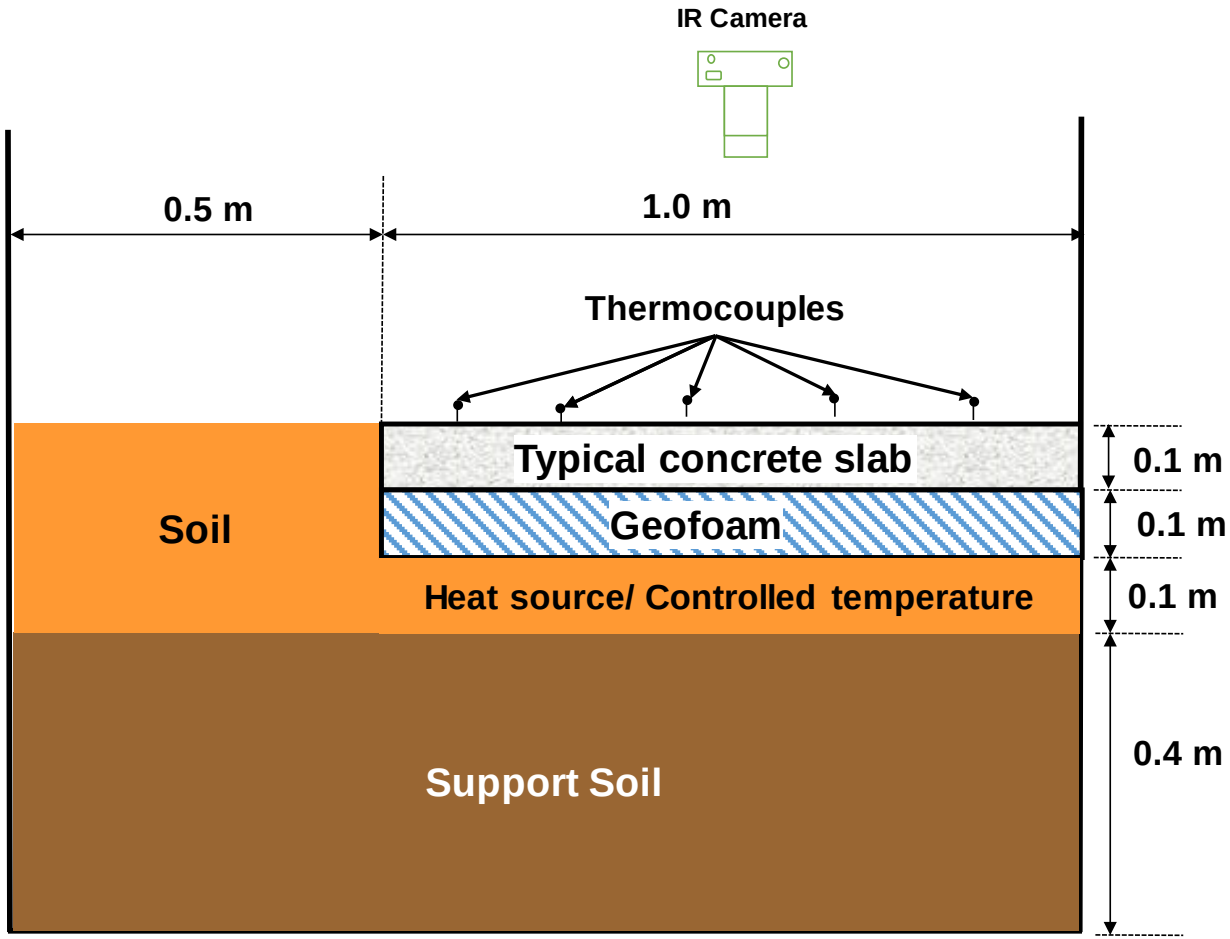
Laboratory setup to evaluate the performance of GBF slab

Laboratory Setup I: Thermal Encapsulation using Geofoam



Laboratory setup to evaluate the performance of GAF slab

Laboratory Setup II: Thermal Encapsulation using Geofoam



Laboratory setup to evaluate the performance of GBF slab

LIFE FORMS

Project: Application of Geofoam in Thermal Encapsulation of Foundations

Number: 1

Center for Integration of Composites into Infrastructure

Utilization of Geocells in Pavement Infrastructure

Graduate Student: Md Ashrafuzzaman Khan

Team: Sayantan Chakraborty & 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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Outline of the Presentation

- Introduction
  - Background
  - Objective
- Field Study
  - Design and Analysis of Test Sections
  - Construction
  - Instrumentation and Data Analysis
  - Monitoring Results
- Future Study

January 2018

November 2018

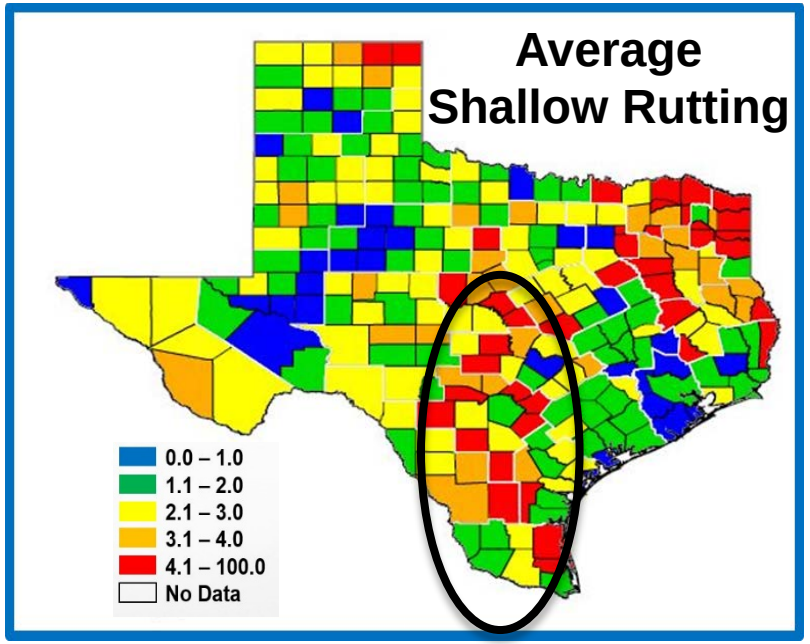
December 2018

May 2020

Introduction

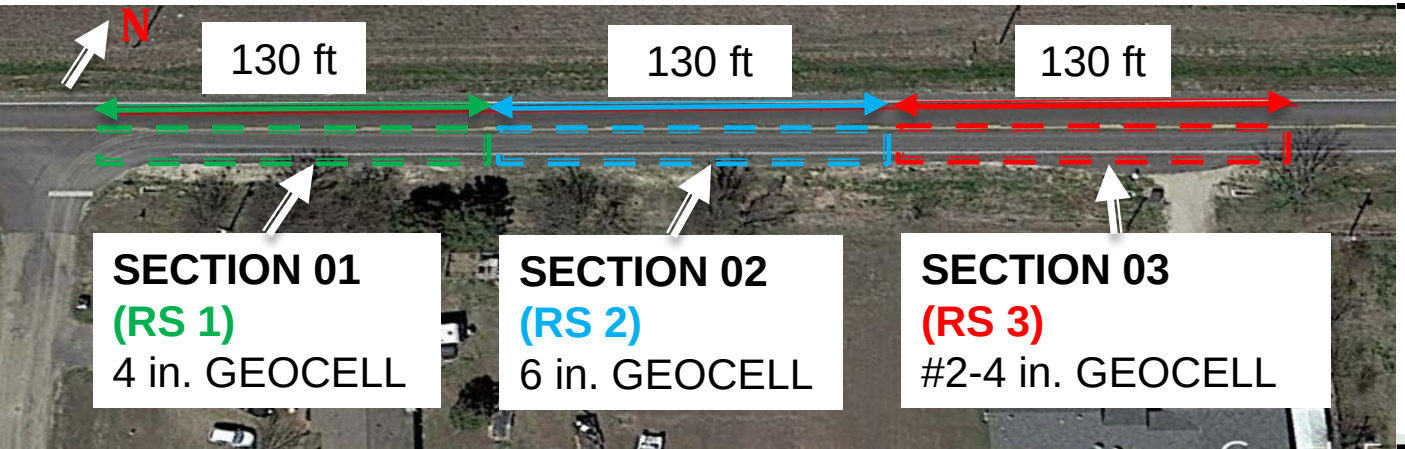
Background

- Majority of the FM roads in North Texas suffer from rutting and crackings
- Recycled materials may provide sustainable solutions
- 102.11 million tons of RAP (NAPA, 2018)
- Need a solution to enhance the performance of RAP



Objective

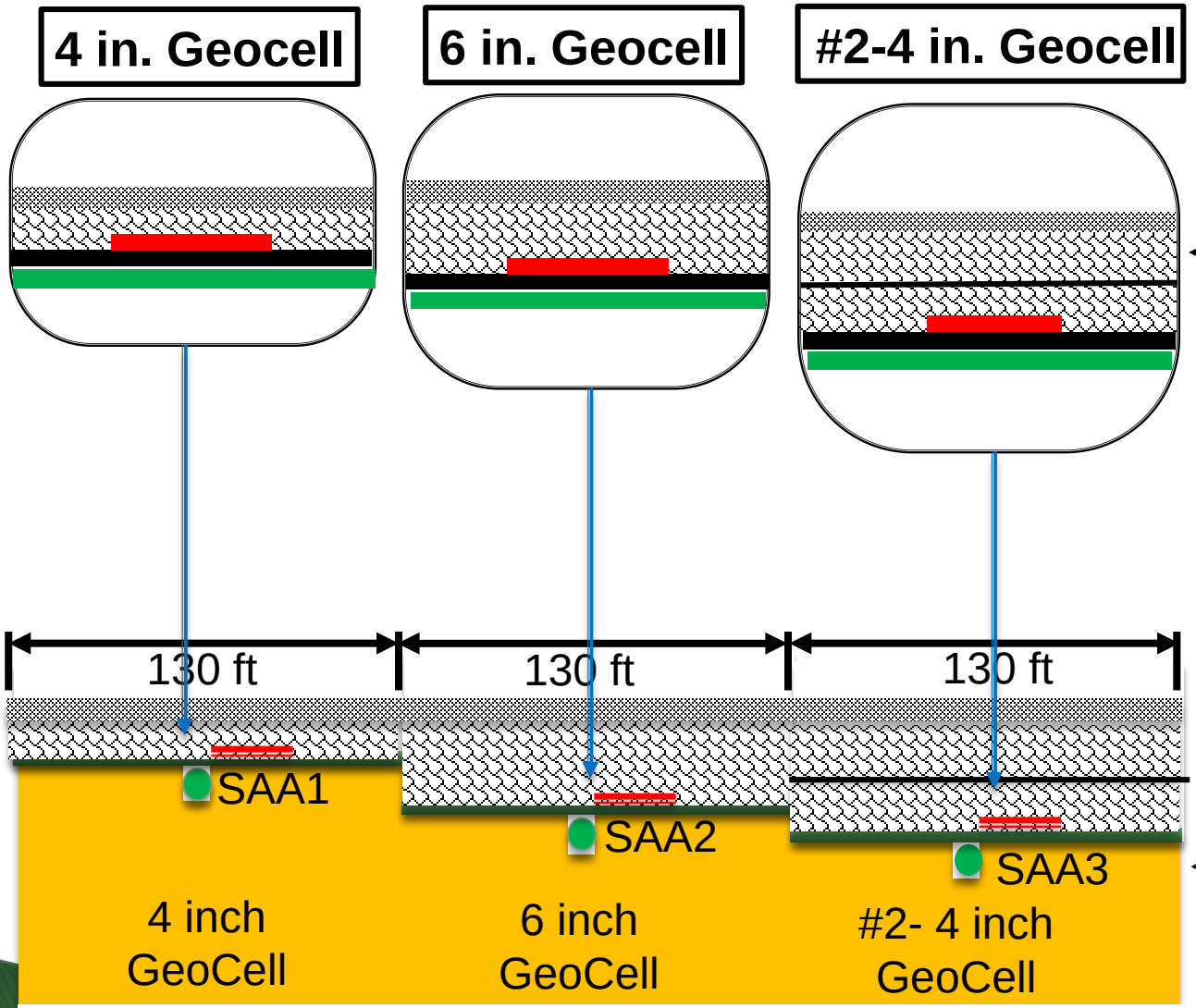
Performance assessment of test sections with geocell-reinforced-recycled-base (GRRB) layers

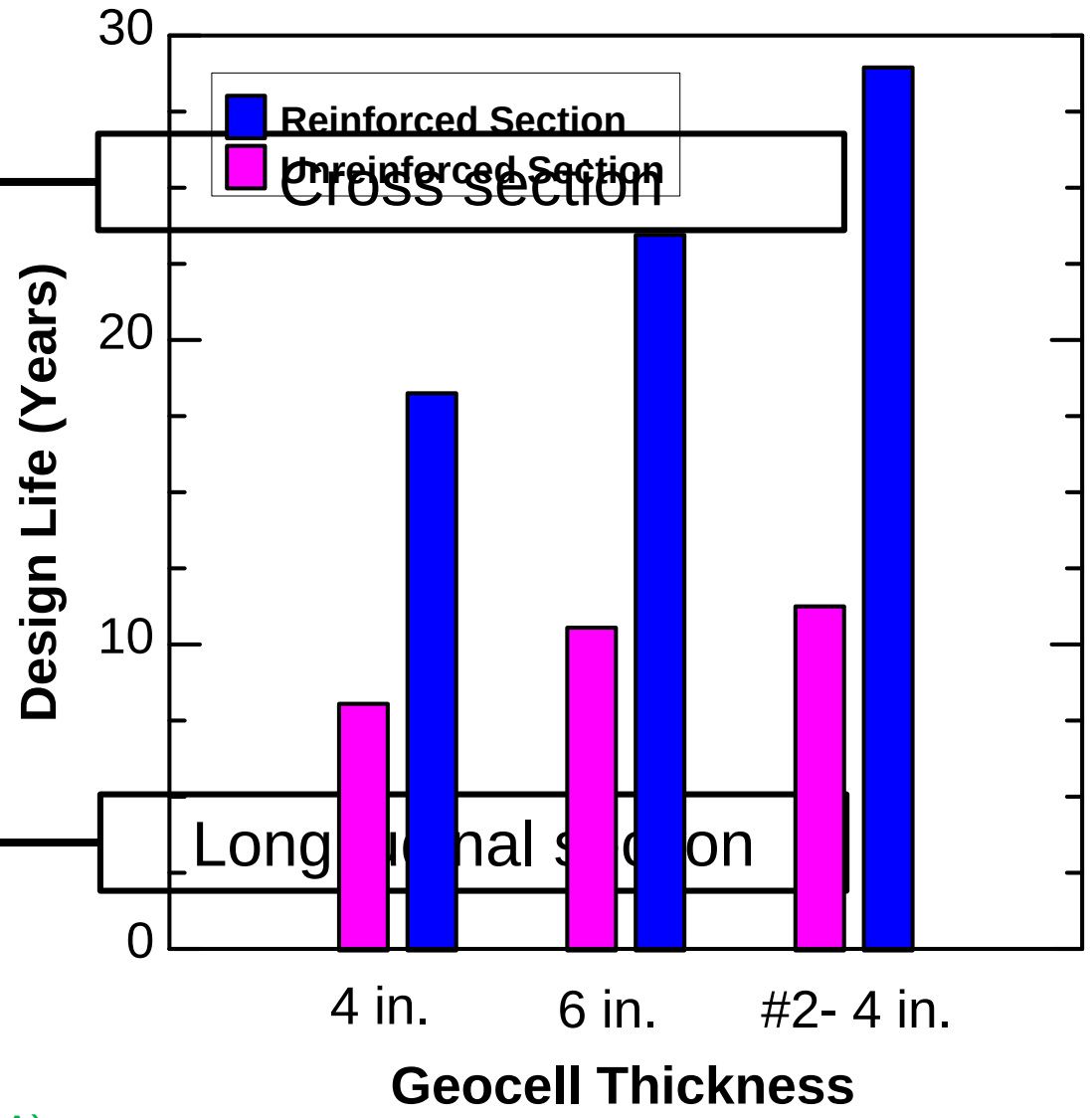


FM 1807
Venus
Texas

RAP Stockpile

Field Study
(Design and Analysis of Test Sections)





Field Study
(Construction of Test Sections)

Milling

Geotextile Installation

Filling Geocell with RAP

Spreading RAP

Scrapping

Compaction

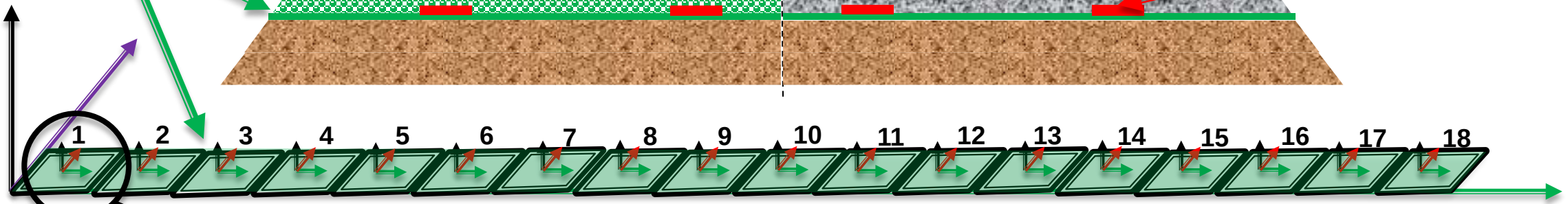
Field Study
(Instrumentation and Data Analysis)

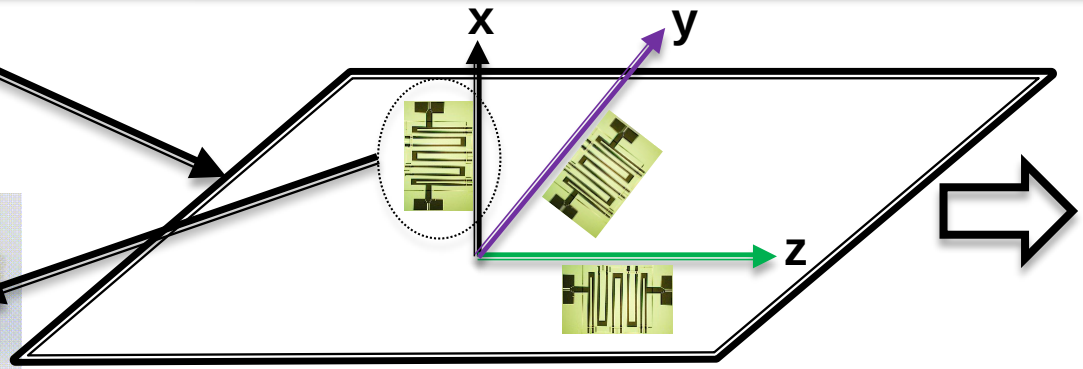
Shape Array Accelerometers (18 segments)

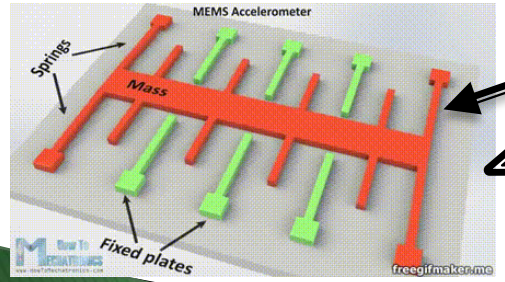
Reinforced lane (Eastbound)

Unreinforced lane/Control (Westbound)

Earth Pressure Cells Placed at the bottom of base layer







Howtomechatronics.com

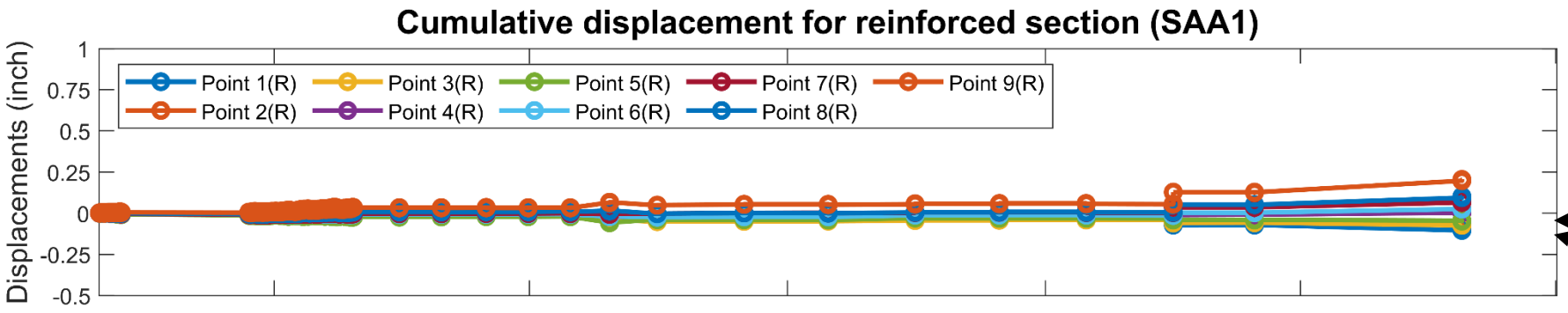
CR800 datalogger collects acceleration data for any time interval

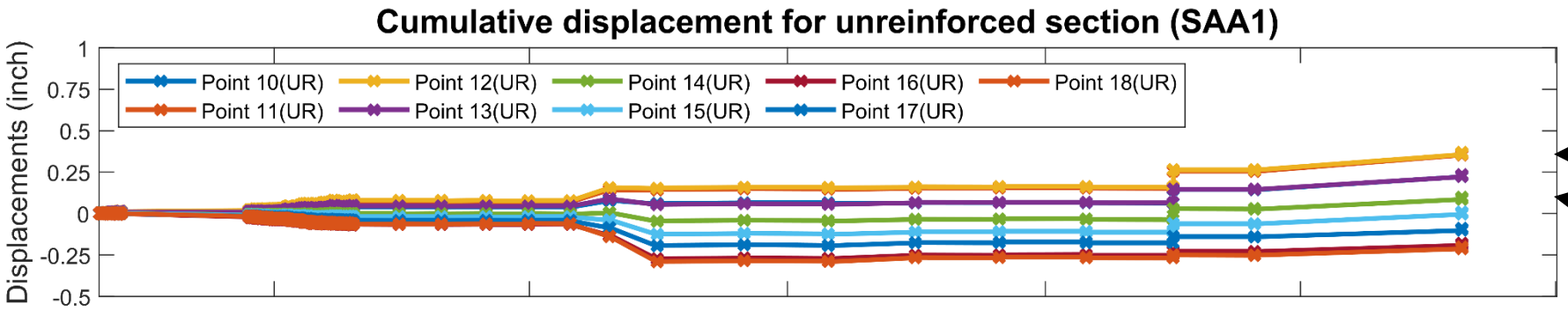
Acceleration in x dir.: a_x
Acceleration in y dir.: a_y
Acceleration in z dir.: a_z

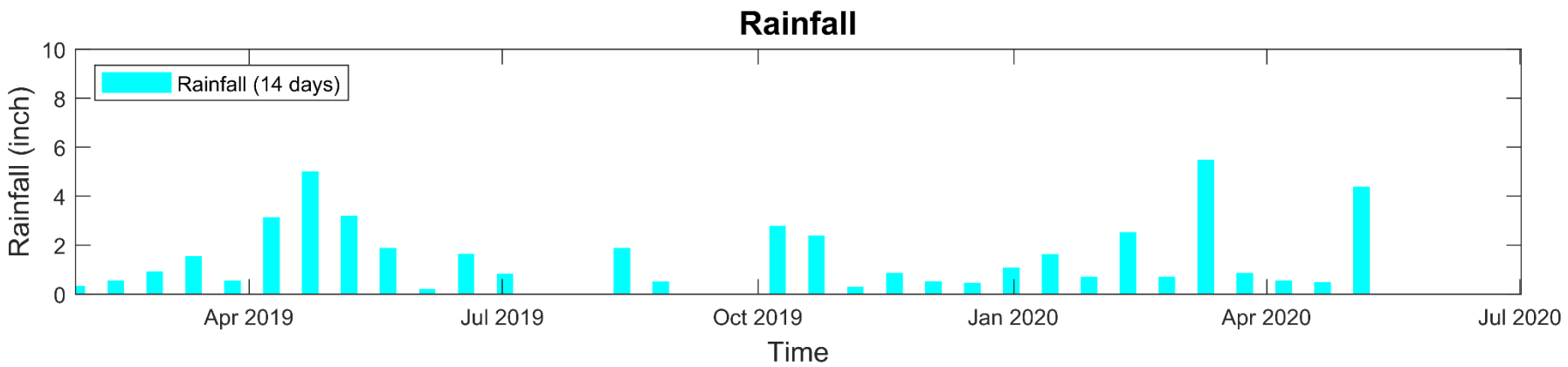
MATLAB Code

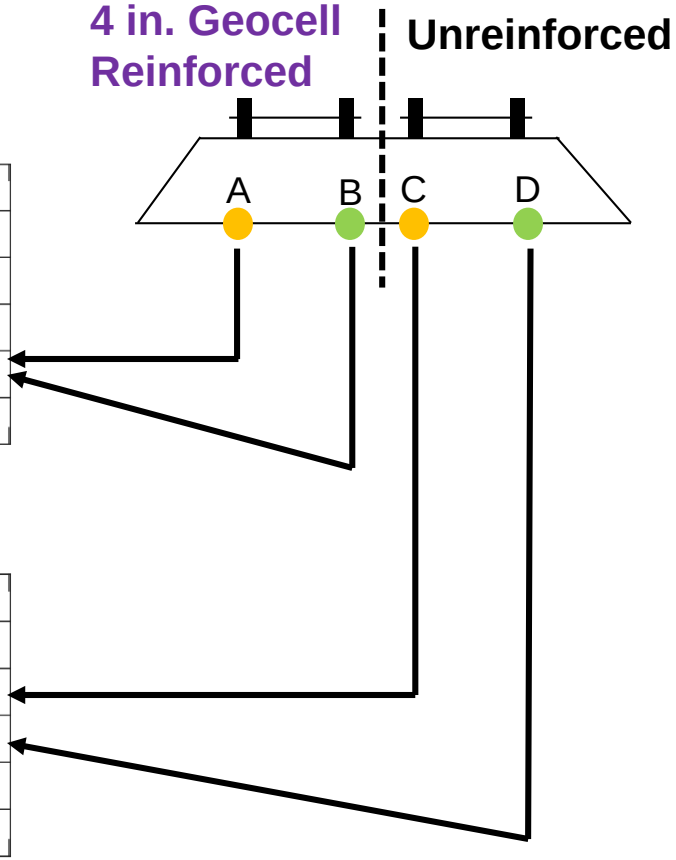
Vertical deformations

Field Study
(Monitoring Results)

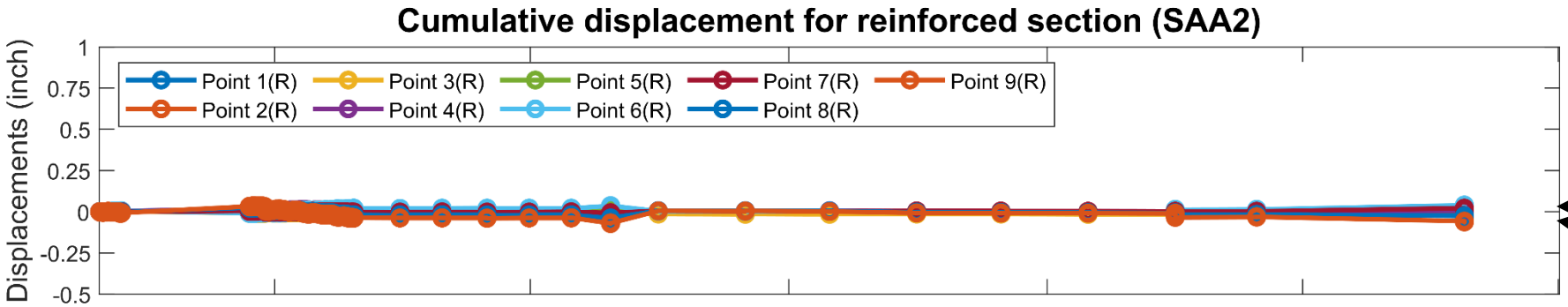


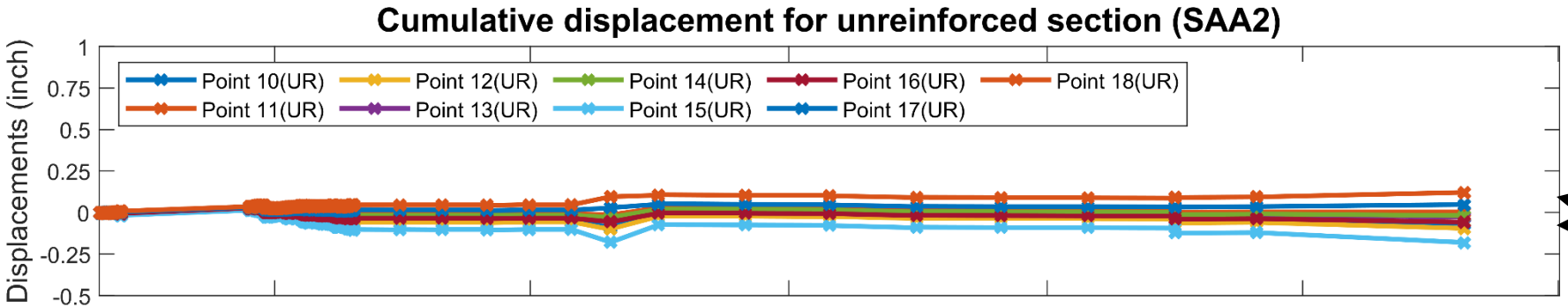


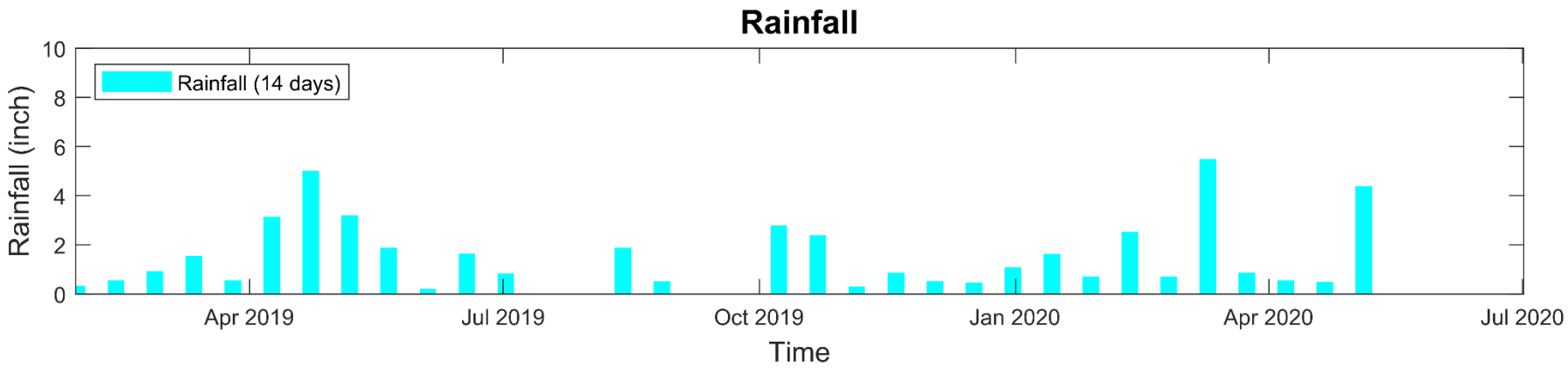


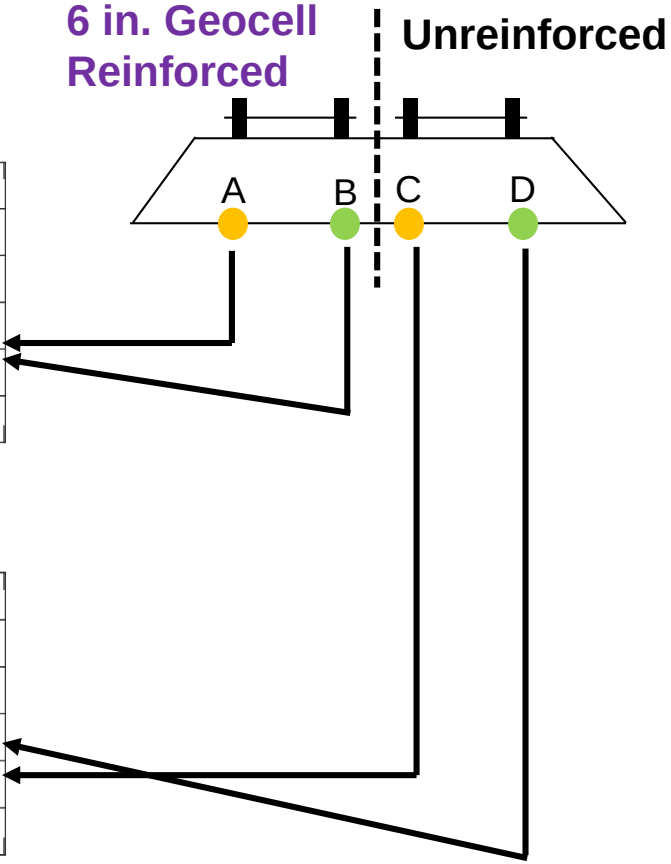


Field Study
(Monitoring Results)

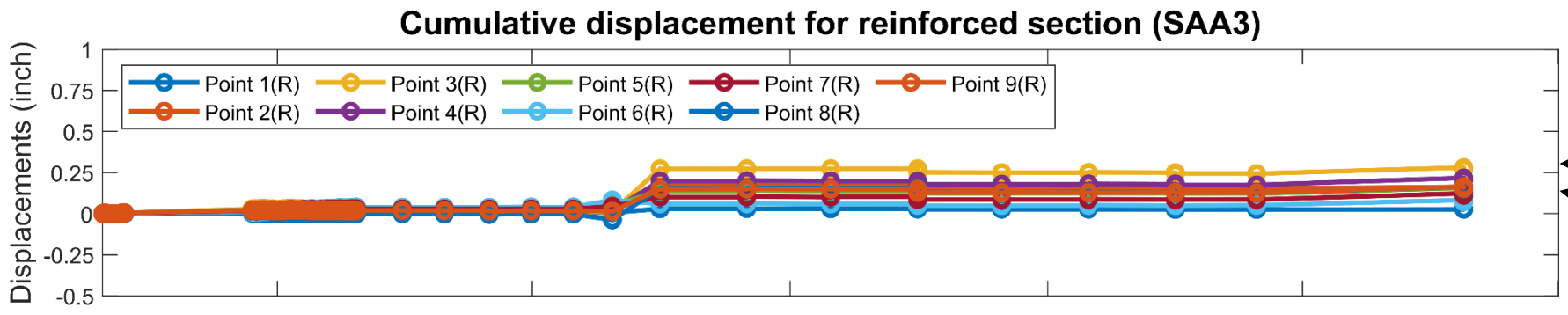


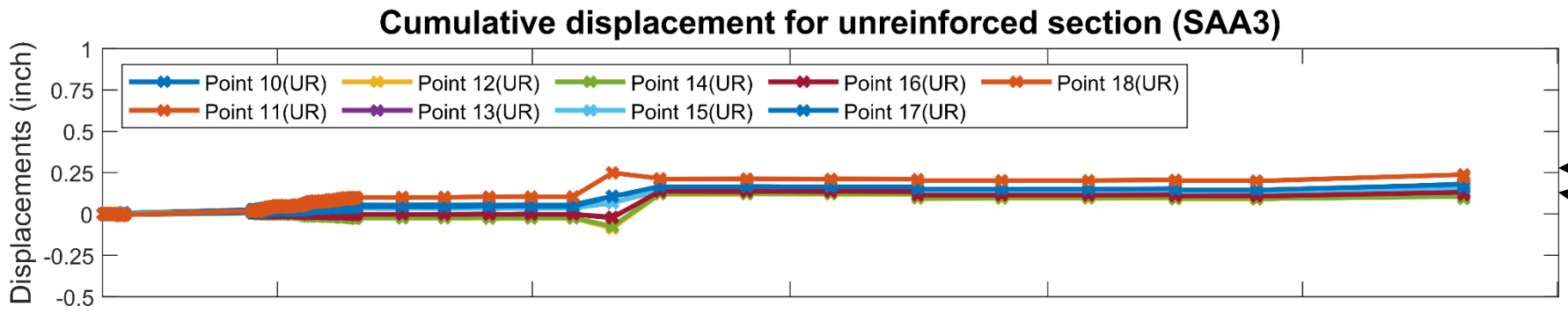


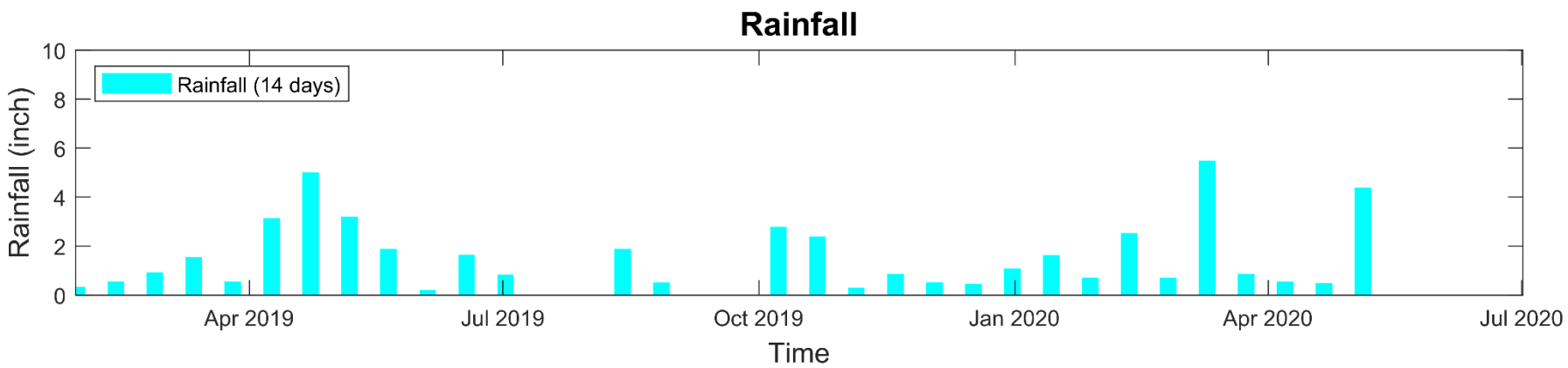


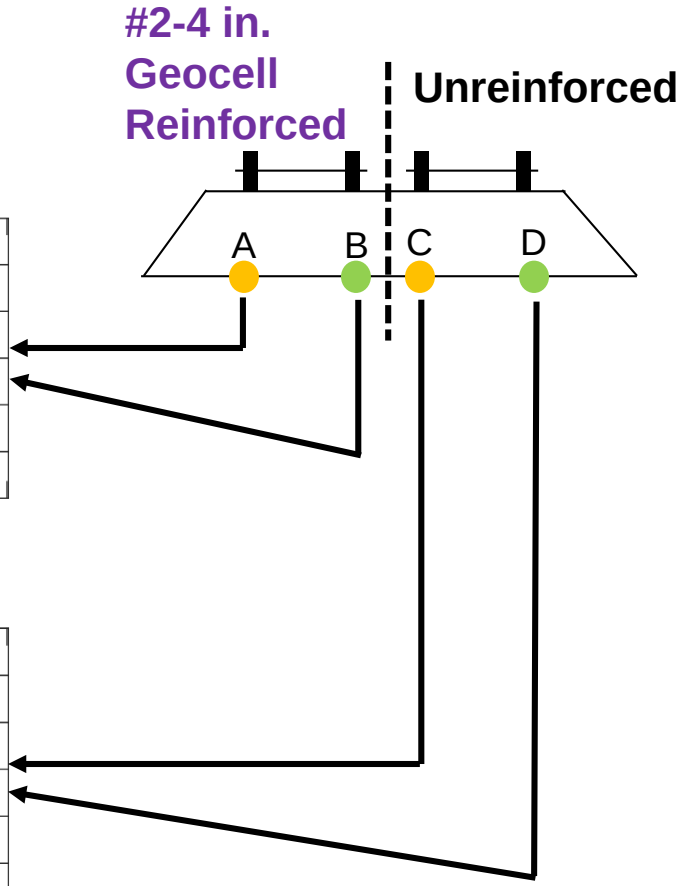


Field Study
(Monitoring Results)

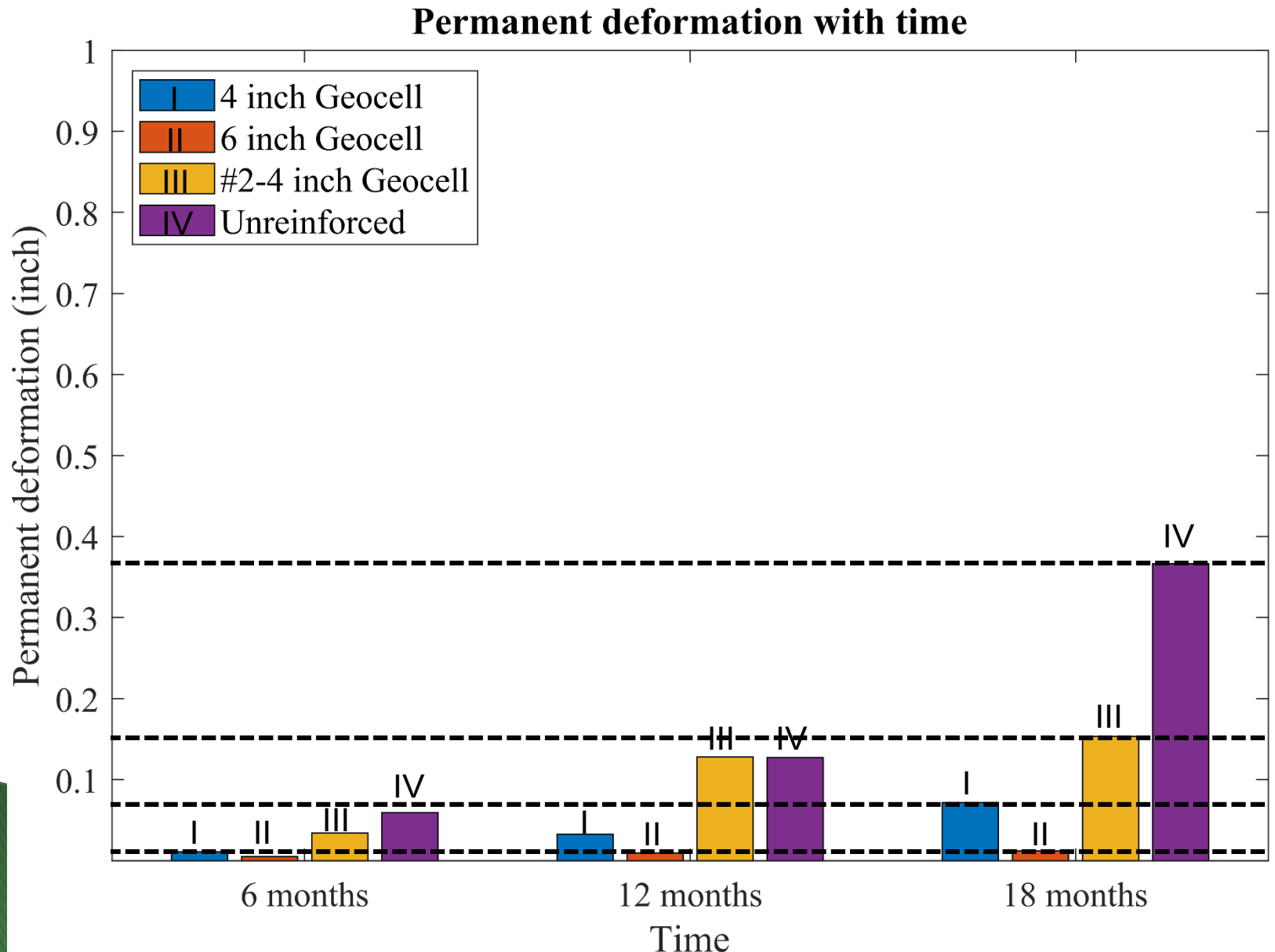








Field Study
(Summary)

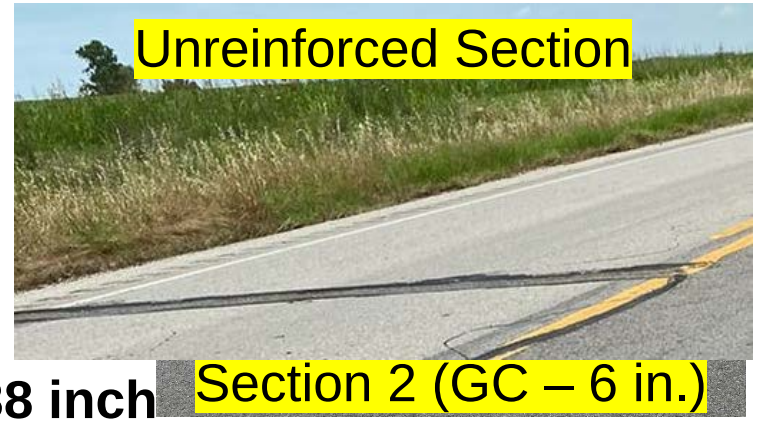


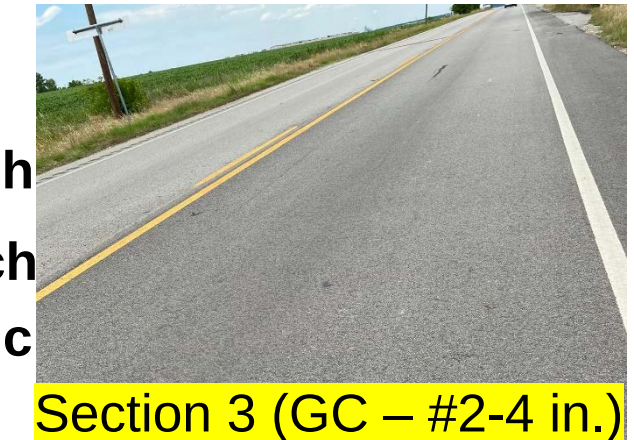
0.38 inch

0.15 inch

0.07 inch

<0.02 inc





Project Duration and Deliverables

Return on Investment (ROI):

With the development of design and construction guidelines for pavements with Geocell supported RAP Base, we anticipate the pavements to be sustainable, resilient and have low magnitude of distress during their service life

The project is currently in the second year of monitoring phase

Deliverables:

A Comprehensive project report will be submitted at the end of the project period

Future Study

- **Current Requirement: Combination of geosynthetic products to meet the design criteria for the foundations constructed over soft soil conditions**
- **Potential Solution: Combination of two geosynthetic products**
  - **Conjunction of Geocomposite with Geocell - Enhances the load-bearing capacity**
- **Aim of the Study: Determine the bearing capacity improvement factors and calibrate the design methodology**
- **Parametric Study: Influence of Geocomposite and Geocell**
  - **Different compositions - Laboratory testing**
- **Possible Outcome: Guidelines for the design of different foundation systems (roads, railways and foundation pads for crane)**

LIFE FORMS

Project: **Utilization of Geocells in Pavement Infrastructure**

Number: **2**

Center for Integration of Composites into Infrastructure

Performance of pavement sections with H_2Ri geosynthetics

Graduate Student: Nripojyoti Biswas

Team member: Md Ashrafuzzaman Khan, Sayantan Chakraborty, and Surya S. C. Congress

PI: Anand J. Puppala

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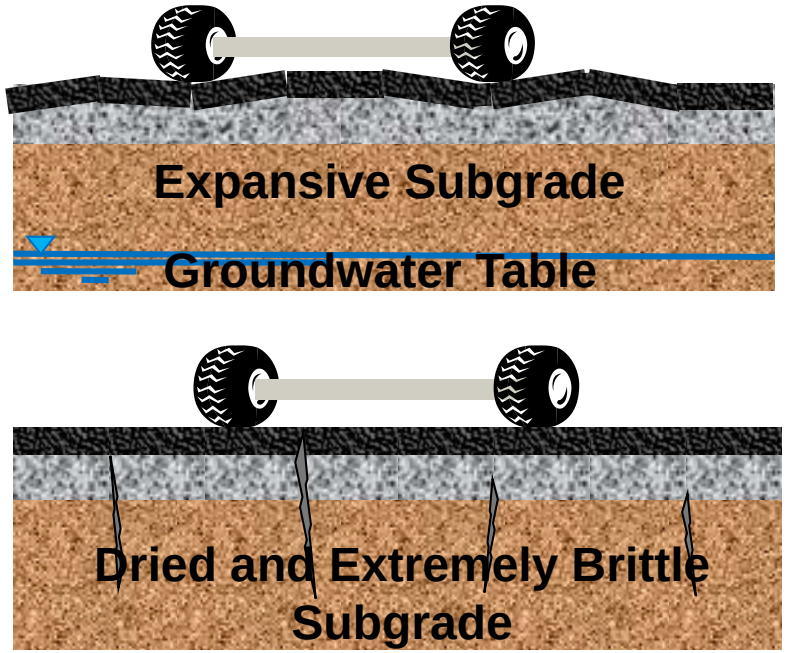
Introduction

❖ Expansive soil issues

- ❑ Pavement failure on expansive soil
  - ➢ Moisture migration
  - ➢ Swelling-Shrinkage behavior
  - ➢ Differential heaving
  - ➢ Cracking, rutting, depression
- ❑ Annual Maintenance ➔ Expenditures ↑



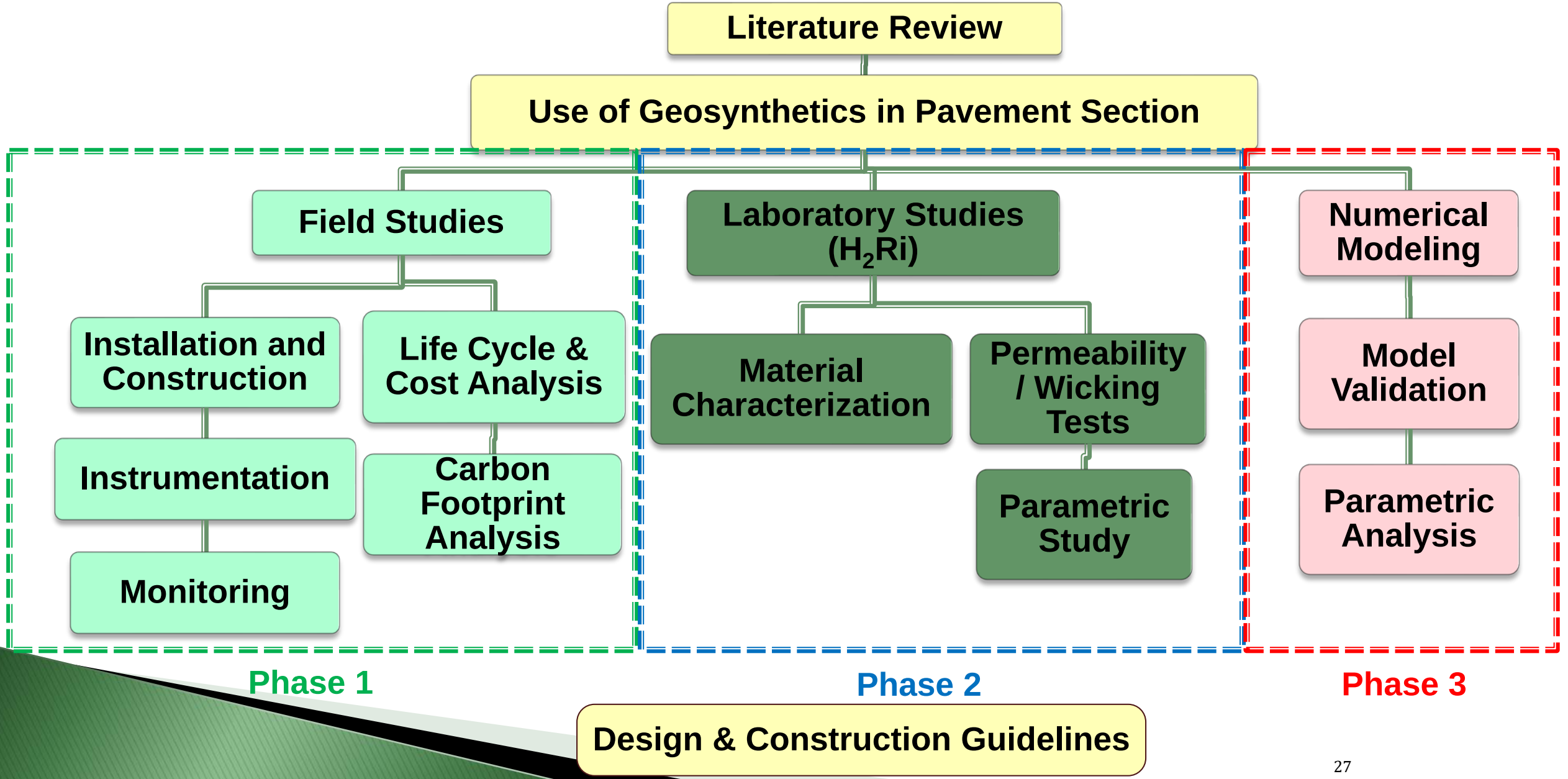
❖ Objective

- ❑ 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

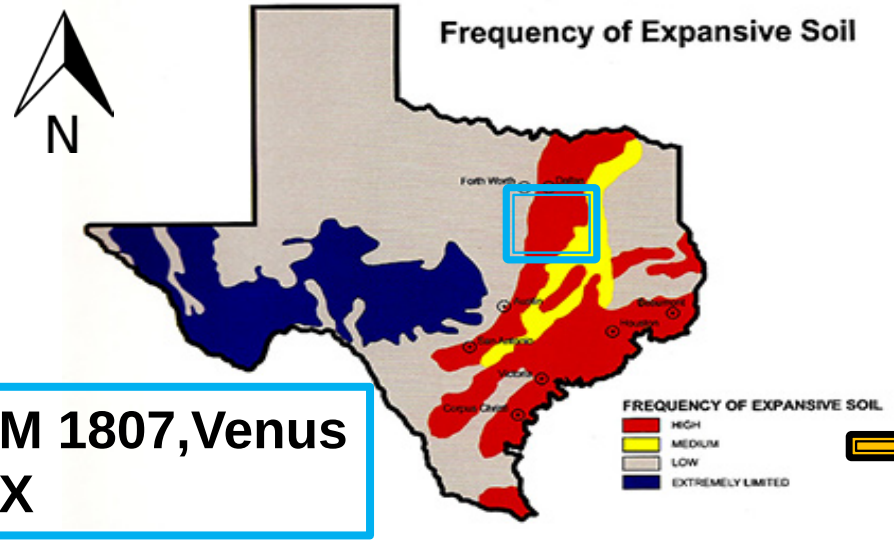
Task Plan

- **Task 1:**
  - **Construction and instrumentation of pavement test sections at FM 1807, Venus, TX - Completed**
- **Task 2:**
  - **Monitor performance of test sections ➔ For 4+ years**
  - **Compare with control section**
- **Task 3:**
  - **Laboratory study and numerical validation**
- **Task 4:**
  - **Design and construction guidelines**
  - **Life Cycle Cost Analysis (LCCA)**

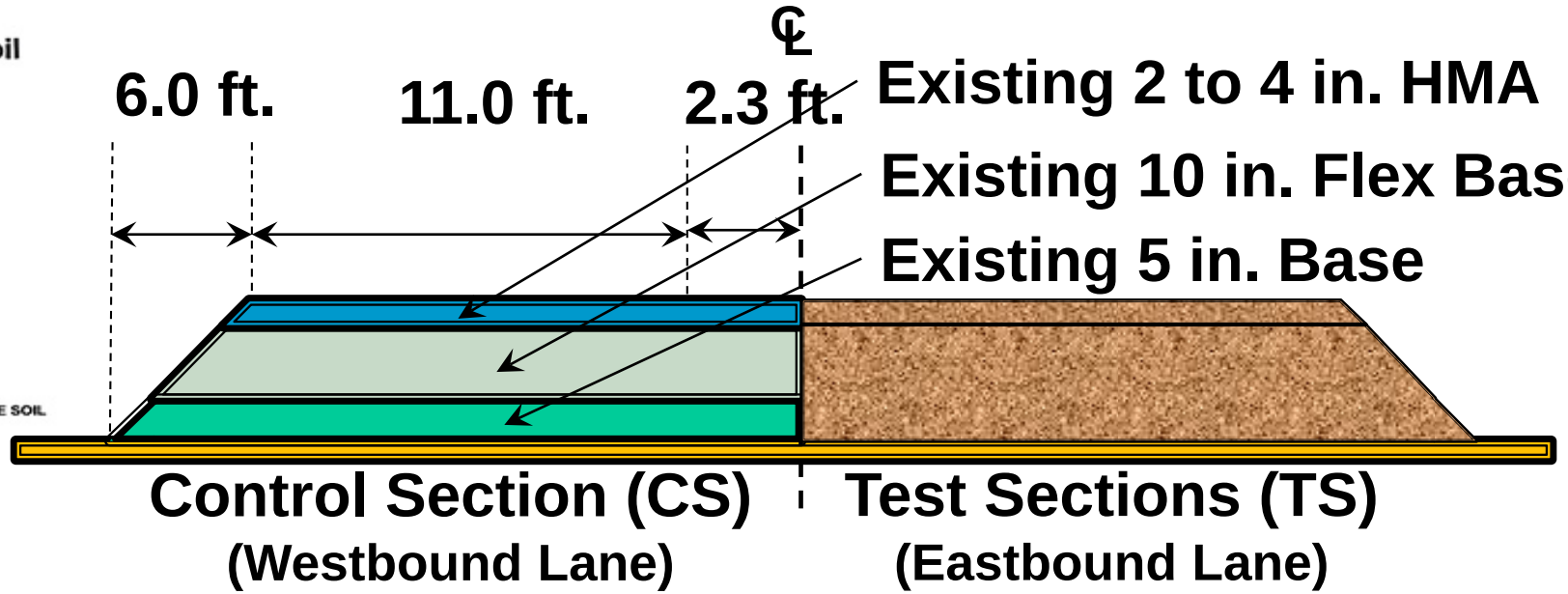
Research Approach



Project Location and Section Details

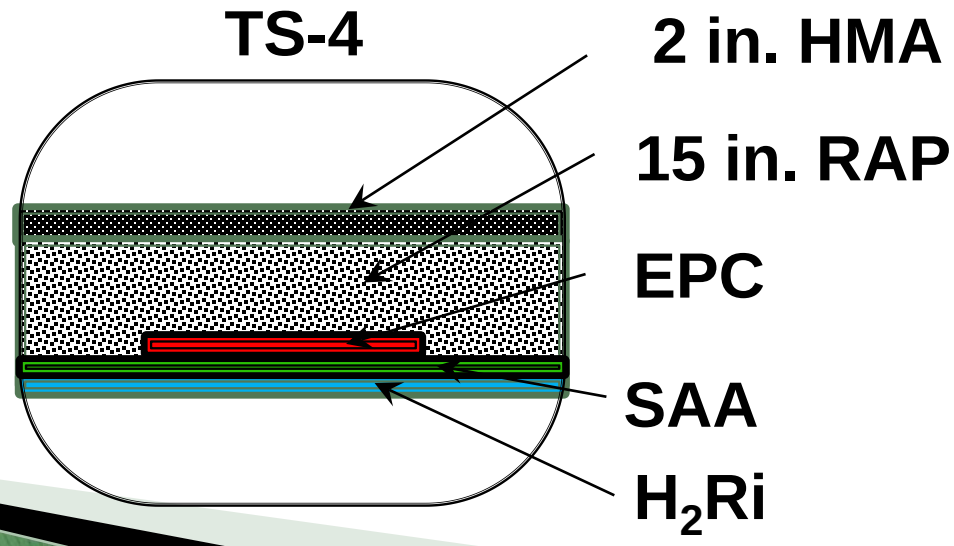


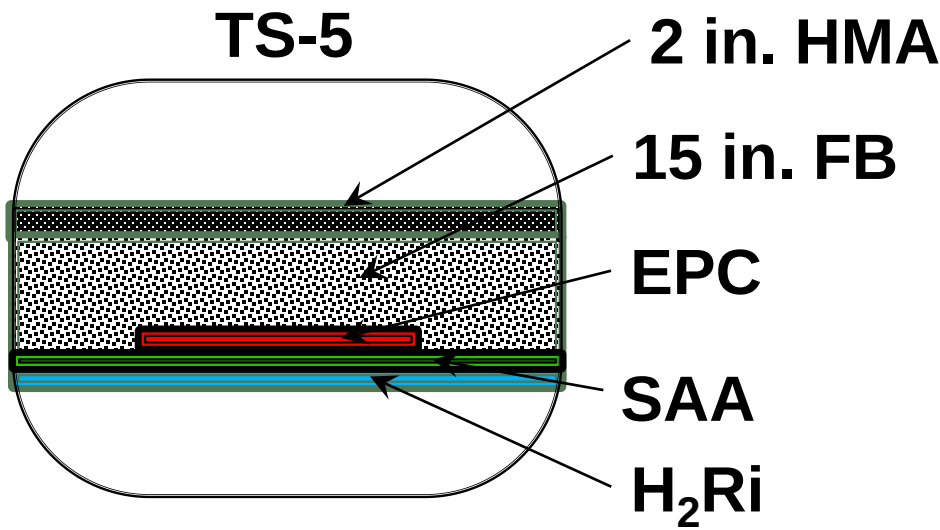
FM 1807,Venus TX



HMA - Hot Mix Asphalt
RAP - Reclaimed Asphalt Pavement Aggregates
FB - Flex Base

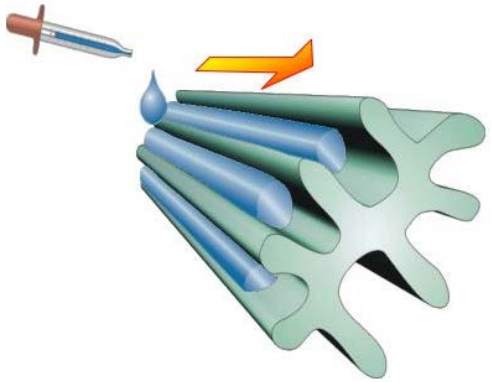
EPC - Earth Pressure Cells
SAA - Shape Array Sensors

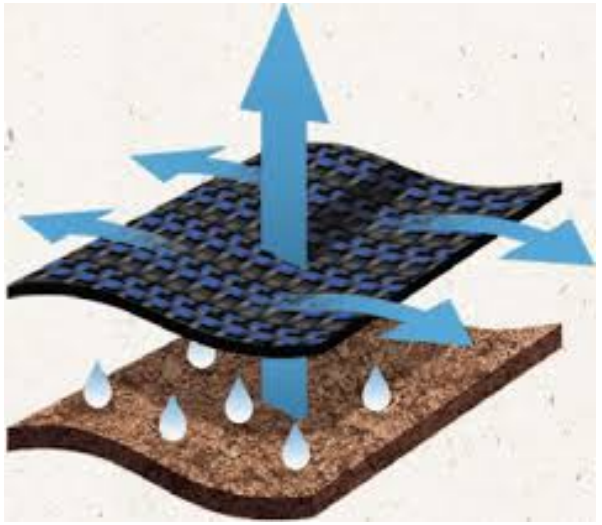




Wicking Geotextile (H_2Ri)

- Made of special hydrophilic and hygroscopic 4DG™ (DG-Deep Groove) fibers
- Single geotextile layer - serves various functions
  - Drainage through capillary action
  - Reinforcement
  - Separation
- Presence of a high number of channels facilitates capillary action





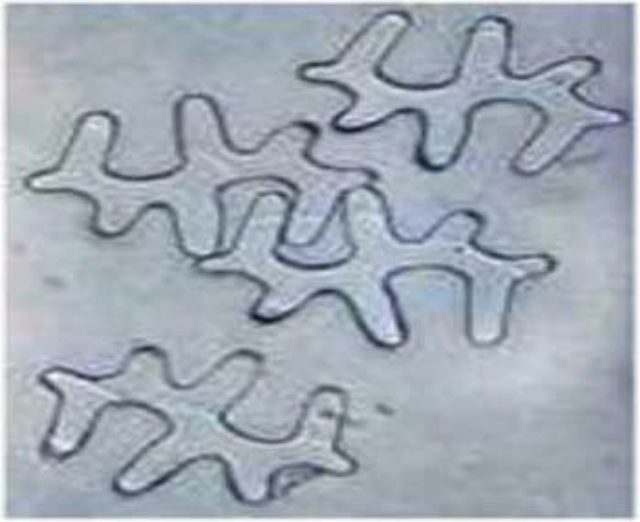


Image-TenCate, Inc.

Construction of Pavement Sections

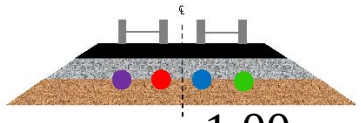




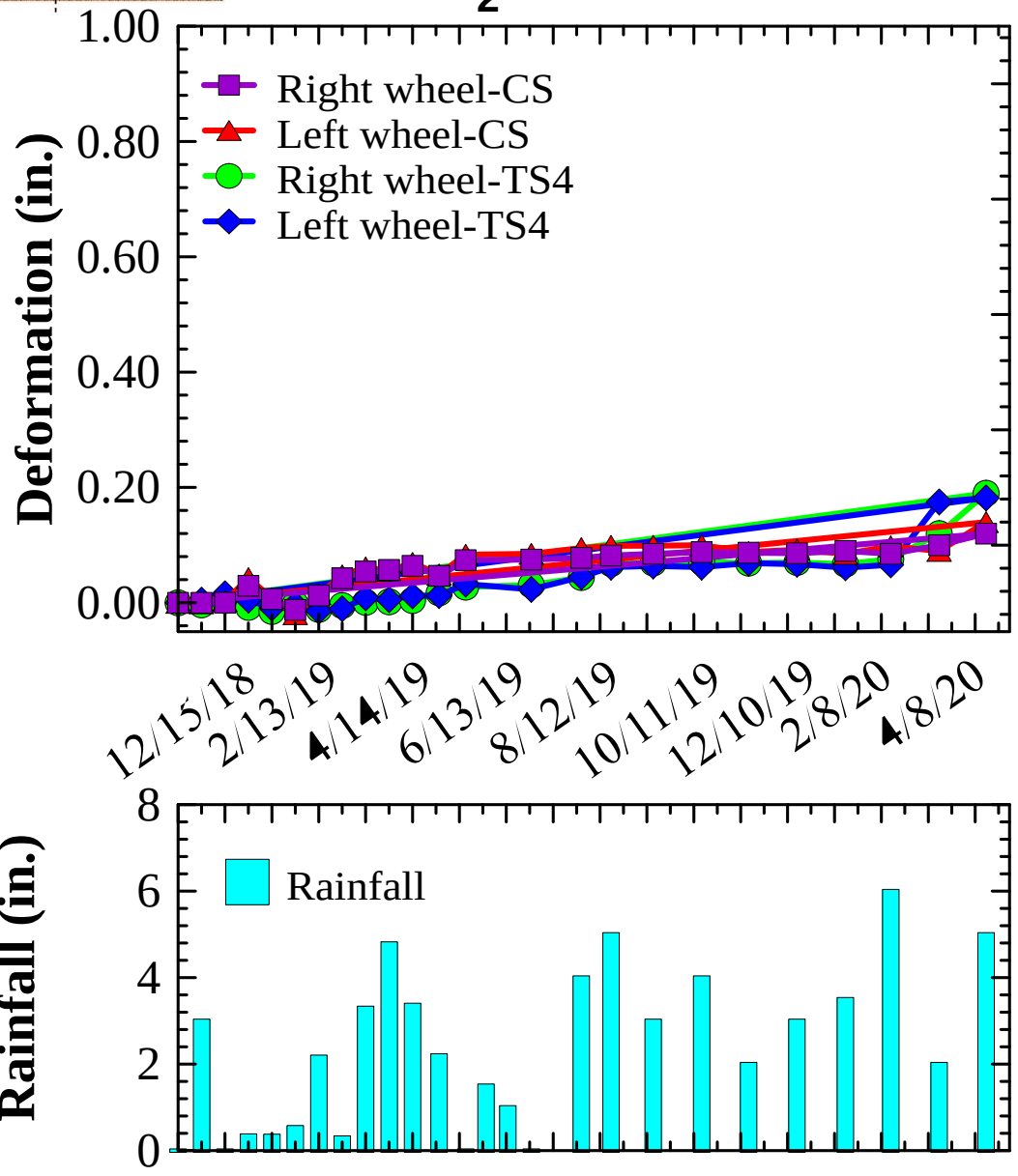


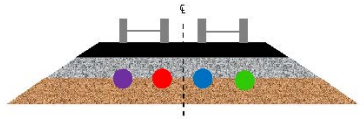



Pavement Deformation

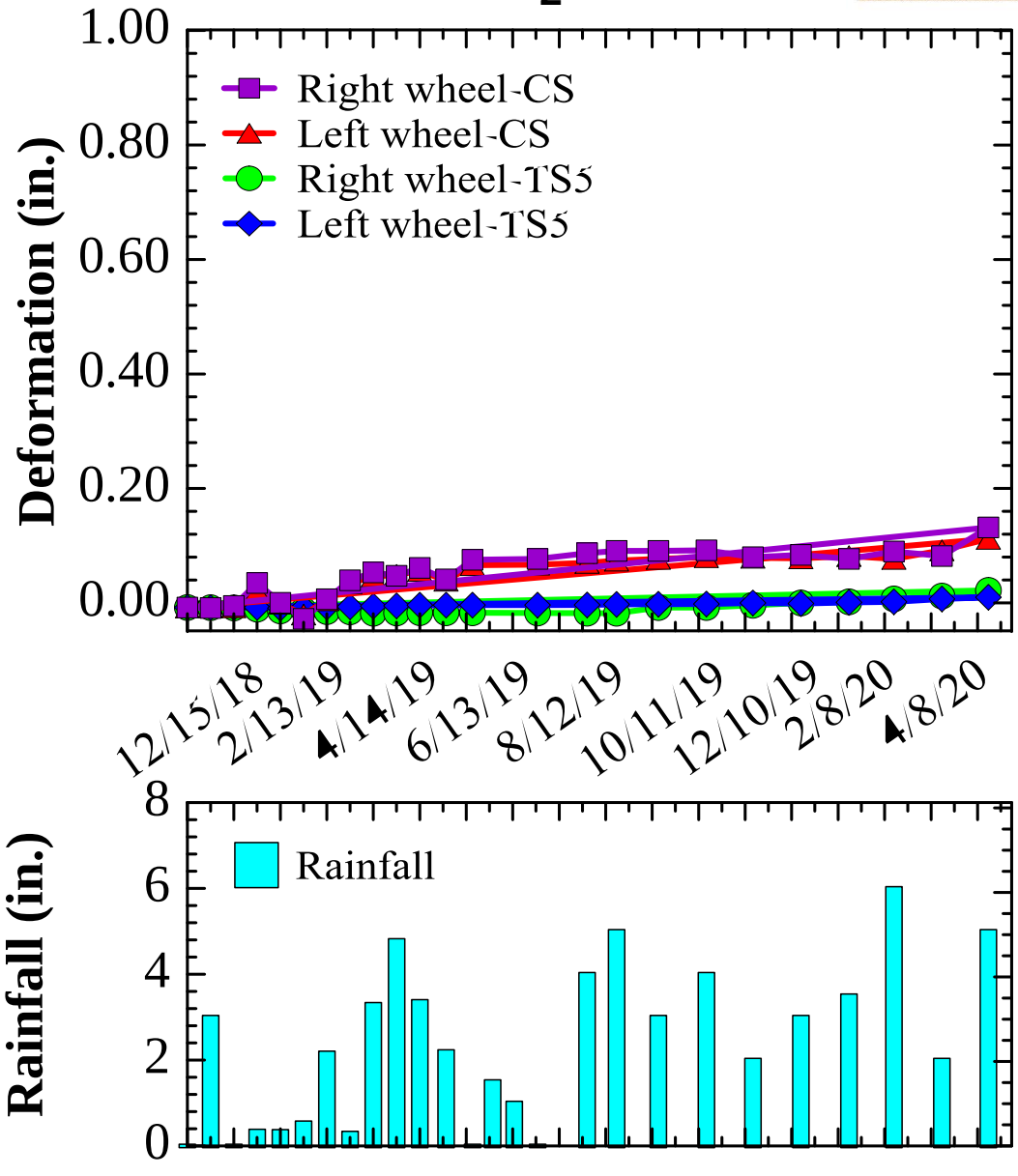


H_2Ri + RAP



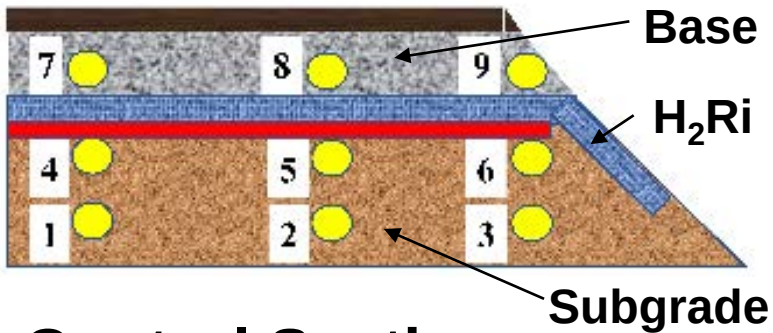


H_2Ri + FB

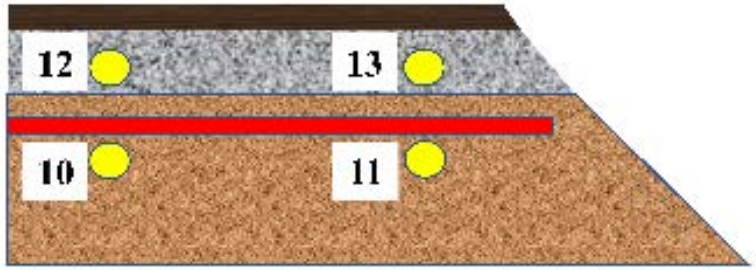


Moisture Variation

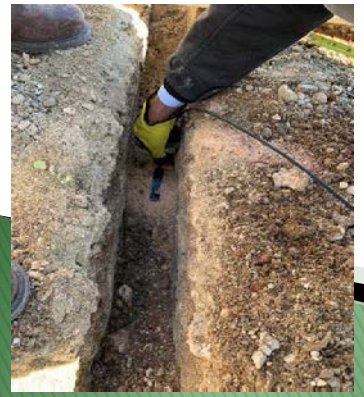
H_2Ri + FB

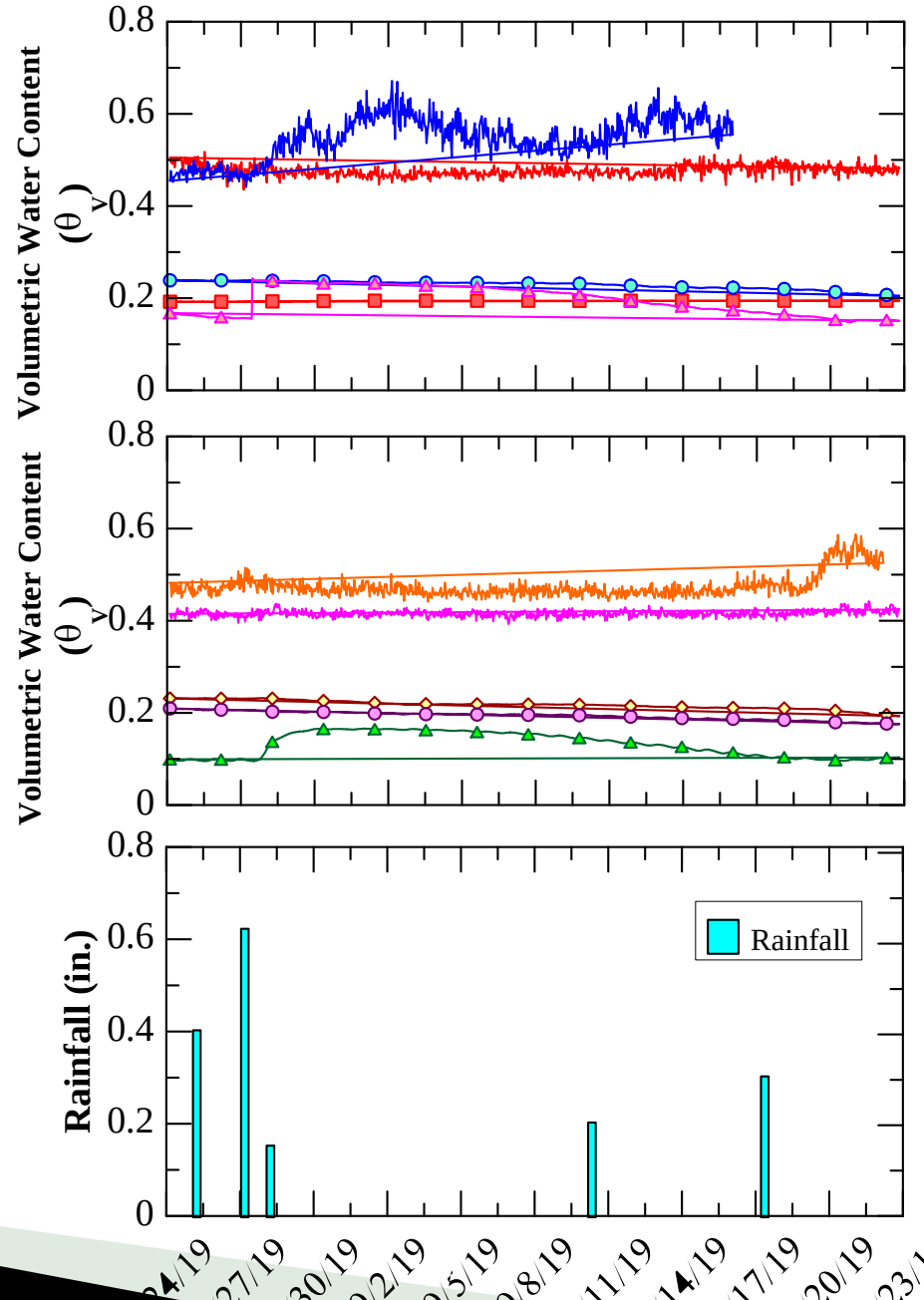


Control Section



Moisture Sensors





Control Subgrade (10,11)

TS-5 Subgrade (4,5,6)

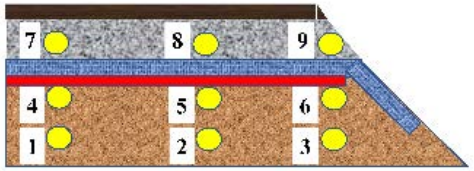
Control Base (12,13)

TS-5 Base (7,8,9)

METER Group, Inc.

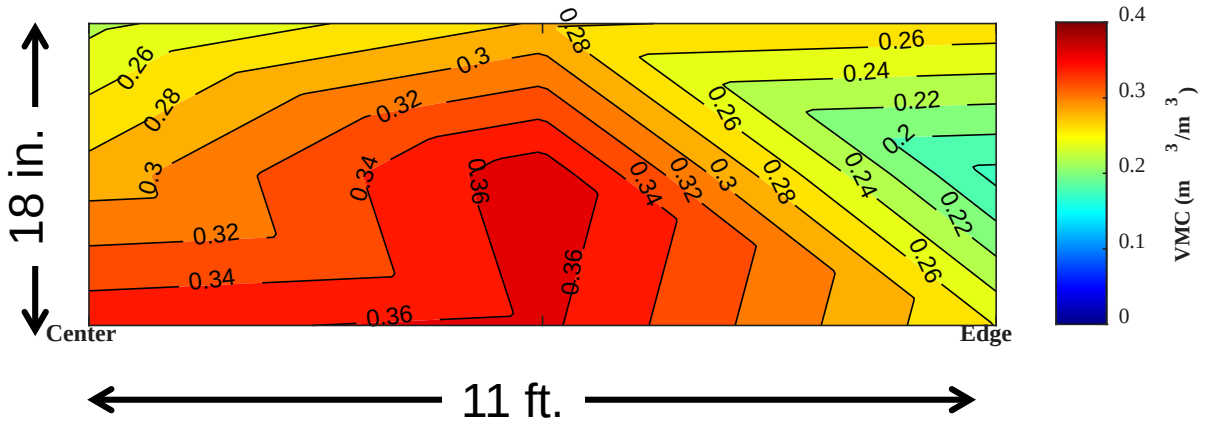
Moisture Distribution

H_2Ri + RAP

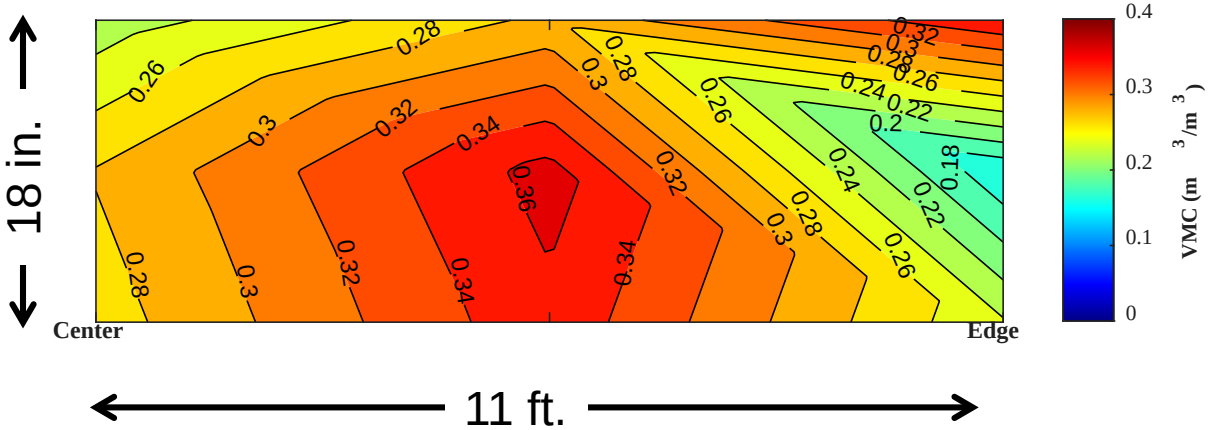


H_2Ri + FB

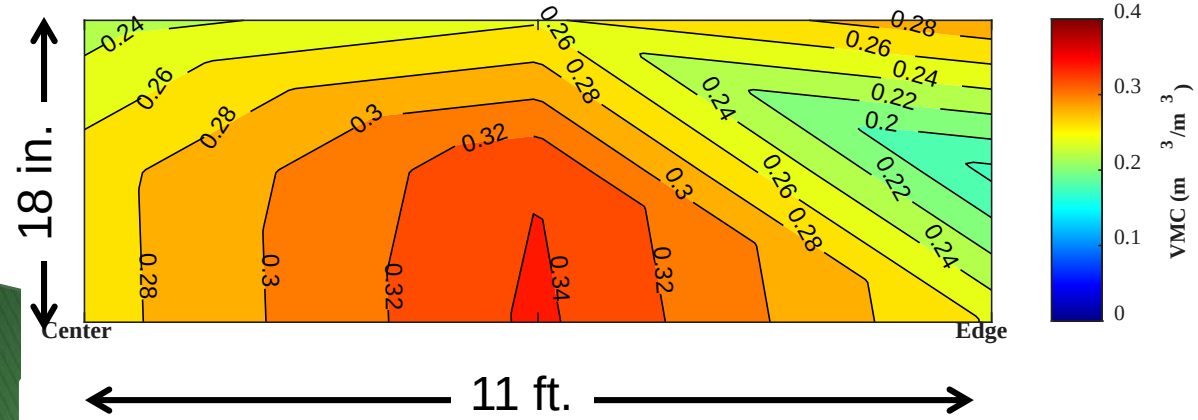
2 hours after rainfall



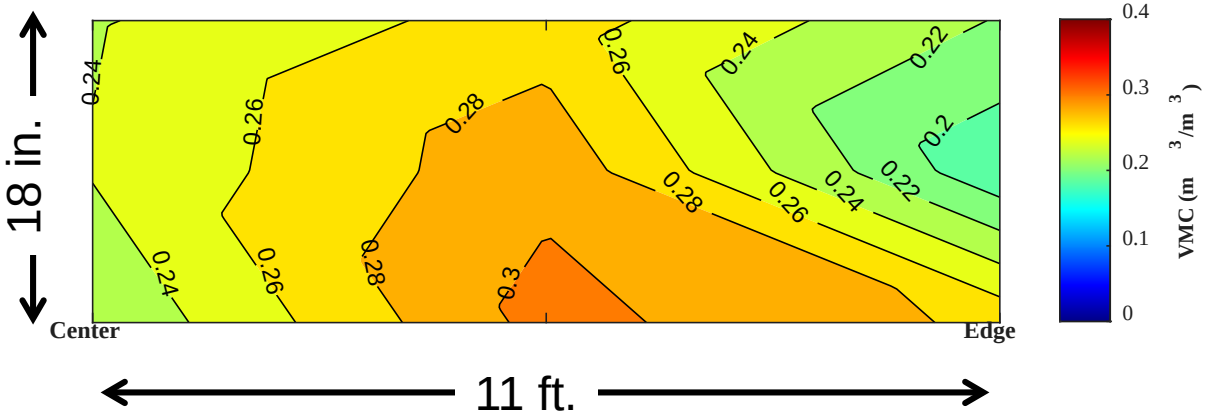
2 hours after rainfall



8 hours after rainfall



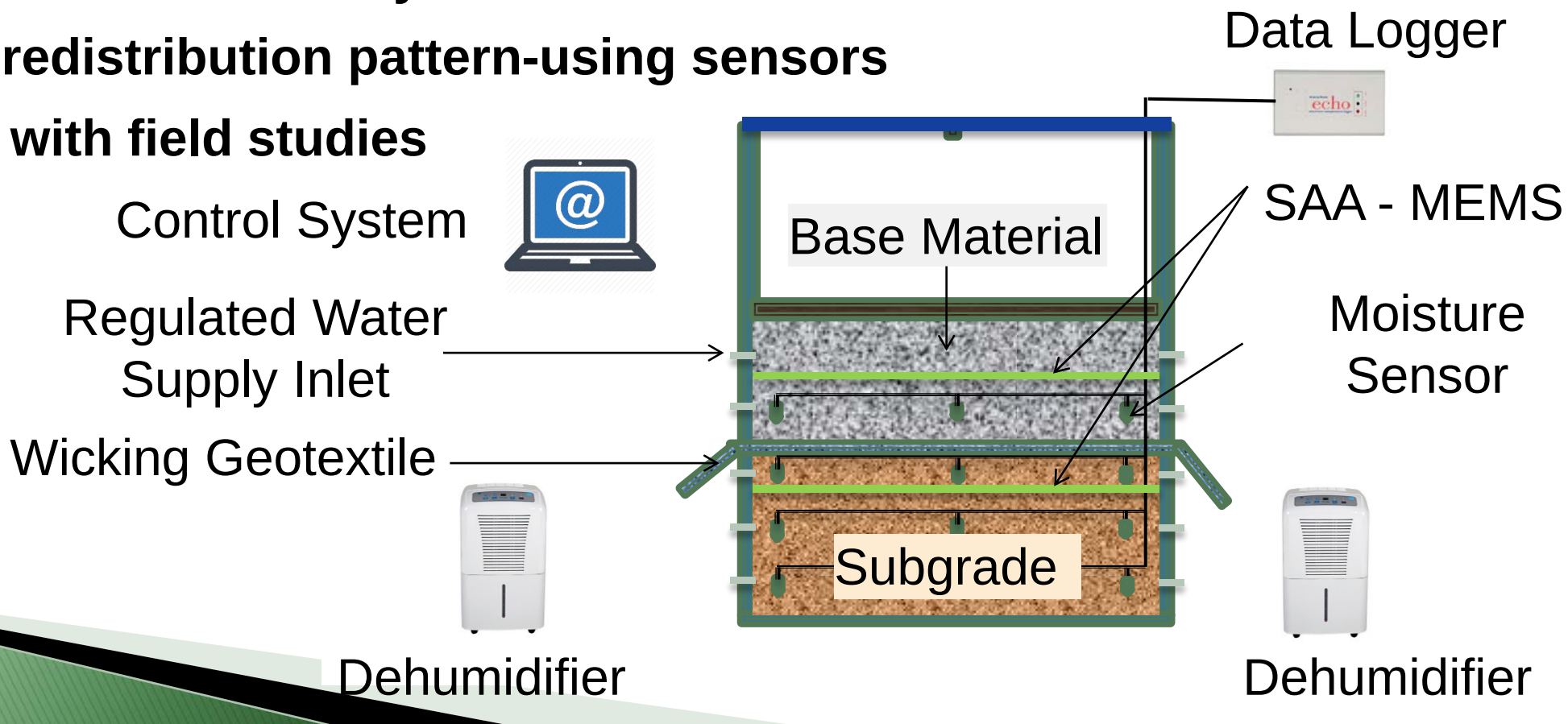
8 hours after rainfall



3rd March, 2020

Future Study

- **Objective: To understand the moisture movements in subsoil due to the placement of H_2Ri in a control environment**
- **Tasks**
  - **Construction of laboratory scale model**
  - **Moisture redistribution pattern-using sensors**
  - **Compare with field studies**



LIFE FORMS

Project: Performance of Pavement Sections with H_2Ri Geosynthetics

Number: 3

Center for Integration of Composites into Infrastructure

Mitigating Sulfate Heaving Using Novel Soil Stabilizers

Project Leader: Sayantan Chakraborty

Team: Nripojyoti Biswas and Jungyeon Jang

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

NSF IUCRC CICI TAMU SITE
NSF IUCRC CICI - IAB Spring 2020 Virtual Meeting

June 16, 2020

TEXAS A&M UNIVERSITY
Zachry Department of Civil & Environmental Engineering

Research Need: Mitigating Sulfate Heaving Using Novel Stabilizers

- **Problem:** Sulfate heaving has a detrimental impact on overlying infrastructure
- **Objective**
  - Study alternate sustainable additives for stabilizing sulfate-rich soils
- **Stabilizers studied**
  - Crystalline silica admixture
    - Quarry fines
    - High surface area → facilitate pozzolanic reaction
    - Suppress ettringite-induced heaving
  - Geopolymer
    - Alkali (Na or K) activated alumino-silicates (fly ash, slag, etc.)
    - Absence of Ca → ettringite-induced heaving↓

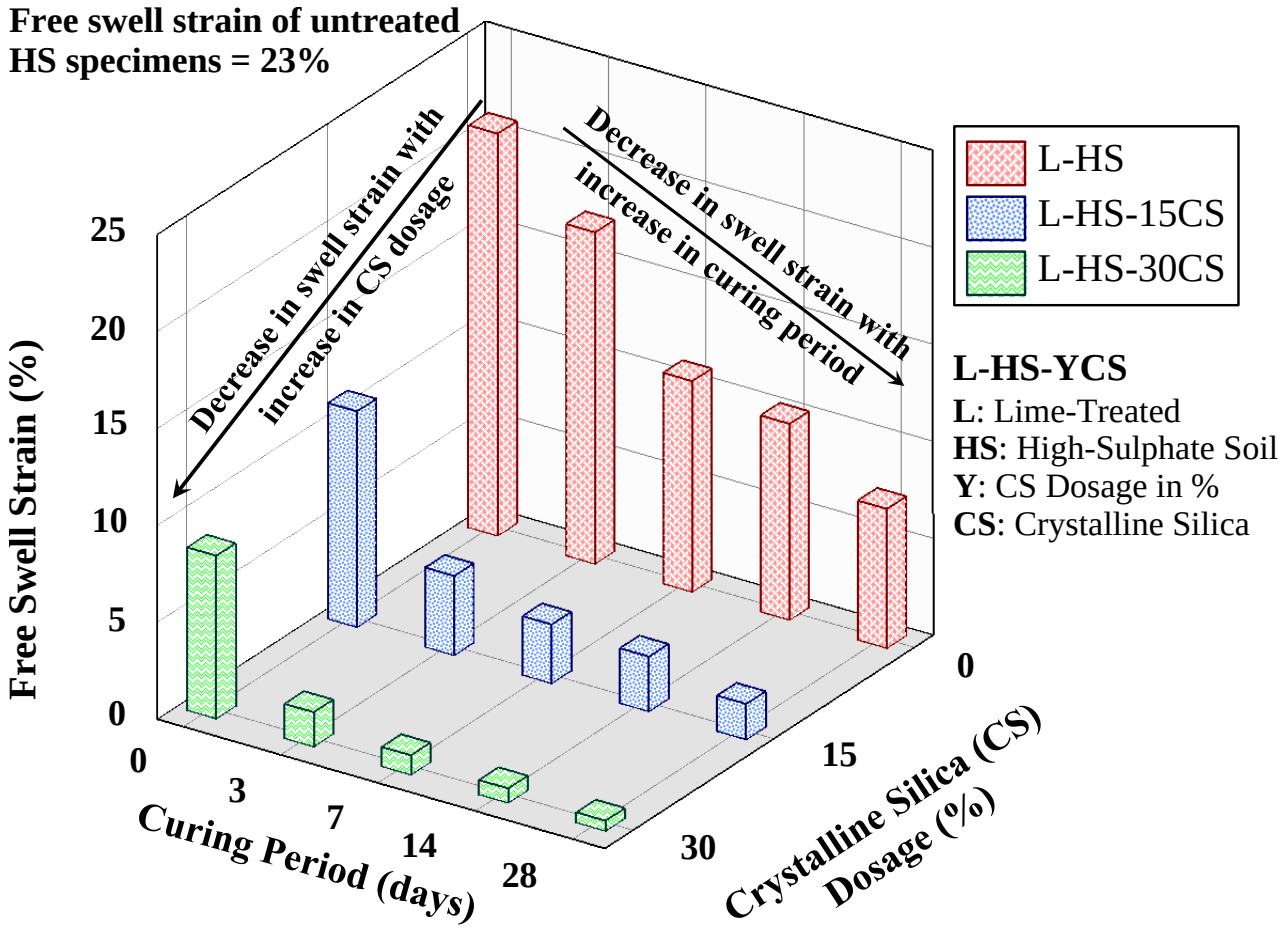
Source: Reed, R.F., 2005. Alternative Explanation of "Lime-Induced Heave". In *PanAm Unsaturated Soils 2017* (pp. 118-130).

Research Plan: Mitigating Sulfate Heaving Using Novel Stabilizers

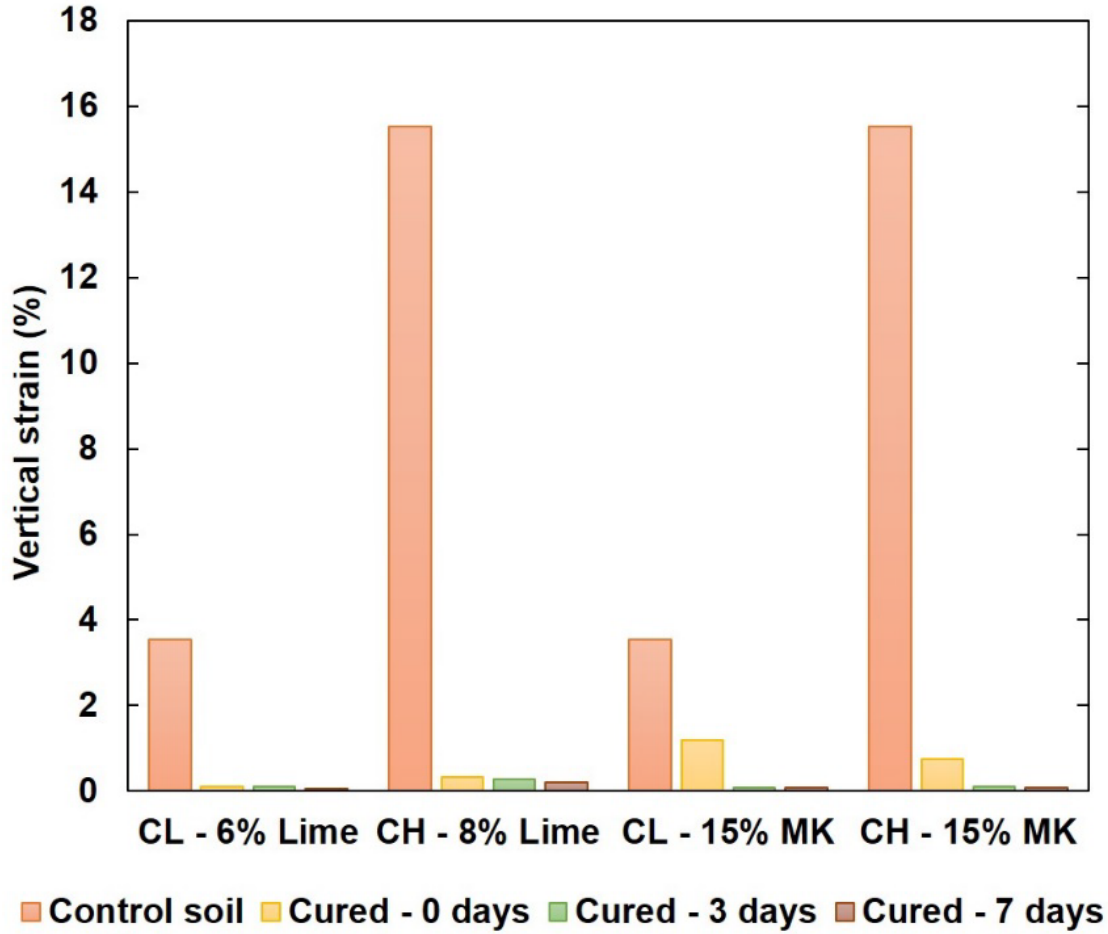
- **Evaluate improvements in engineering properties**
  - Free swell, unconfined compressive strength, and resilient modulus tests
- **Mineralogical and microstructural analyses**
  - Identify chemical reaction products in treated soils
  - X-Ray Diffraction (XRD) and Field Emission Scanning Electron Microscope (FESEM) imaging
- **Sustainability and resiliency studies**
  - Resource consumption, environmental impact, and socio-economic impact
  - Resilience of infrastructure to withstand normal and extreme events

Preliminary Test Results: Free Swell Strain

Crystalline Silica Admixture



Geopolymer

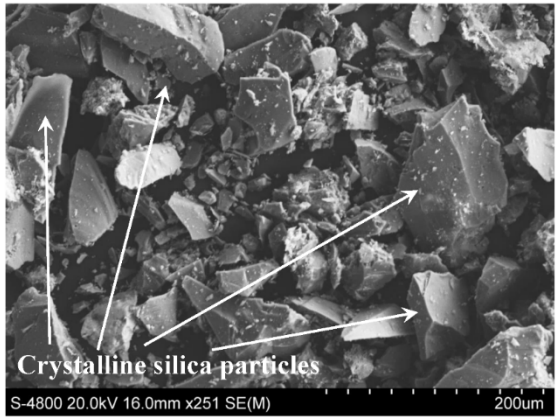


CL: Low plasticity clay; CH: High plasticity clay; MK: Metakaolin

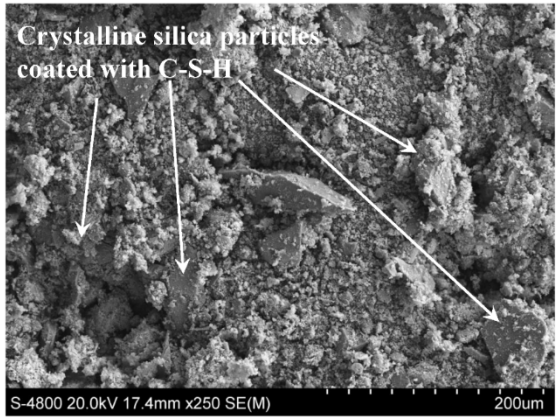
- Crystalline silica and geopolymer reduce swelling characteristics

Preliminary Test Results: FESEM Imaging

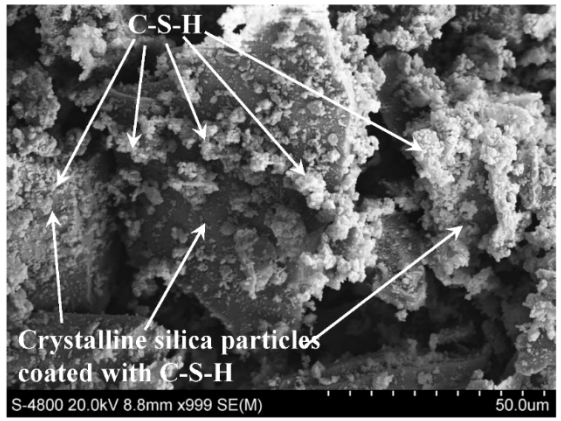
Crystalline Silica Admixture



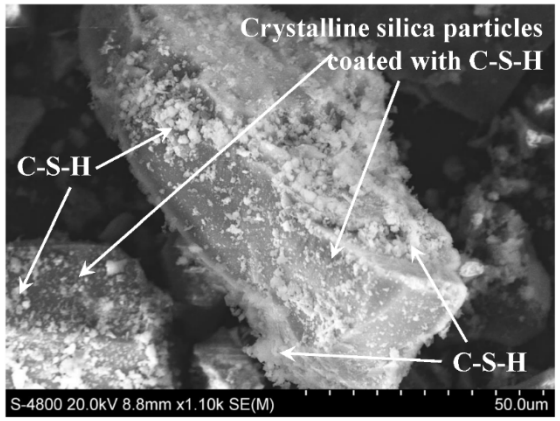
Crystalline Silica (CS) Particles at 250x
(a)



Lime-Treated Crystalline Silica (L-CS) Particles at 250x
(b)

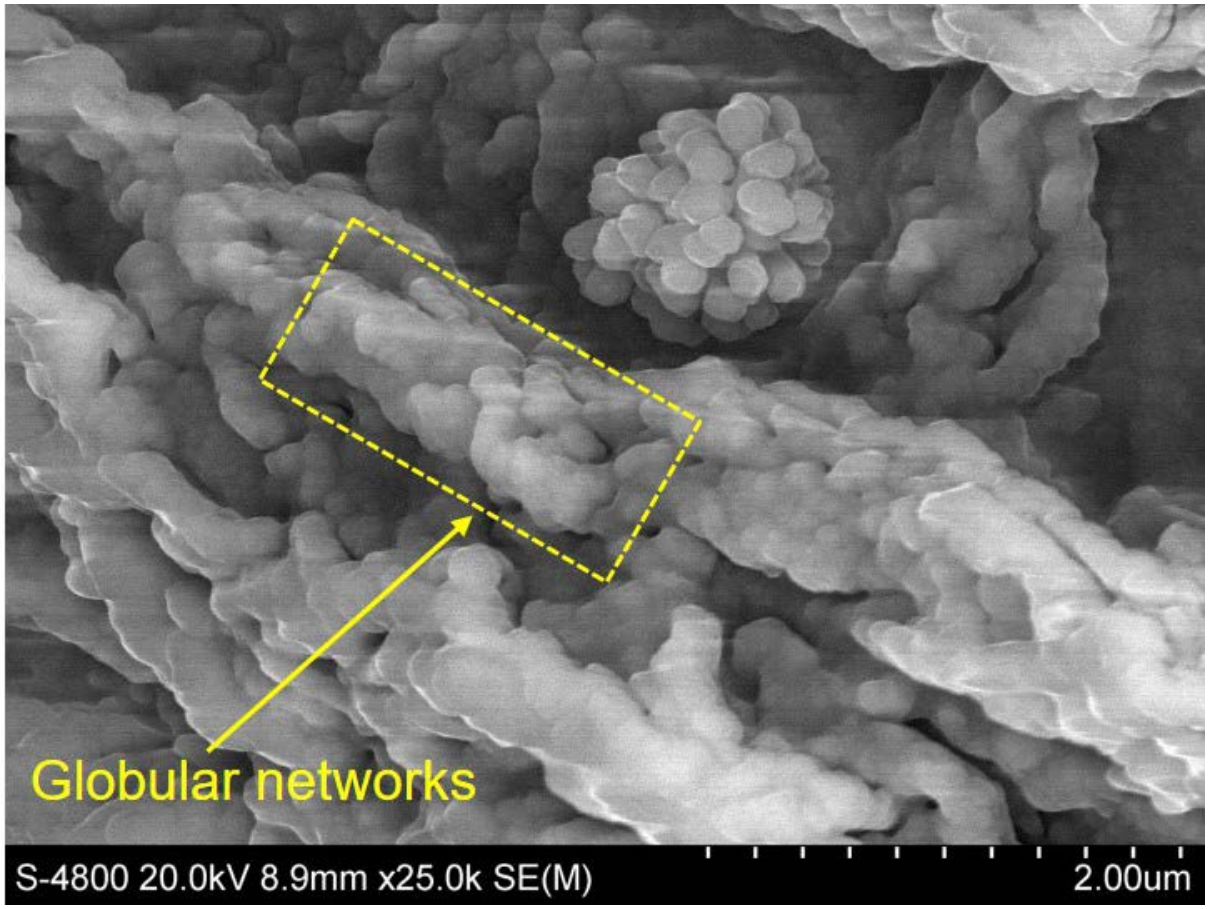


Lime-Treated Crystalline Silica (L-CS) Particles at 1,000x
(c)



Lime-Treated Crystalline Silica (L-CS) Particles at 1,100x
(d)

Geopolymer



- Crystalline silica reacts with lime to form C-S-H phases
- Geopolymer network can bind soil particles

Future Studies

- Geopolymer treatment of high-sulfate soils
- Optimize stabilizer dosages
- Sustainability and resiliency studies

LIFE FORMS

Project: Mitigating Sulfate Heaving Using Novel Soil Stabilizers

Number: 4