Center for Integration of Composites into Infrastructure

Evaluating the Performance of Fiber-Based Concrete Mixes for Various Applications

Project Leader: Surya Sarat Chandra Congress

Team: Krishneswar Ramineni, Clay Caldwell

PI: Anand J. Puppala

Professor | A.P. and Florence Wiley Chair

Interim Director – Center for Infrastructure Renewal

Closed Meeting

TAMU Site Proprietary

NSF IUCRC CICI TAMU SITE

NSF IUCRC CICI - IAB Spring 2022 Virtual Meeting

May 11th, 2022

WARSTONE INNOVATIONS, LLC

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

Presentation Outline

- Introduction
- Progress of Work
- Laboratory Testing
- Results
  - Absorption
  - Drying
- Preliminary Findings
- Future Work

Introduction

- Climate change and rising seawater levels → huge concerns for coastal areas
- Increase in intensity of storm surges → coastal areas are vulnerable
  - Coastal flooding
  - Shoreline erosion
  - Water pollution
  - High salinity of coastal waters
- Objective
  - To develop optimized fiber-based concrete mixes to address the erosion-related coastal infrastructure problems caused due to climate change

Progress of Work

Task List

- ❖ Characterization of materials
- ❖ Wetting and Drying studies
  - ❑ Control (Potable water and 20°C)
  - ❑ Temperature Controlled (40°C and 4°C)
  - ❑ Seawater
- ❖ Large-scale laboratory studies

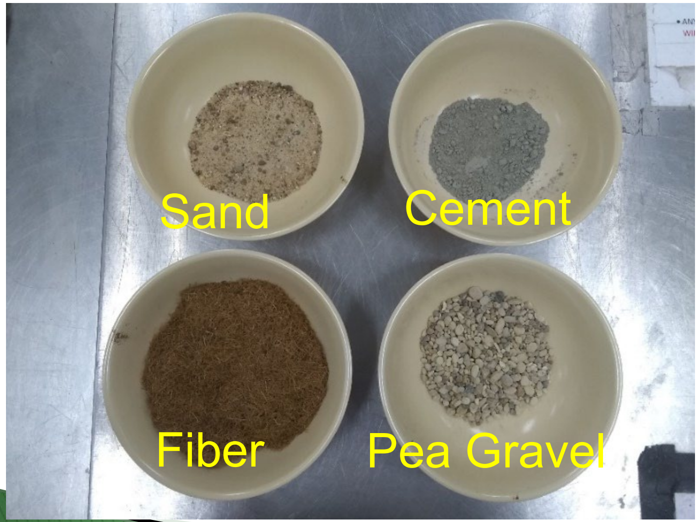
IUCRC meeting
11th May 2022

Laboratory Testing

Concrete mix proportion

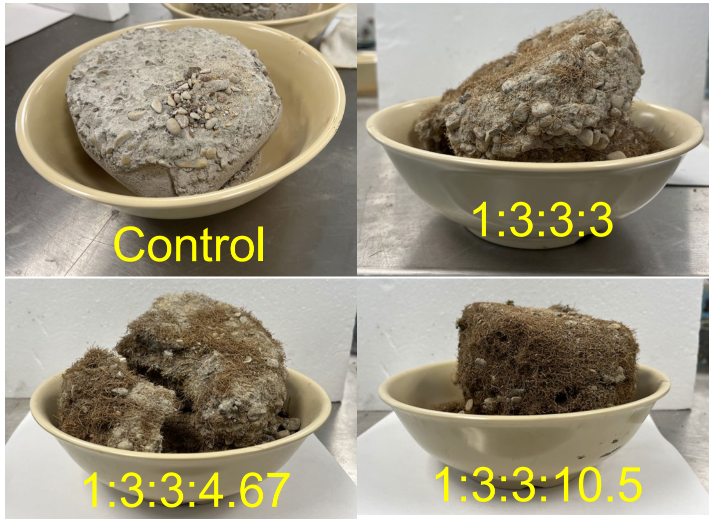
Percentage	60%	50%	40%	30%	control
Proportions	1:3:3:10.5	1:3:3:7	1:3:3:4.67	1:3:3:3	1:3:3:0
Cement (g)	86.3	107.8	129.4	151.0	215.7
Sand (g)	322.1	402.6	483.0	563.6	805.2
Pea Gravel (g)	296.2	370.3	444.2	518.4	740.6
Fiber (g)	135.9	113.2	90.6	67.9	0

*Note - A:B:C:D = Cement: Fine aggregate: Coarse aggregate: Fibers



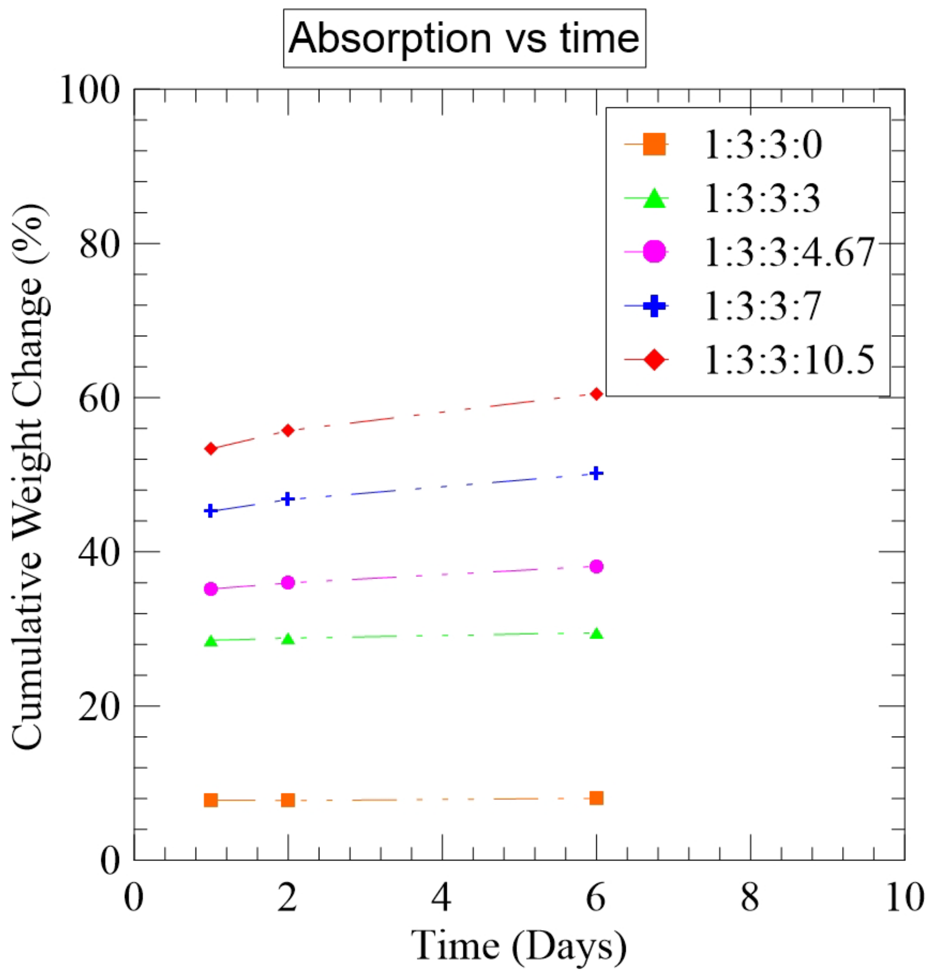
Concrete mix constituents

Concrete mixes during wetting and drying cycles

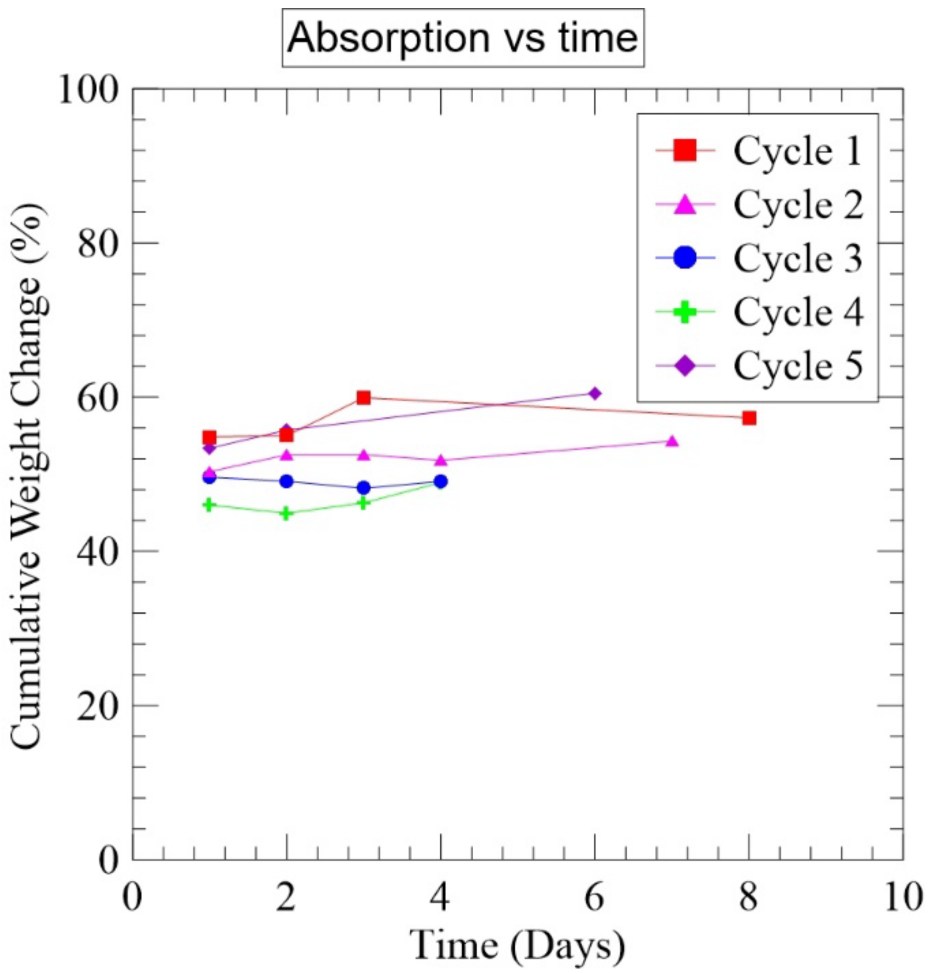


Concrete mixes after wetting and drying cycles

Results



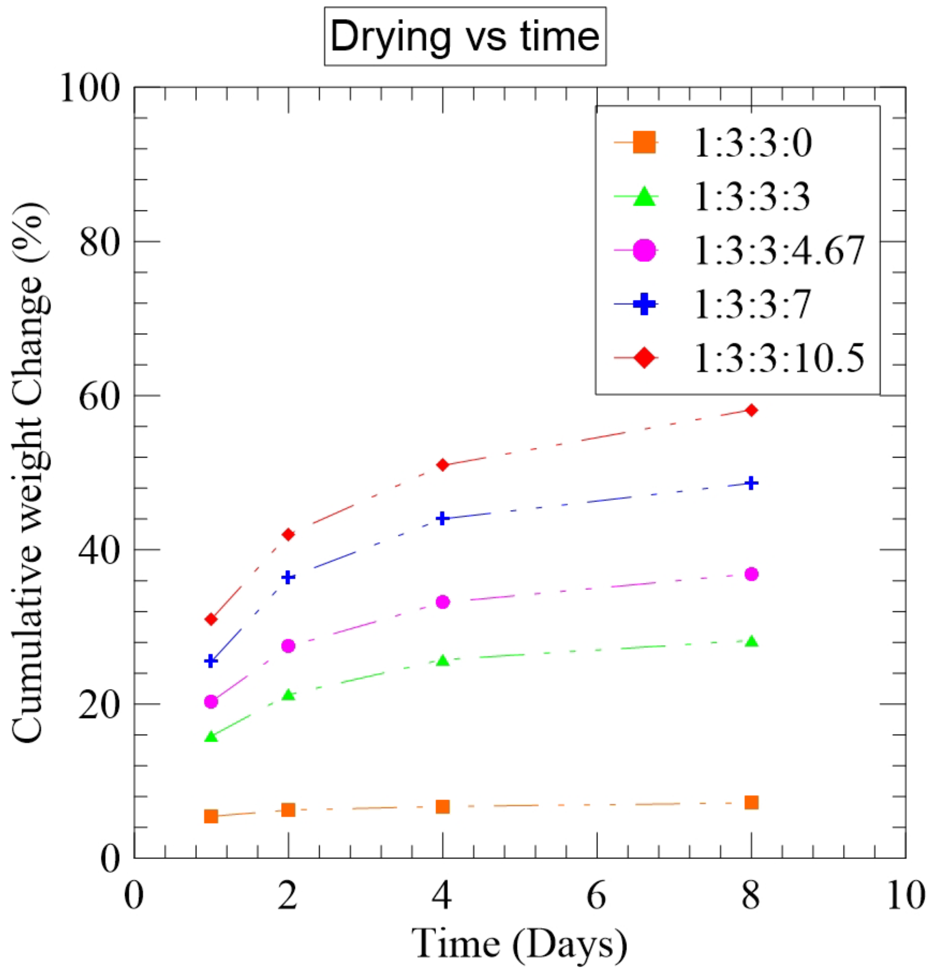
Water absorption vs time for cycle 5



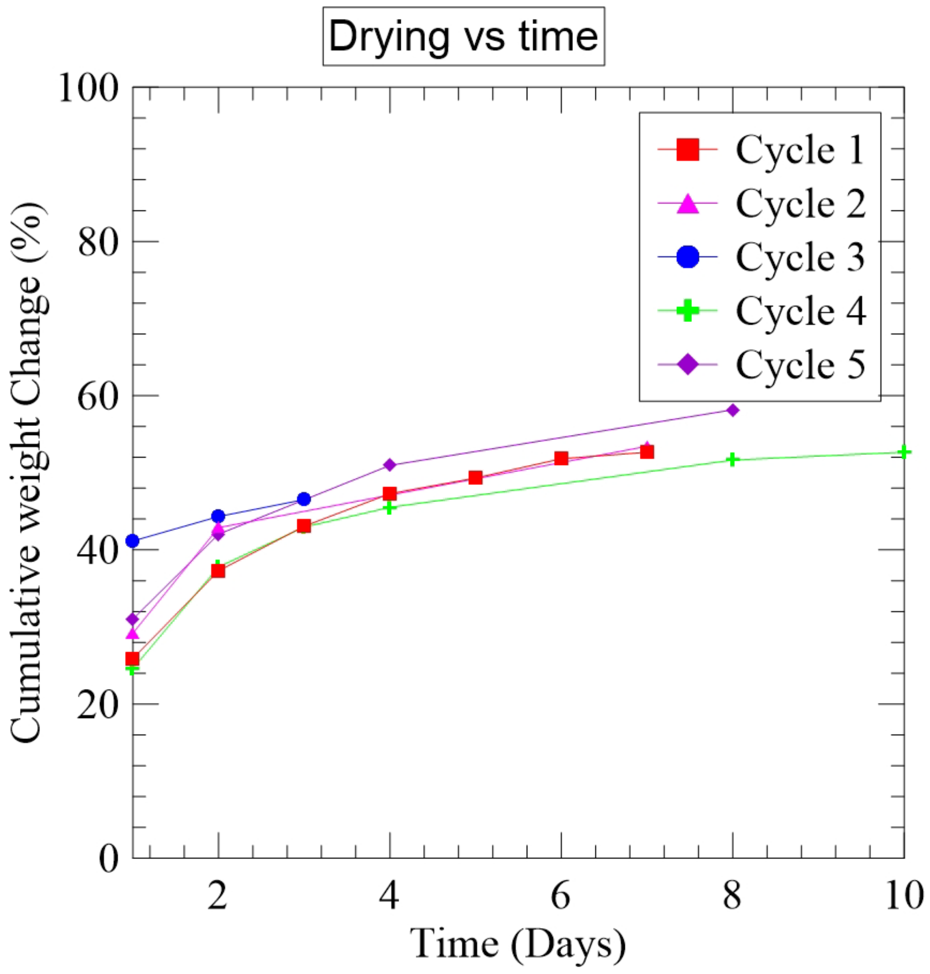
Water absorption vs time for mix 1:3:3:10.5

- ❖ **Fiber dosage ↑→ Water Absorption ↑**
- ❖ **The water absorption after 2 days is constant in all the fiber mixes**

Results



Drying vs time for cycle 5



Drying vs time for mix 1:3:3:10.5

- **Fiber dosage ↑→ Weight change due to drying ↑**
- **The weight change due to drying after 5 days is negligible**

Preliminary Findings

- Fiber mixes undergone higher absorption and drying compared to control mix
  - Concrete mix 1:3:3:10.5 – Highest
- Absorption and drying cycles – Remained constant
  - Water absorption – After 2 days
  - Drying – After 5 days
- The cumulative weight change from one cycle to the next cycle is within ± 10%
- Both water absorption and drying ↑ with fiber content ↑

Future Work

- ❖ Wetting and Drying studies at 40°C and 4°C
- ❖ Wetting and Drying studies using seawater composition

LIFE FORMS

Project: Evaluating the Performance of Fiber-Based Concrete Mixes for Various Applications

Number: 5

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

Closed Meeting

TAMU Site Proprietary

NSF IUCRC CICI TAMU SITE
NSF IUCRC CICI - IAB Spring 2022 Virtual Meeting

May 11th, 2022

ThermaFoam LLC

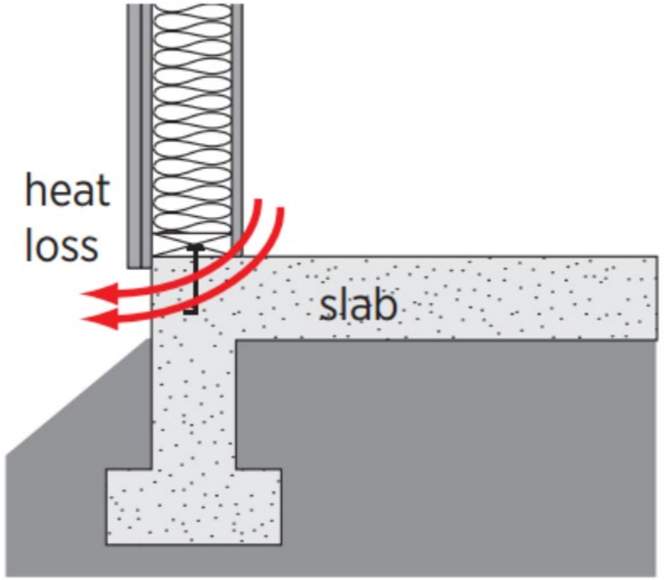
TEXAS A&M UNIVERSITY
Zachry Department of Civil & Environmental Engineering

Presentation Outline

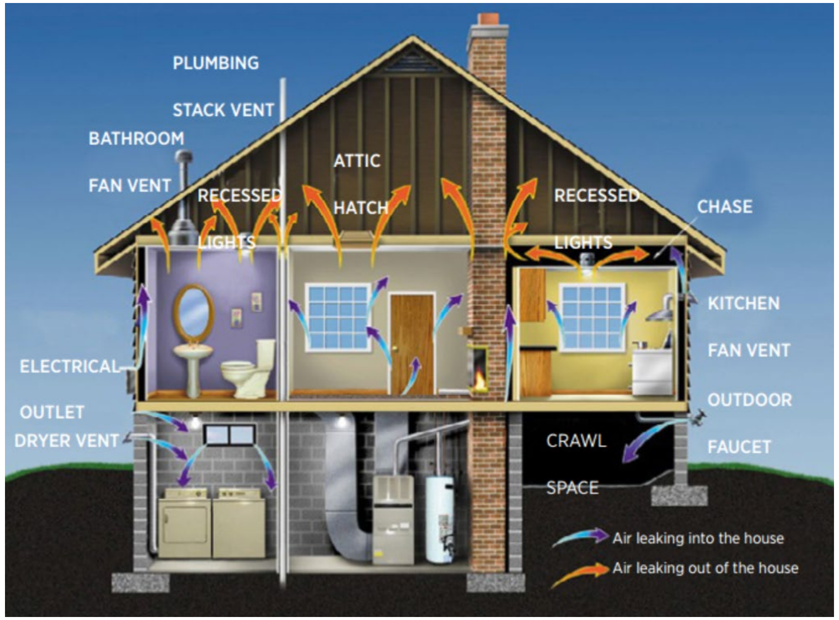
- Introduction
- Test Methodology
- Control Test (Baseline)
- GBF-8 in. R-250
- GBF vs Control
- Numerical Simulation: Control Test
- Conclusions
- Future Works

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)

Test Methodology

Control Tests (Baseline)

*GBF-8" Geofoam-R-250

GBF-4" Geofoam-R-250

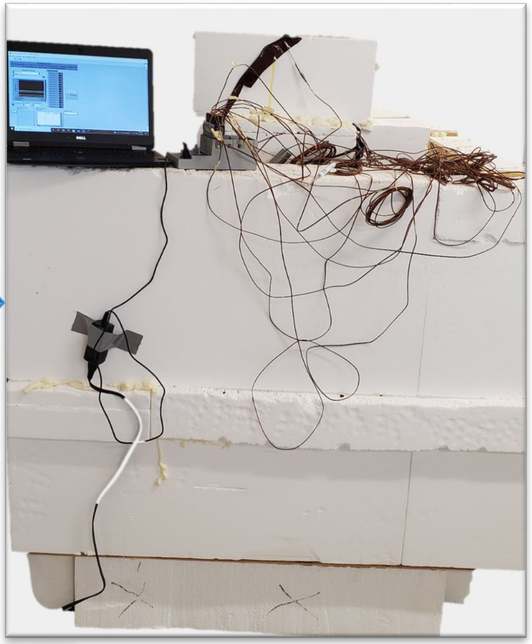
GBF-2" Geofoam-R-250

Repeat set for R-100, R-130 and R-150

Repeat set for *GAF

COMSOL Modeling of Laboratory Tests

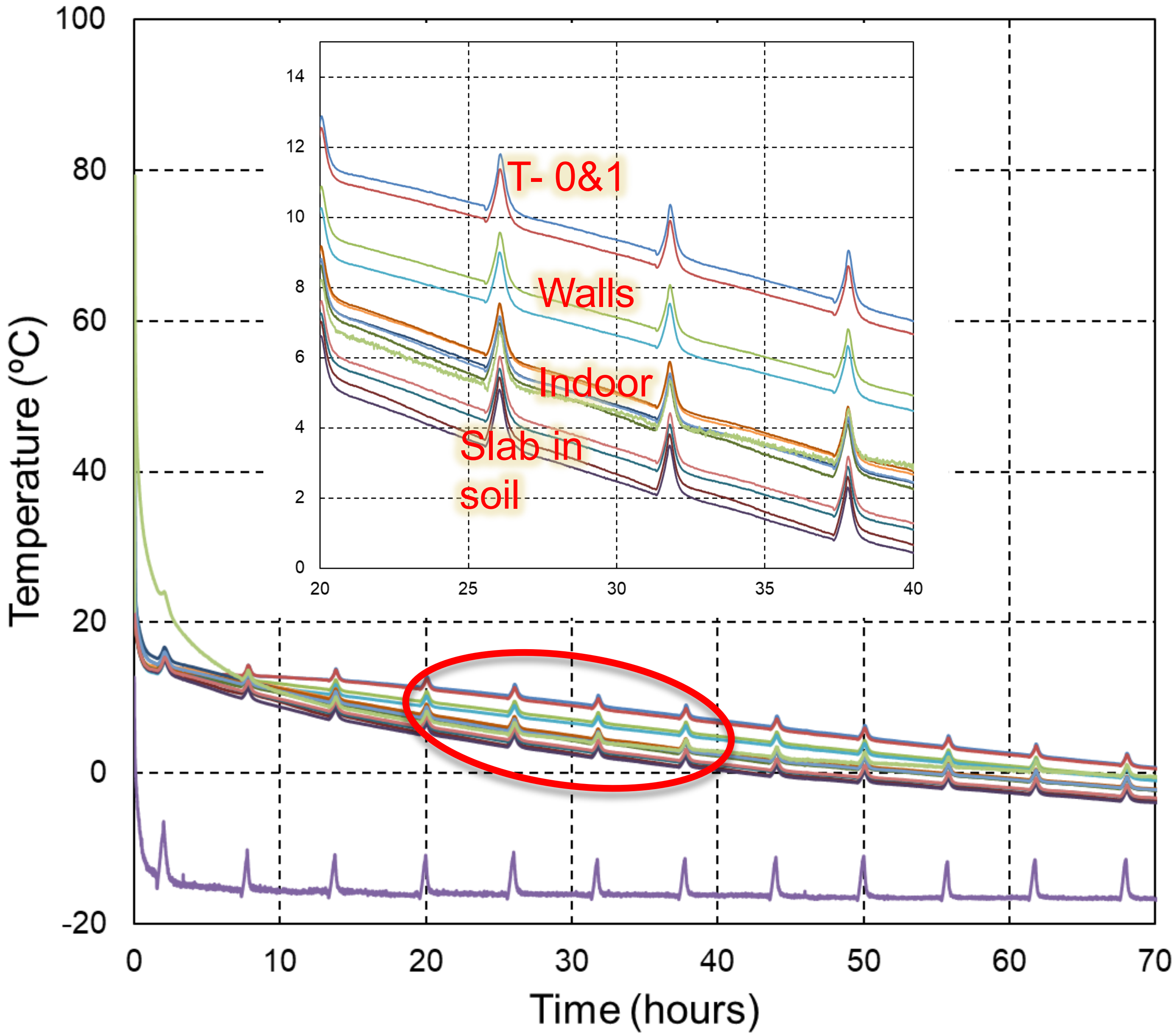
Initial Setup

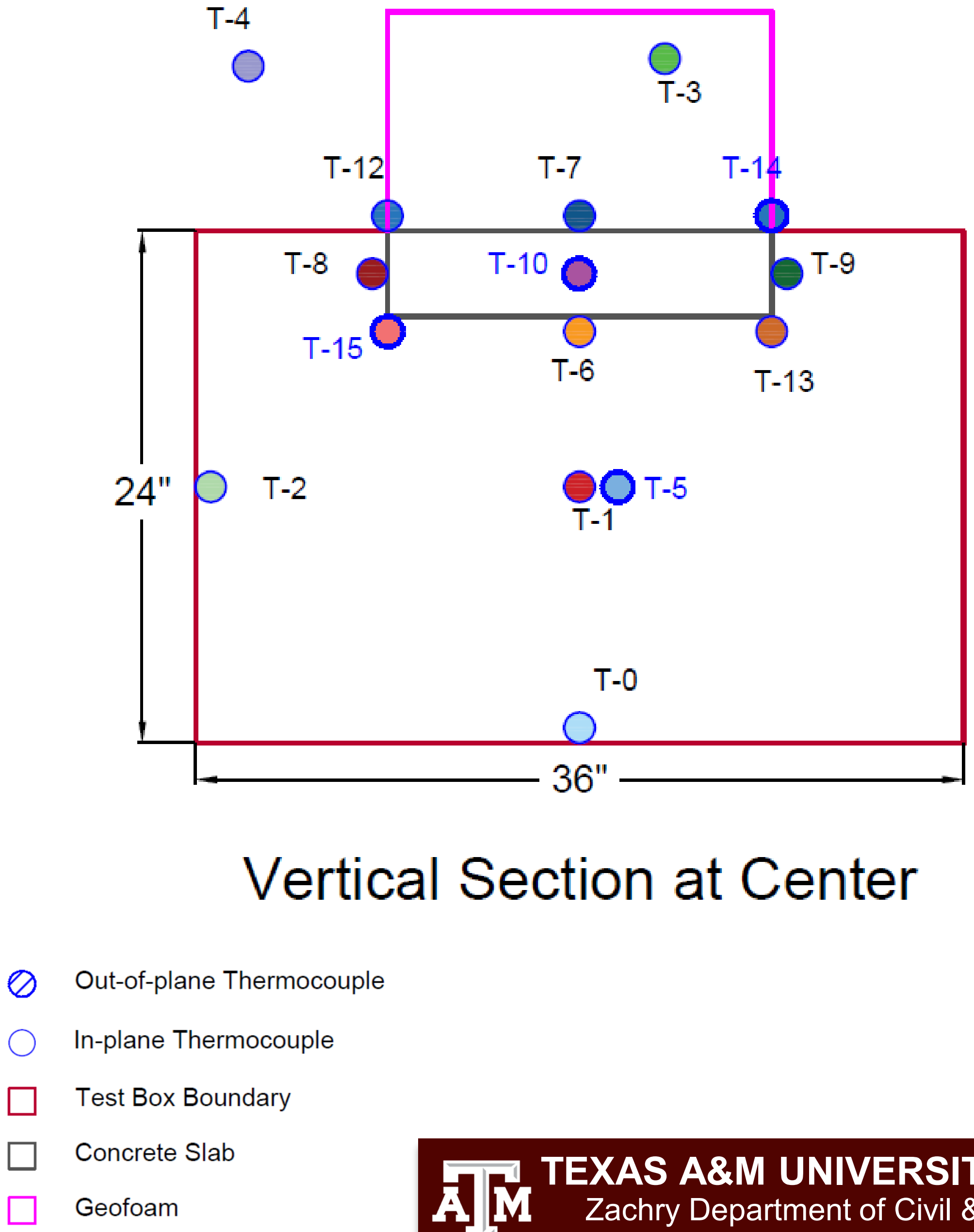


Additional Insulation for Superstructure

*GBF: Geofoam Below Foundation
GAF: Geofoam Around Foundation

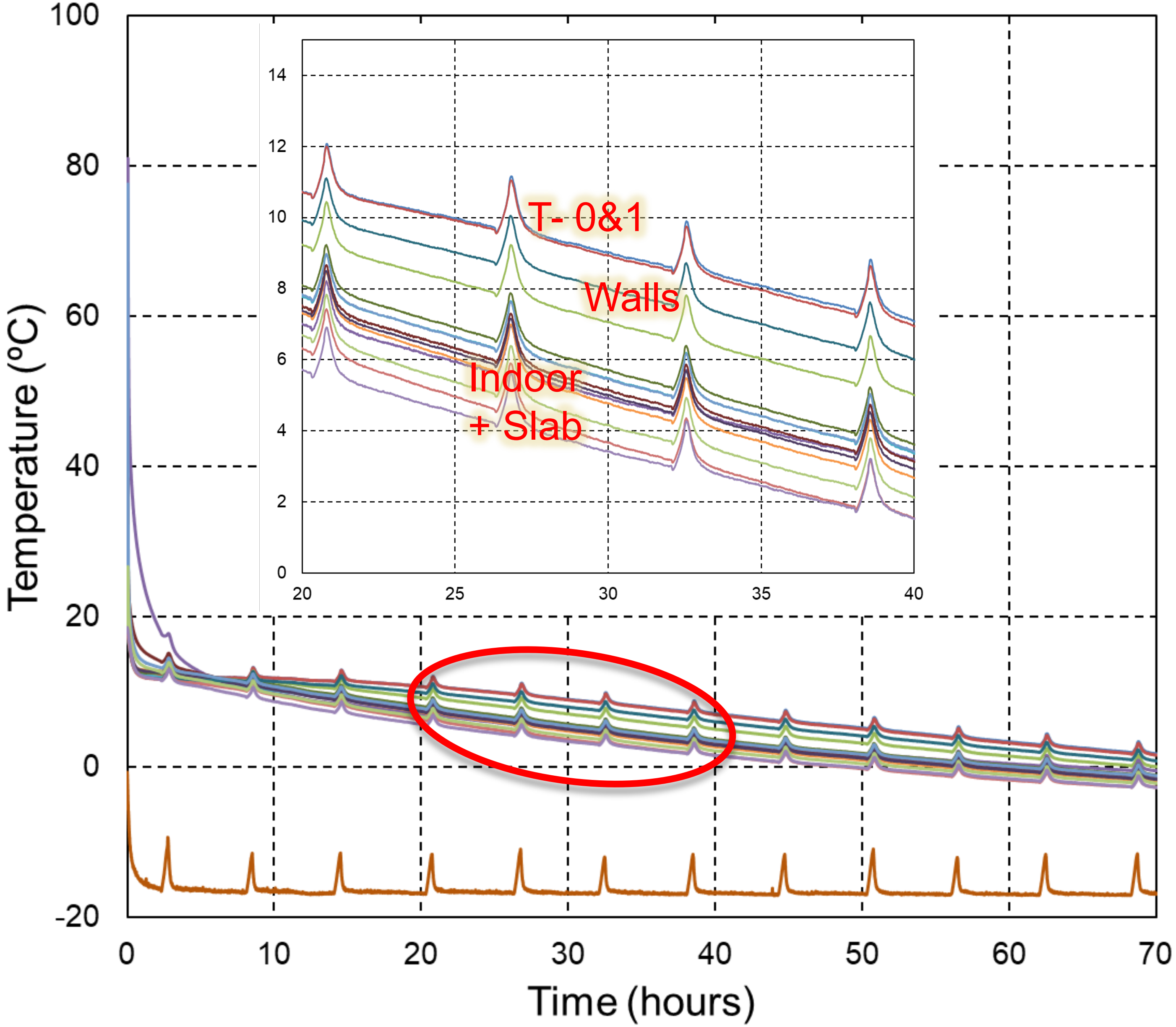
Control Test (Baseline)

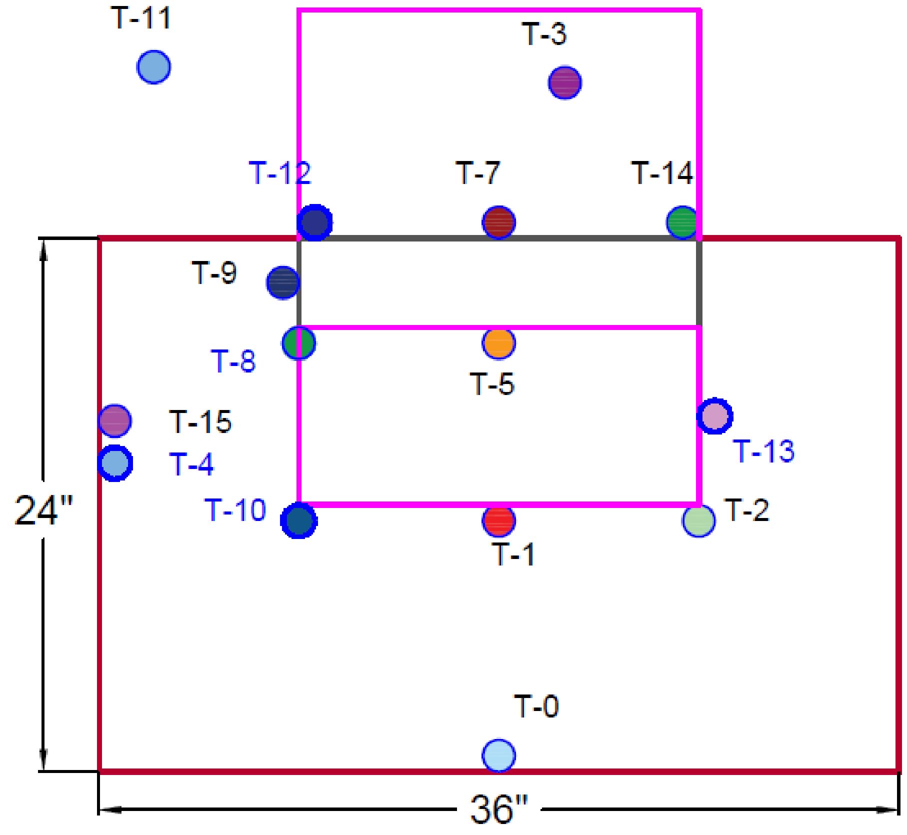




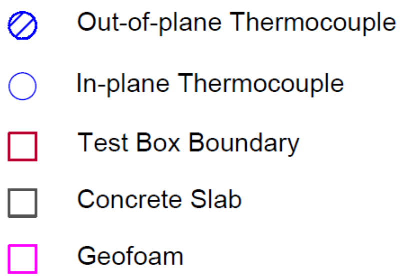
TEXAS A&M UNIVERSITY
Zachry Department of Civil & Environmental Engineering

GBF–8 in. R-250



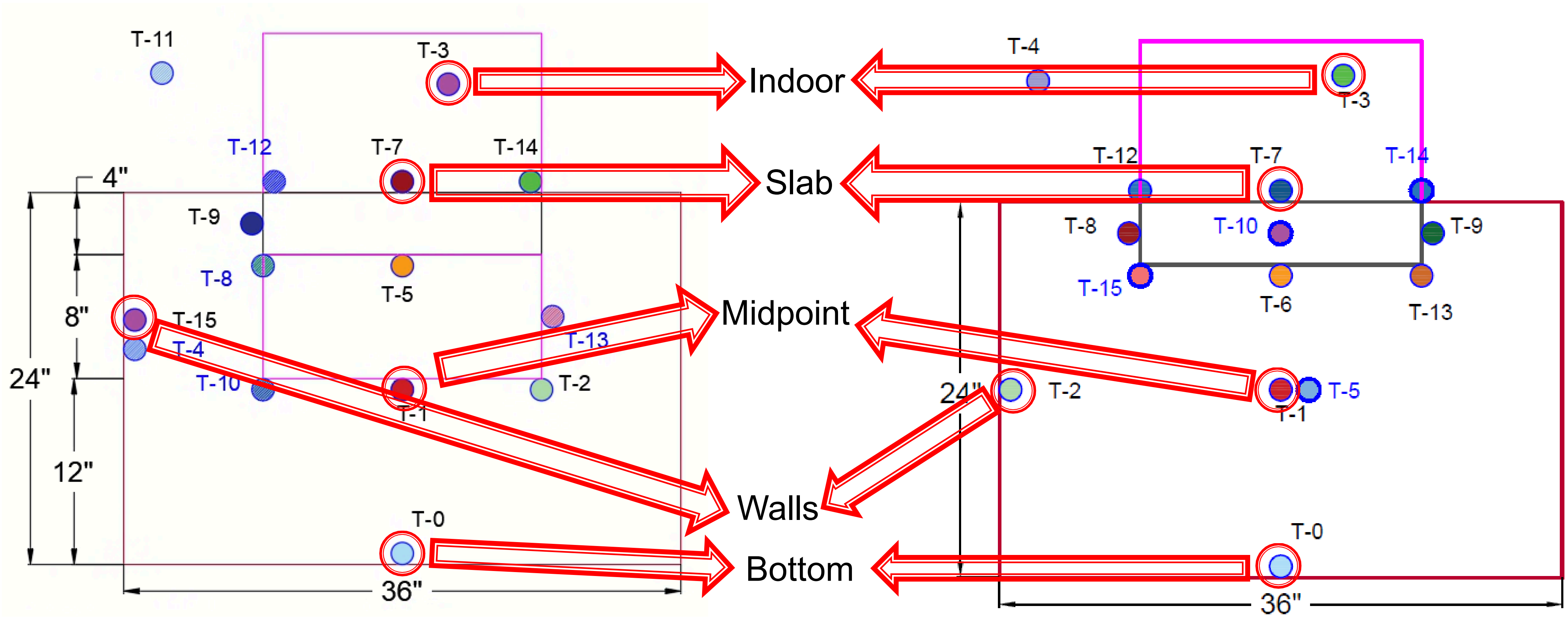


Vertical Section at Center

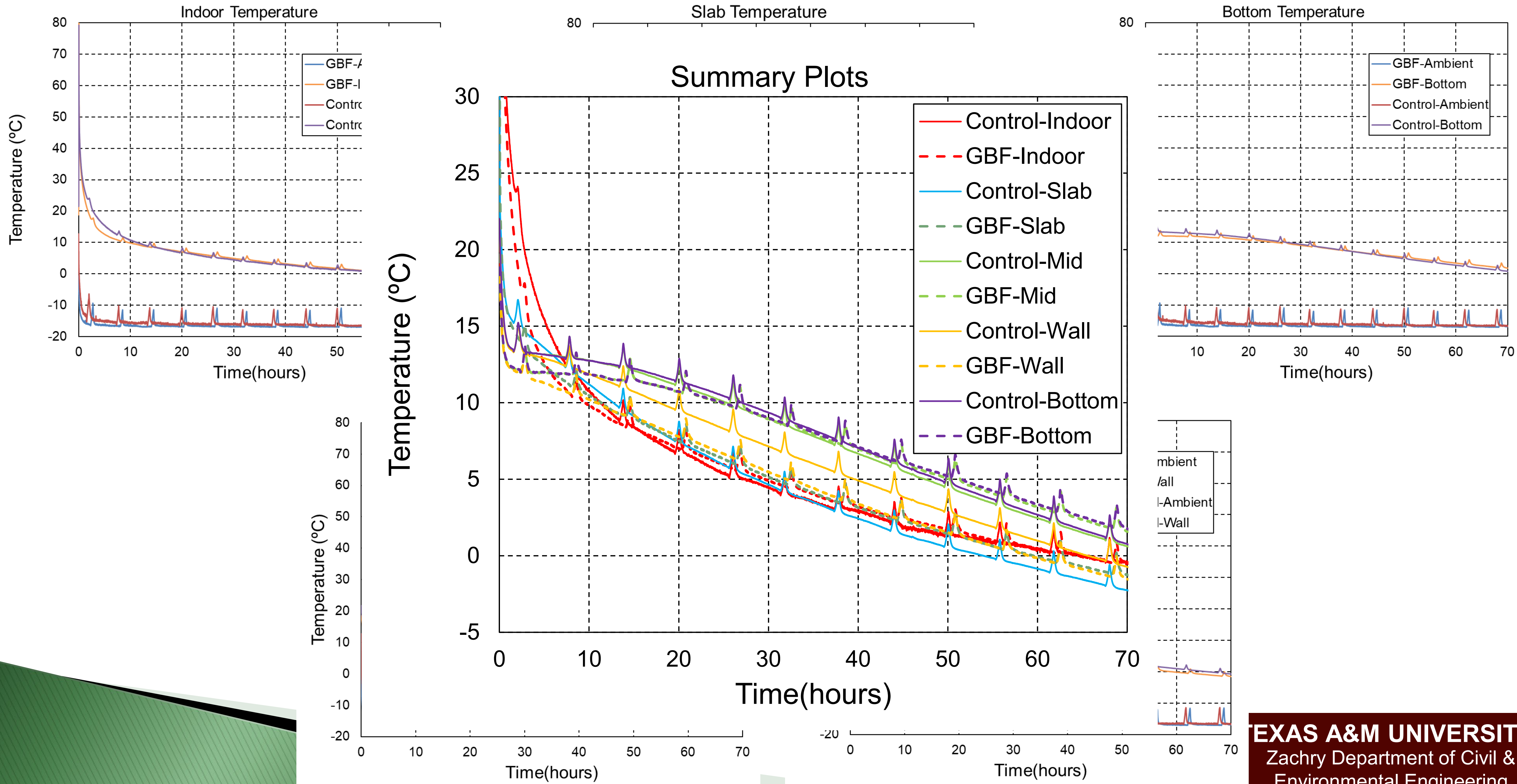


TEXAS A&M UNIVERSITY
Zachry Department of Civil & Environmental Engineering

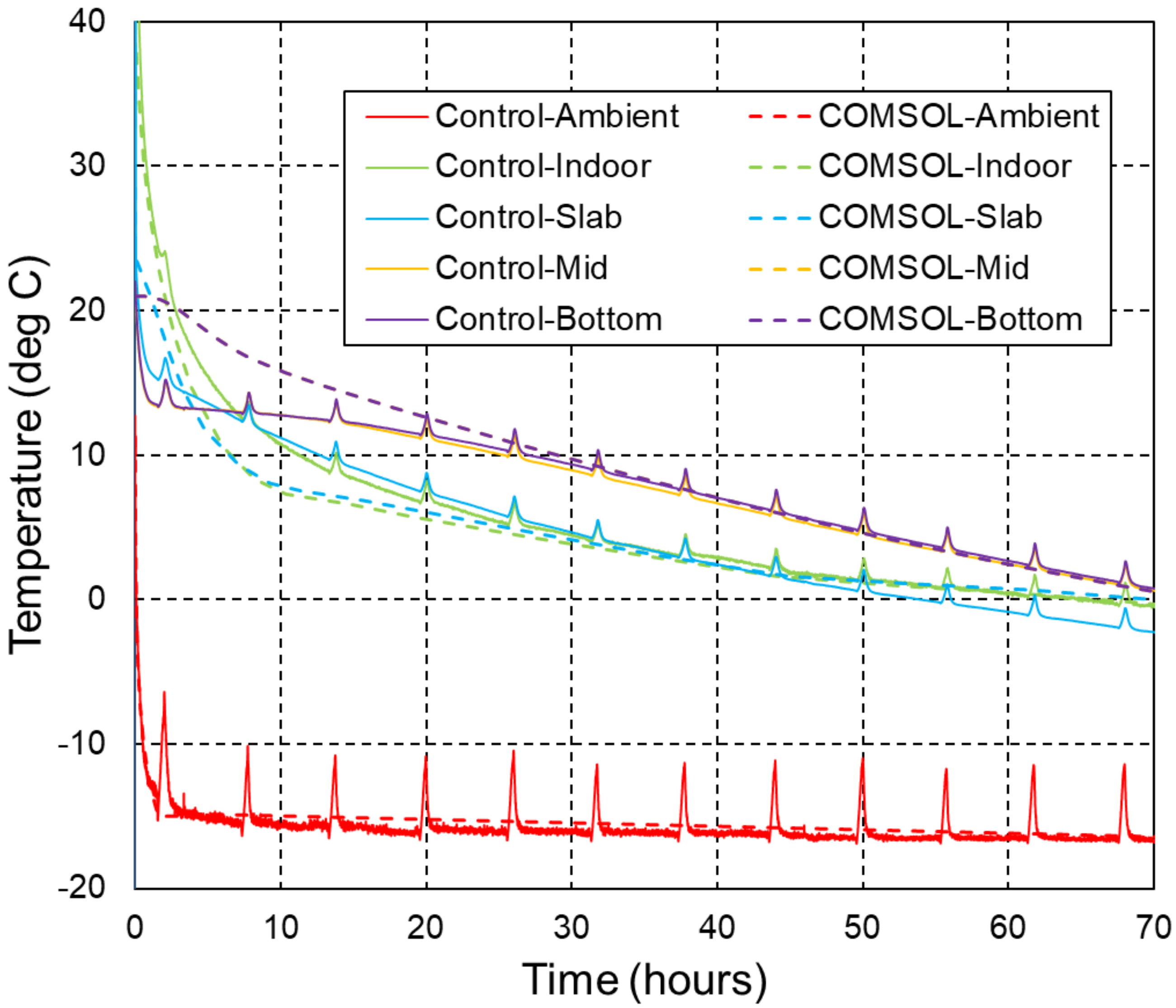
GBF vs Control



GBF vs Control

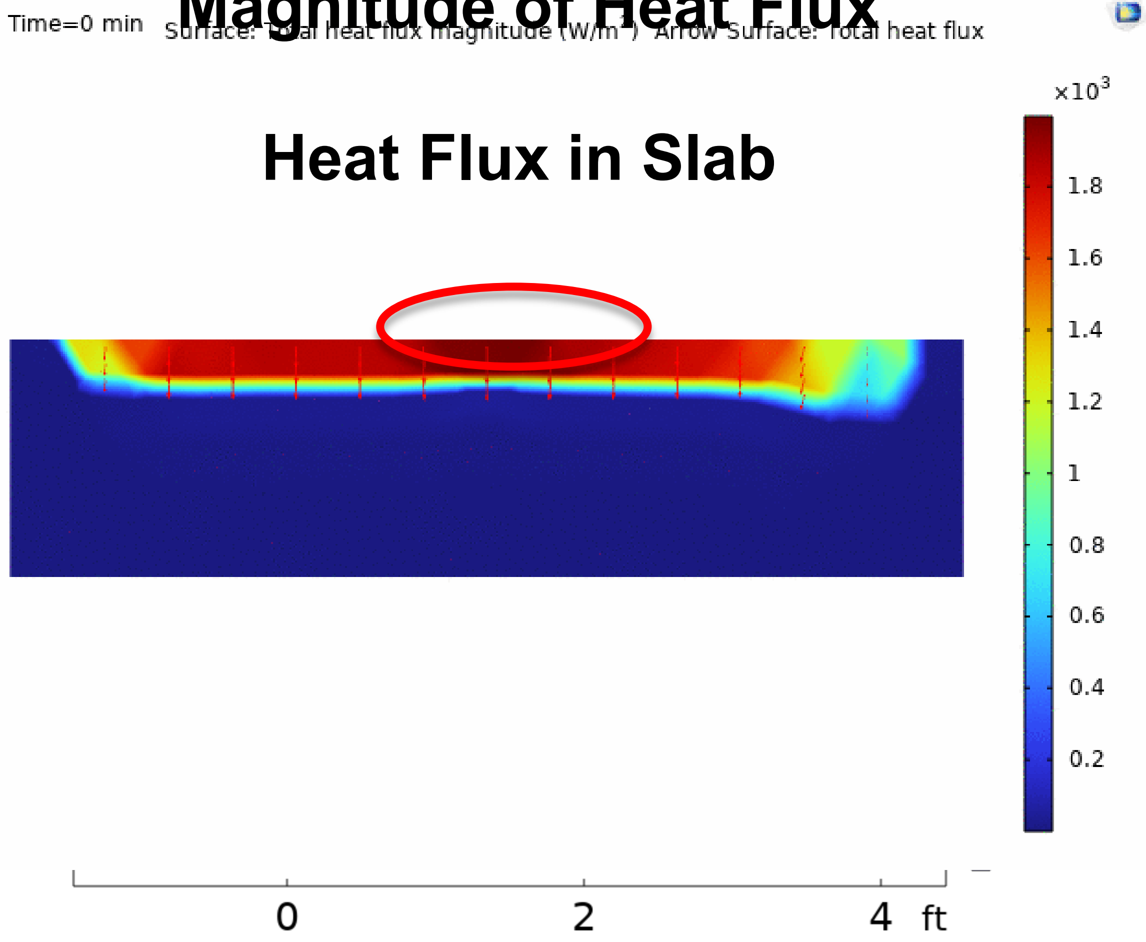


Numerical Simulation: Control Test



Magnitude of Heat Flux

Heat Flux in Slab



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

Conclusions

- Temperature variation with depth – Temperature Zones
  - 2° Celsius – Control test
  - Less than 1° Celsius – GBF
- Temperature dropped with time
  - GBF (T-7,T-1,T-0) was warmer compared to control test
- Numerical simulation of control test
  - Good match with the test results
  - Indicates major heat loss of the slab is to the ambient air

Future Works

- Continue lab tests for other combinations of geofoam grade, thicknesses and arrangements
- Numerical Simulation

LIFE FORMS

Project: Application of Geofoam in Thermal Encapsulation of Foundations

Number: 6

Design and Testing of IFI Geosynthetic Products

Team: Md Ashrafuzzaman Khan,
Nripojyoti Biswas, Krishneswar Ramineni, and Surya S.C. Congress

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

Closed Meeting

TAMU Site Proprietary

NSF IUCRC CICI TAMU SITE
NSF IUCRC CICI - IAB Spring 2022 Virtual Meeting

May 11, 2022

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

Background and Objectives

Background

- ❑Problematic subgrades – Millions of infrastructure damages
- ❑HDPE geosynthetic products may provide sustainable and economic solution
- ❑There is a lack of knowledge about their 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 in a large-scale laboratory setup to calibrate design parameters based on Giroud-Han (G-H) method

Large-scale repeated load test section
(Base = 12 inch; Subgrade = 18 inch)

Progress of Work

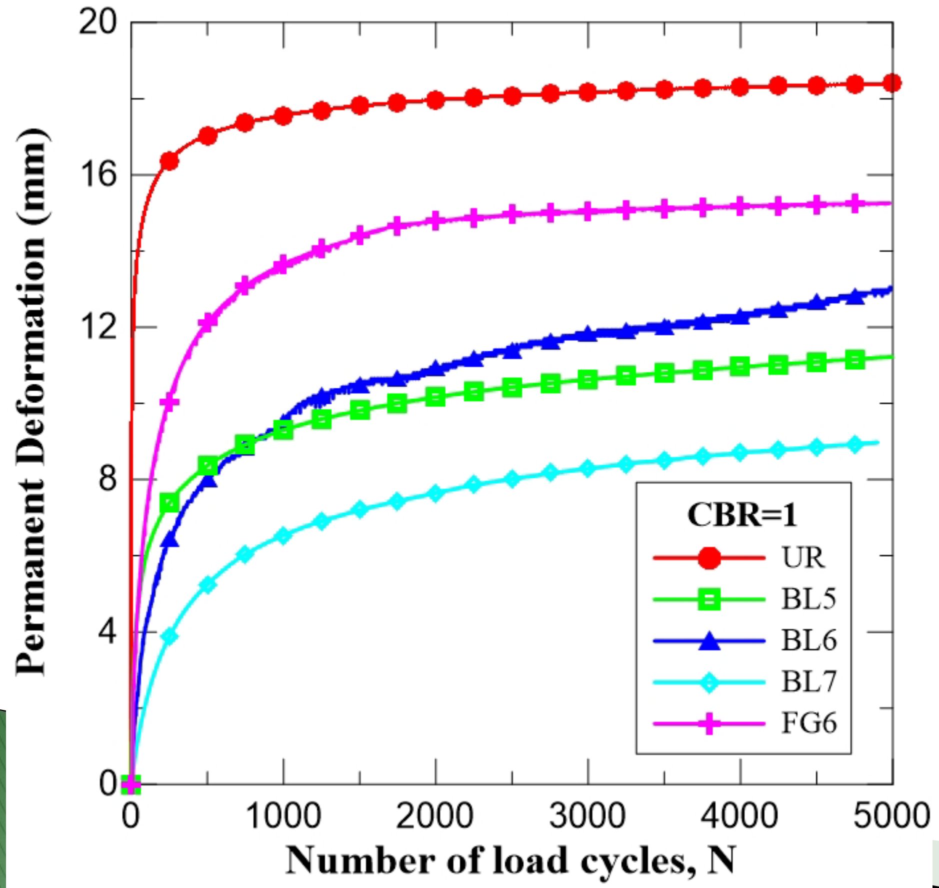
Task List

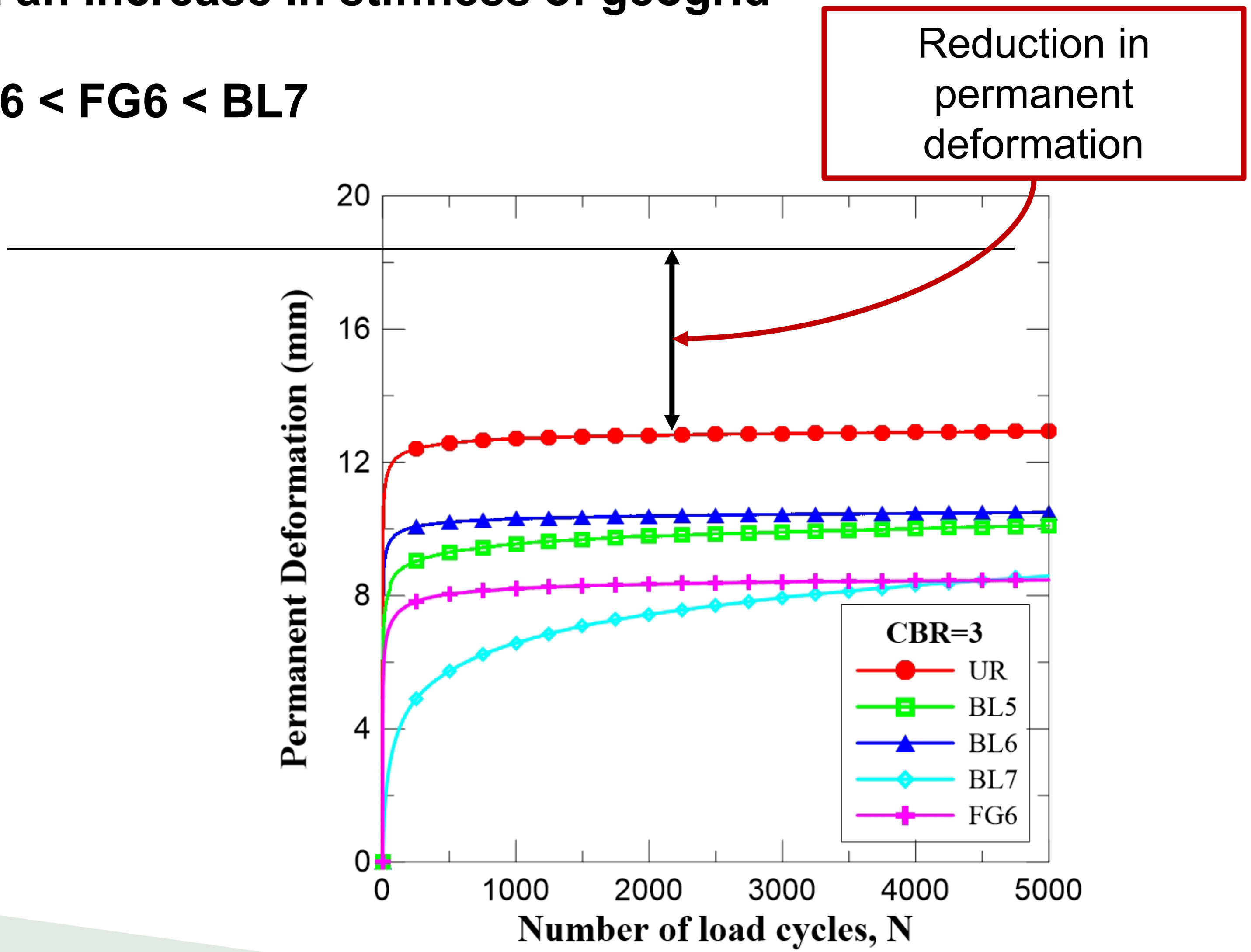
- ❑ **Characterization of subgrade material** → IUCRC meeting 2nd December 2020
- ❑ **Characterization of base material**
- ❑ **Construction of large-scale test section**

  → IUCRC meeting 26th May 2021
- ❑ **Large-scale repeated load testing results for CBR = 1** → IUCRC meeting 8th December 2021
- ❑ **Large-scale repeated load testing results for CBR = 3**
- ❑ **Calibration for high-strength geogrids**

Test Results

- ❑ **Permanent deformation decreased with higher CBR value of subgrade soil**
- ❑ **Permanent deformation decreased with an increase in stiffness of geogrid**
- ❑ **Strength of various geogrids: BL5 < BL6 < FG6 < BL7**

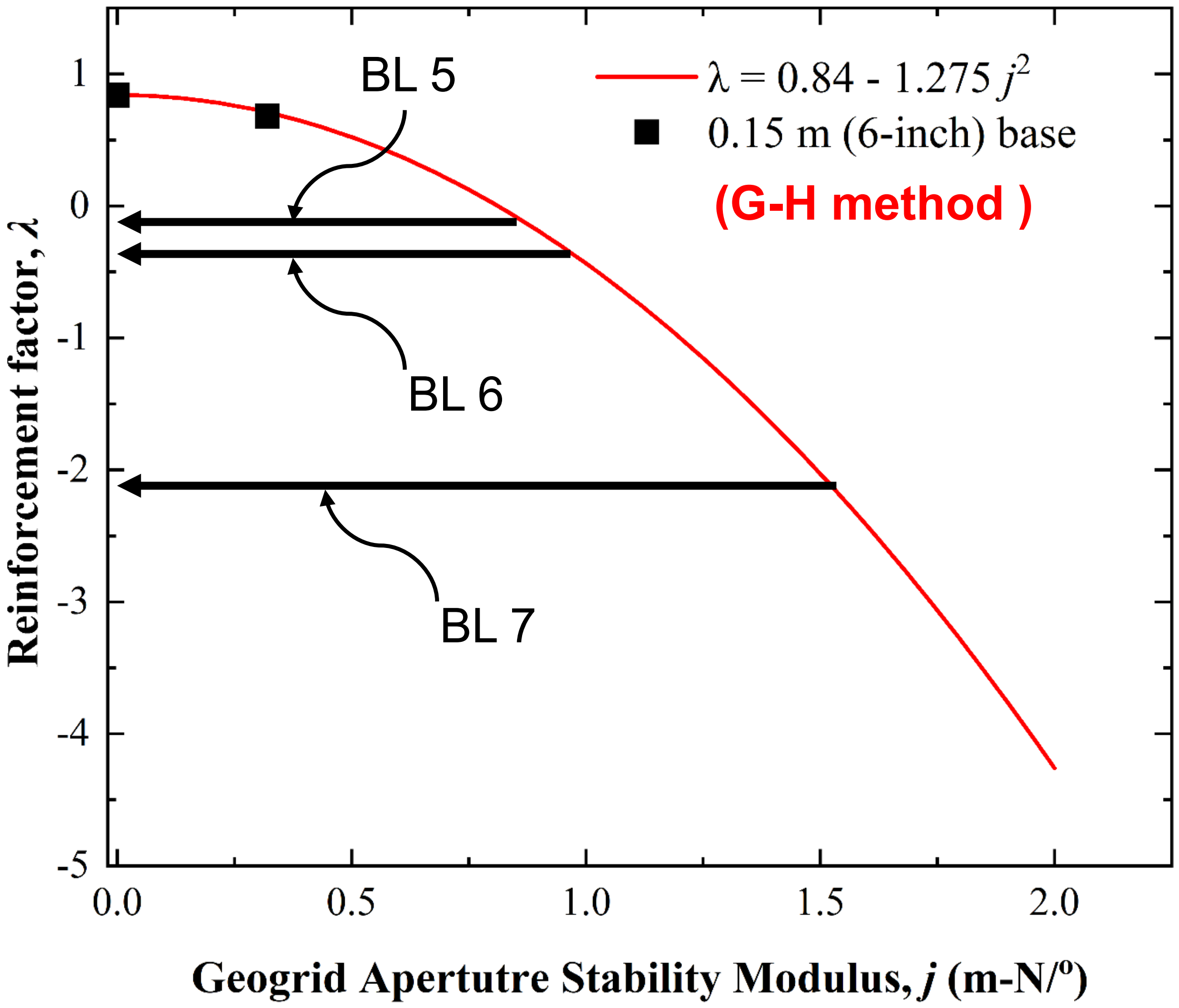




Calibration of G-H Method

- G-H method is based on the laboratory test results available for low-strength geogrids (j < 0.40)
- Current research is focused on high strength geogrids (j > 0.7)
- The proposed reinforcement factor, λ, needs to be calibrated for the high strength geogrids

Product ID	Aperture stability m-N/deg.
BL 5	0.80
BL6	0.98
BL7	1.50
FG6 (FAB)	0.98



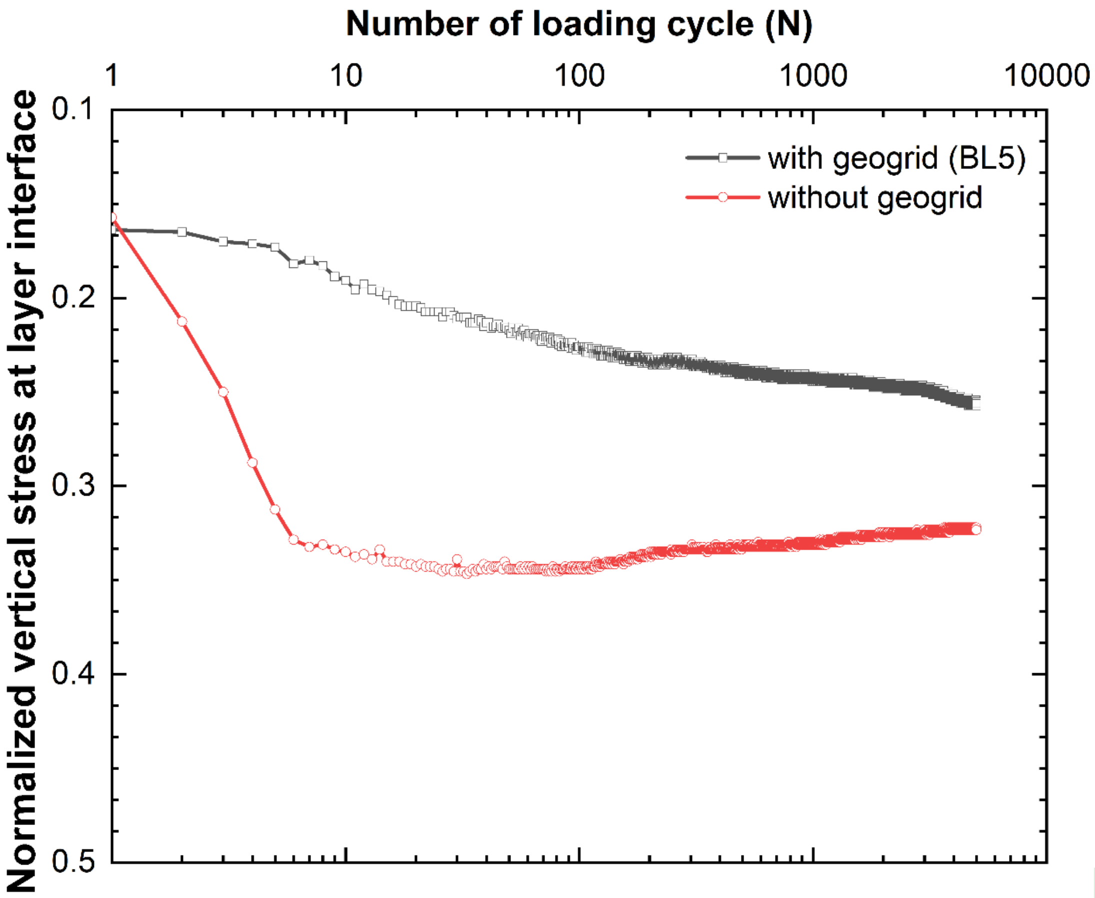
Calibration of G-H Method Continued…

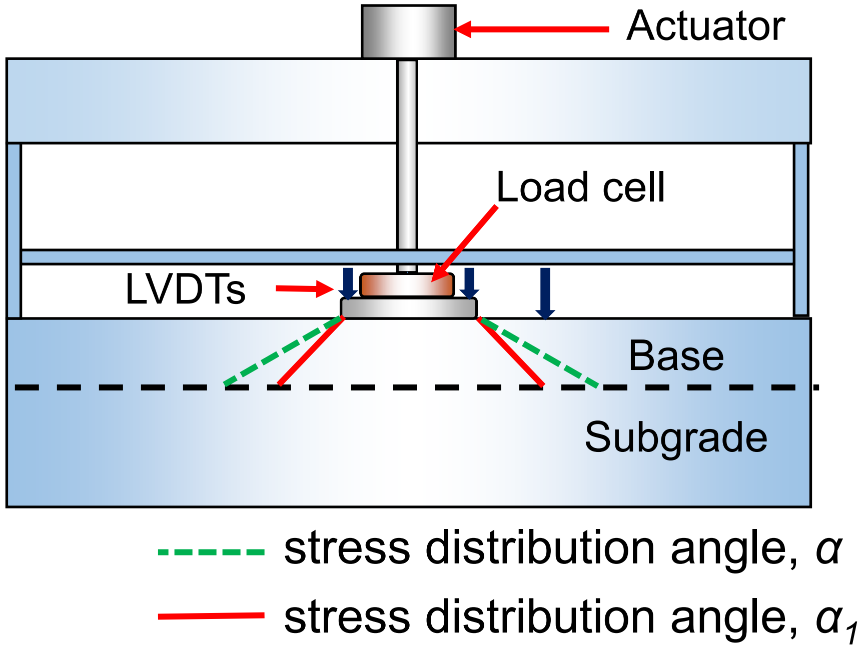
- ❑ ***λ* values depend on stress distribution angle**
- ❑ **Inclusion of geocell reduced the stresses at the interface between base and subgrade**

$$\frac{1}{\tan\alpha} = \frac{1}{\tan\alpha_1} + \lambda^* \log N$$

α = stress distribution angle for the case where the number of passes is *N*;

α_1 = stress distribution angle for the case where the number of passes is one





LIFE FORMS

Project: Design and Testing of IFI Geosynthetic Products

Number: 7

Center for Integration of Composites into Infrastructure

Performance of pavement sections with H_2Ri geosynthetics

Project Leader: Nripojyoti Biswas

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

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

Closed Meeting

TAMU Site Proprietary

Texas Department of Transportation

TENCATE

NSF IUCRC CICI TAMU SITE
NSF IUCRC CICI - IAB Spring 2022 Virtual Meeting

May 11, 2022

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

Presentation Outline

- Introduction
- Task Plan
- Laboratory setup:
  - Control Section
  - Reinforced and Two-way drainage
  - Reinforced and One-way drainage
- Life Cycle Analysis

Introduction

❖ Objective

- ❑ Evaluate the feasibility/efficiency of using H_2Ri geosynthetic for improving drainage and strength of pavement sections built on high-plastic expansive soil

- ❖ Field Studies indicated efficacy of application
- ❖ Laboratory studies
  - ❑ Control Section
  - ❑ Reinforced Sections

Control Section

Reinforced Section

Task Plan

Task 1

- ✓ Literature Review
- ✓ Geomaterial Characterization
- ✓ Construction of Test Sections
- ✓ Instrumentation and Monitoring

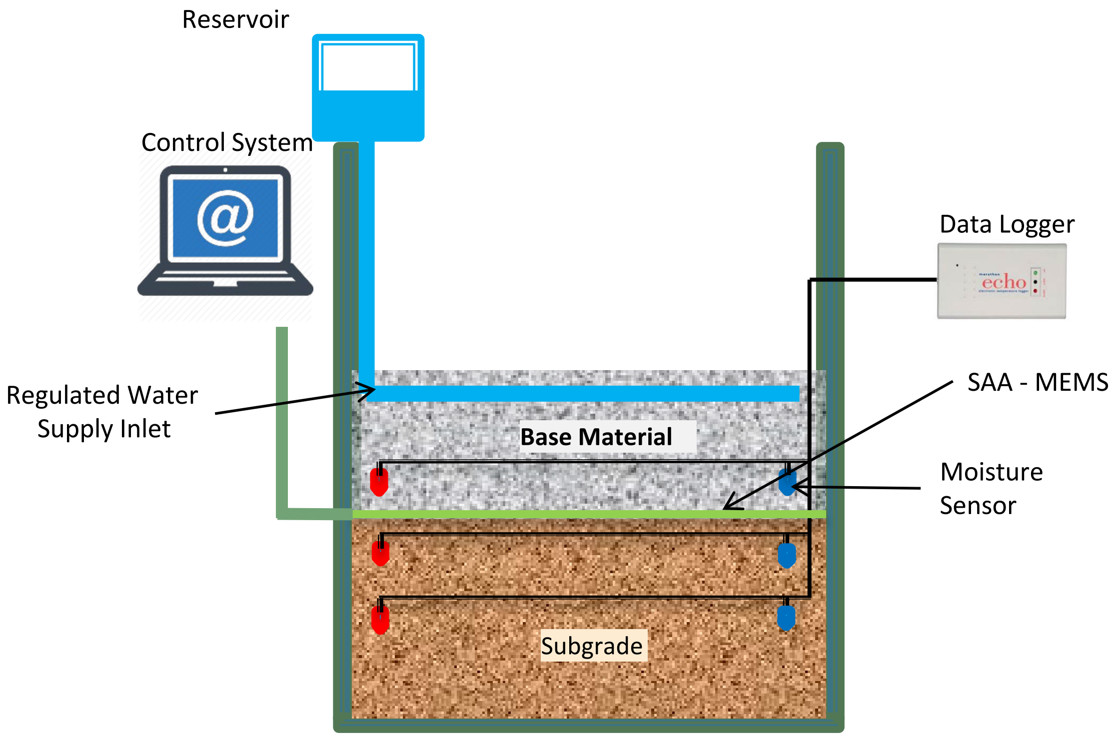
Task 2

- ✓ Laboratory Studies (H_2Ri)
- ✓ Wicking Tests
- ✓ Parametric Study

Task 3

- Life Cycle Analysis
- Carbon Footprint Analysis
- Design & Construction Guidelines

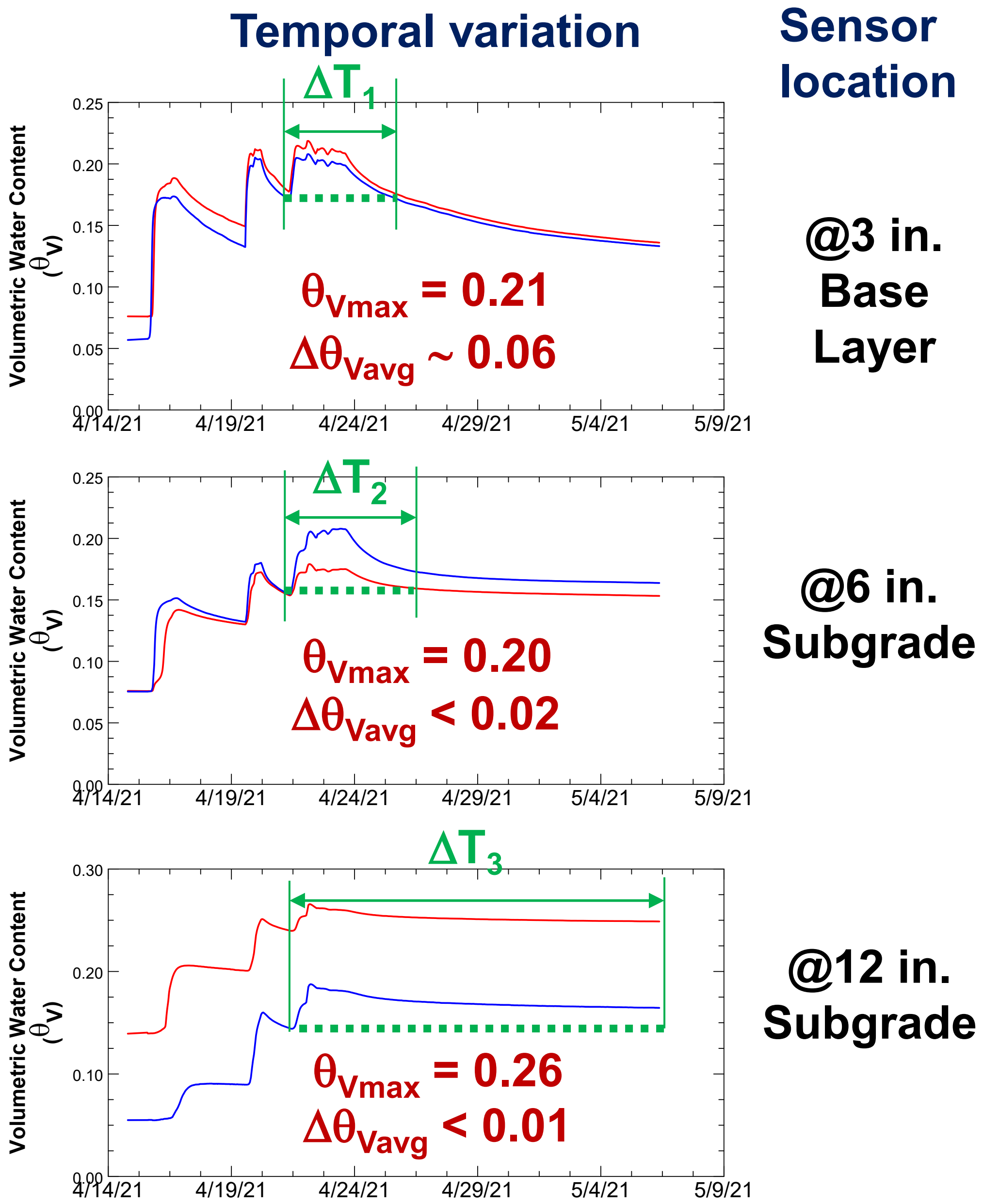
Laboratory setup – Control Section



$\Delta T_1 \sim$ 4.5 days

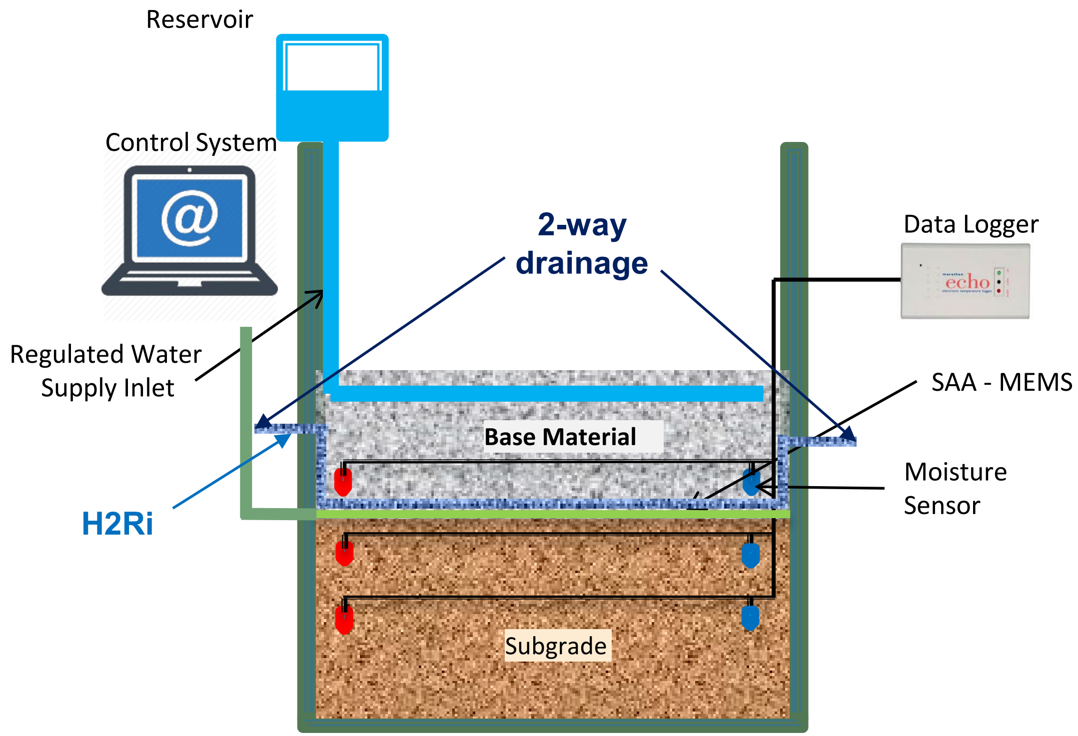
$\Delta T_2 \sim$ 5.25 days

$\Delta T_3 \sim$ N/A



- **Subgrade Soil → $\theta_{Vmax} \sim 0.26$**
- **Drainage →**
  - ❑ **Base → Gravity & Evaporation**
  - ❑ **Subgrade → Gravity**

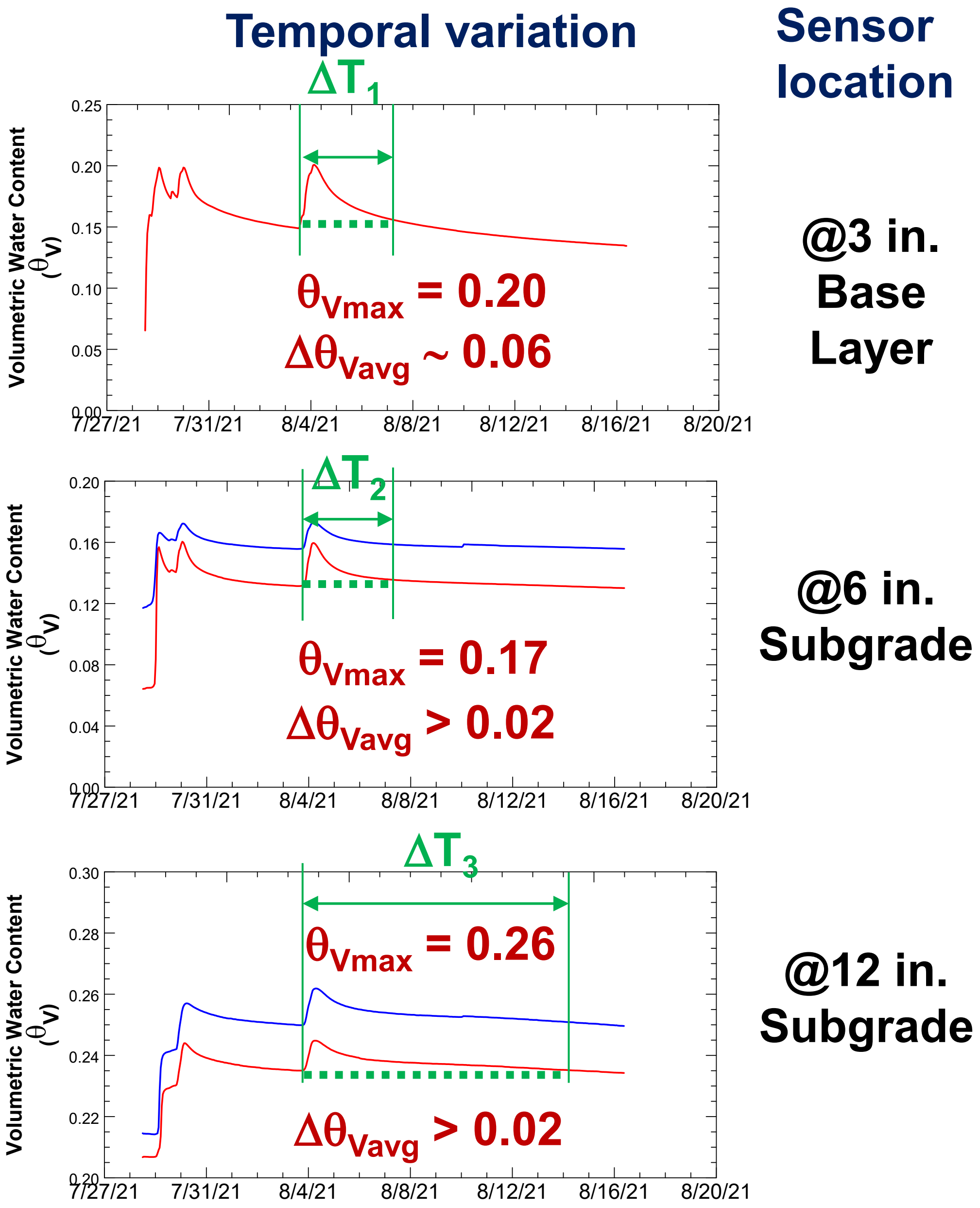
Laboratory setup – Reinforced and Two-way drainage



$\Delta T_1 \sim$ 3.75 days

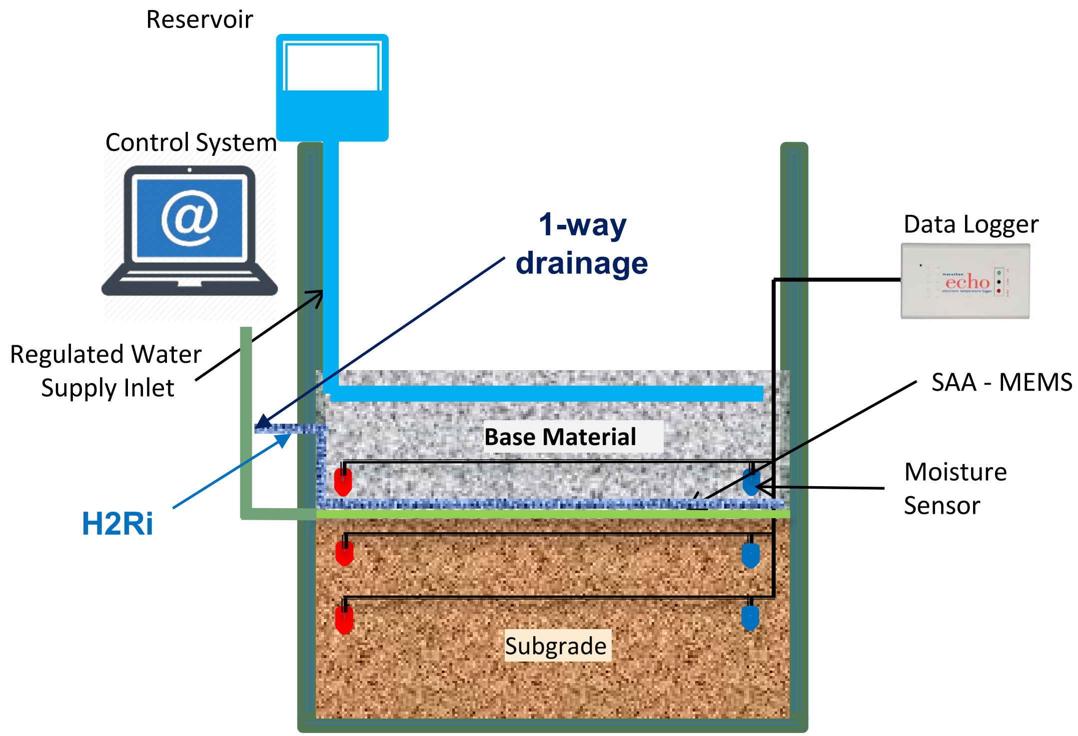
$\Delta T_2 \sim$ 3.75 days

$\Delta T_3 \sim$ 10 days



- ❖ **Wicking Fibers → Drainage Performance ↑**
- ❖ **Base Layer → Drainage Rate ↑**
- ❖ **Zone of Influence in Subgrade ~ 12 in.**

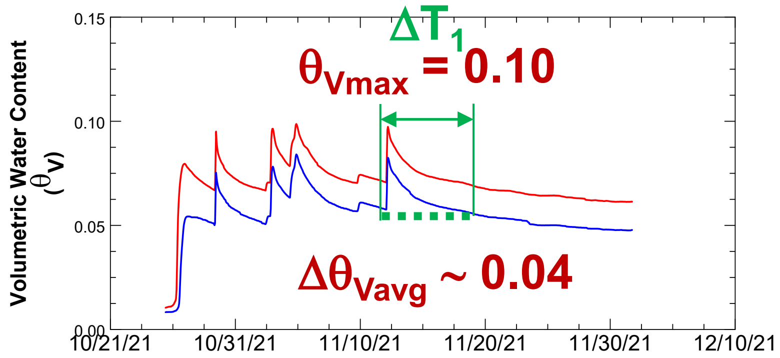
Laboratory setup – Reinforced and One-way drainage



- **Wicking Fibers → Drainage Performance ↑**
- **One-way drainage → Effective ↓**

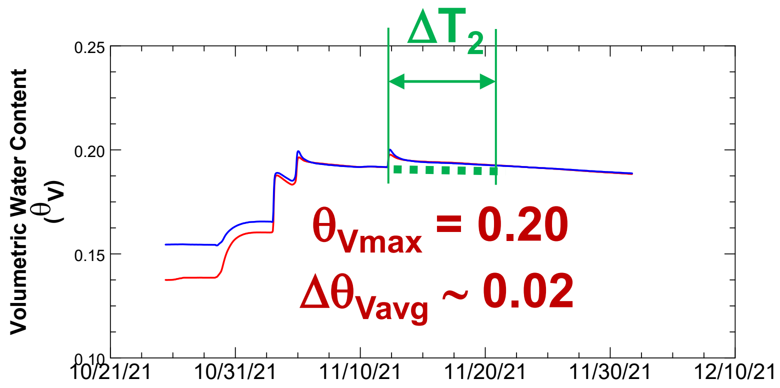
Temporal variation | **Sensor location**

$\Delta T_1 \sim 3.75$ days



@3 in. Base Layer

$\Delta T_2 \sim 4.5$ days



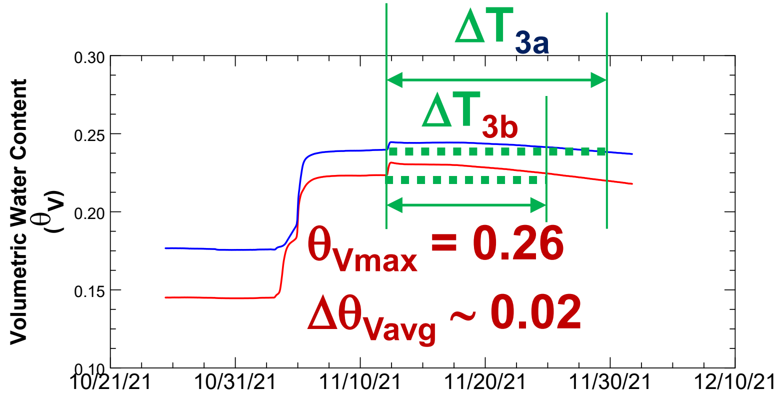
@6 in. Subgrade

$\Delta T_{3a} \sim 10$ days

$\Delta T_{3b} \sim 6.5$ days

*a- closed end

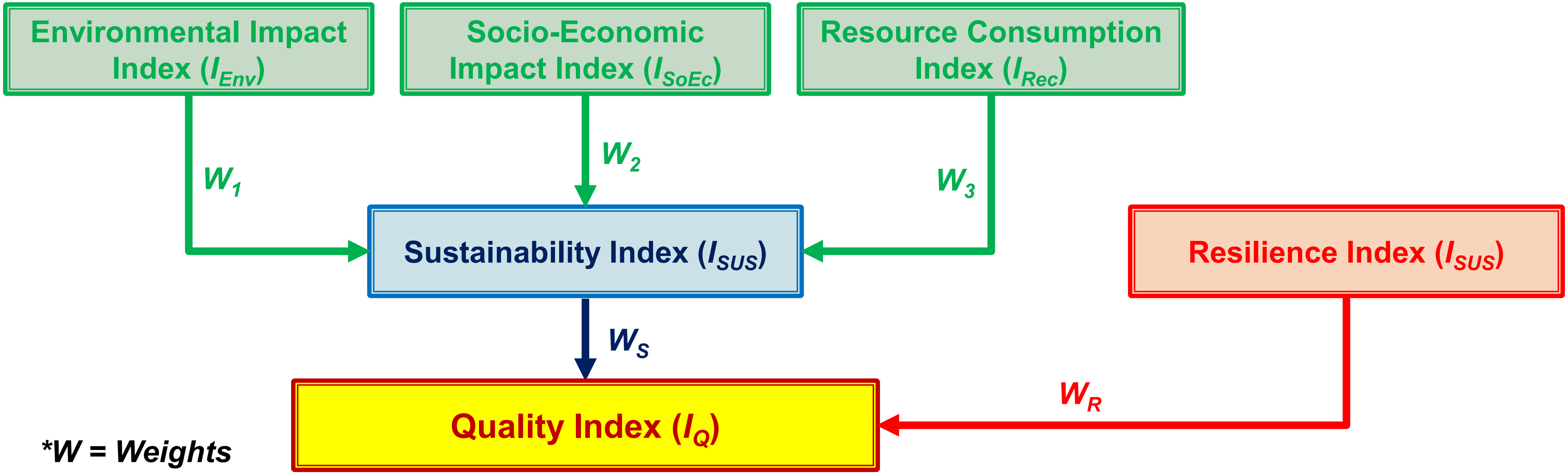
*b- drainage end



@12 in. Subgrade

Life Cycle Analysis

Combined Assessment Framework (Das 2018)



$$I_{SUS} = W_1 \times I_{Env} + W_2 \times I_{SoEc} + W_3 \times I_{Rec}$$

$$I_Q = W_s \times I_{SUS} + W_R \times I_{Res}$$

LIFE FORMS

Project: Performance of pavement sections with H_2Ri geosynthetics

Number: 8