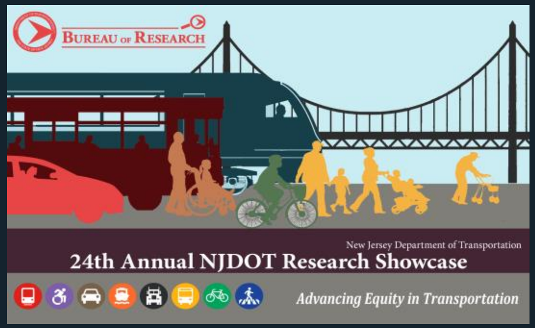

Developing Electrically Heated Flexible Pavements for Self Deicing Application

Ashith Marath, M.S

Center for Research and Education in Advanced Transportation Engineering Systems (CREATES)

Rowan University

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Rowan University
CENTER FOR RESEARCH & EDUCATION IN ADVANCED TRANSPORTATION ENGINEERING SYSTEMS

Background

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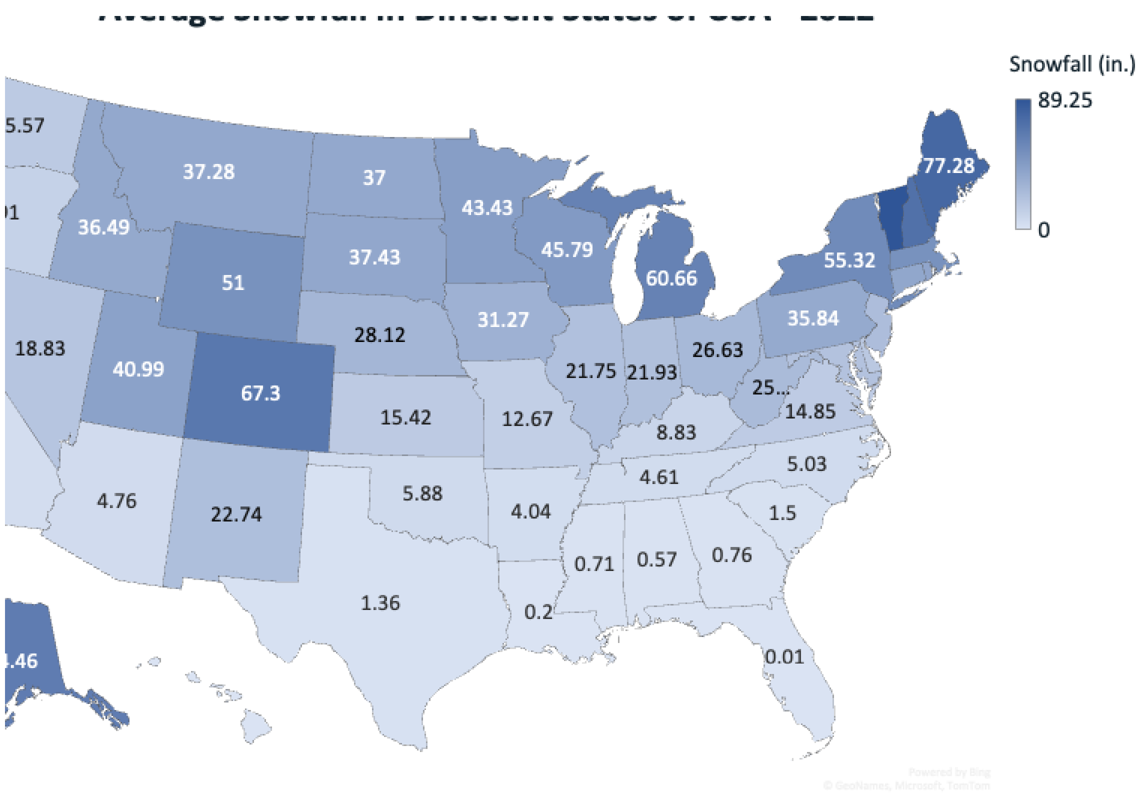

Data source: www.usa.com

Background

Snow/Ice Mitigation Techniques

Use of chemicals and salts

Source: Willowpix/iStock

Snow plowing

Source: https://commons.wikimedia.org/w/index.php?curid=4747960

Problem Statement

Labor intensive and time-consuming techniques → Operational delays, safety concerns

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Deteriorating pavement structures → Durability issues

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Labor intensive and time-consuming techniques → Operational delays, safety concerns

Deteriorating pavement structures → Durability issues

Increased salinity → Groundwater contamination

Research Goal

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Evaluate the efficiency of electrically-heated pavements for deicing applications in cold regions

Study Objectives

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- Develop electrically-conductive asphalt mixtures using different dosages of conductive additives
- <u>Construct full-scale pavement test strips</u> using selected electrically-conductive mixtures
- Monitor <u>heating performance and power consumption</u> for each test strip
- Long-term performance evaluation

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Materials and Design of Conductive Asphalt Mix

Selected Asphalt Mixture for Modification

High Performance Thin Overlay (HPTO) JMF	
NMAS	4.75 mm
Air Void	3.5 ± 1%
Optimum Binder Content	7.7 %
Gmm	2.459
Dust to Binder Ratio	0.9 (Target : 0.6 – 1.3)
Binder	PG 76-22

Preparation of Conductive Asphalt Mixture (ECA)

Graphite

Asphalt

FA

CA

Carbon fiber

Preparation of Conductive Asphalt Mixture (ECA)

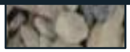
Graphite

Carbon fiber

Preparation of Conductive Asphalt Mixture (ECA)

Asphalt

Until achieved
3.5% Air Voids



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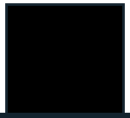

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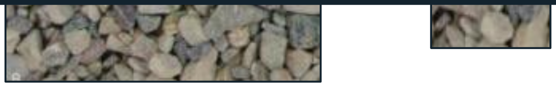
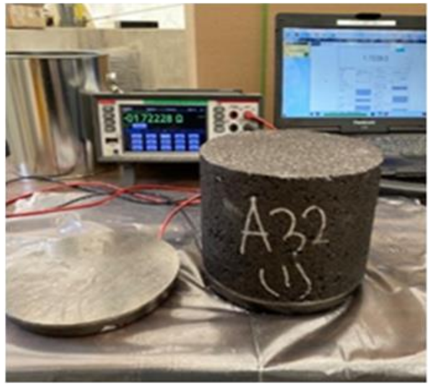


Resistivity Testing and Results

Place graphite
on a steel plate

Test contact
resistance



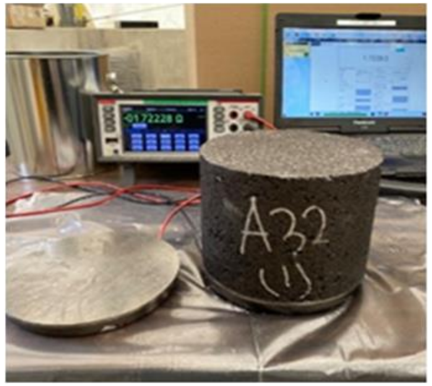
Place graphite on
top of sample

Test resistivity of
asphalt sample

Resistivity Testing and Results

Place graphite on a steel plate

Test contact resistance



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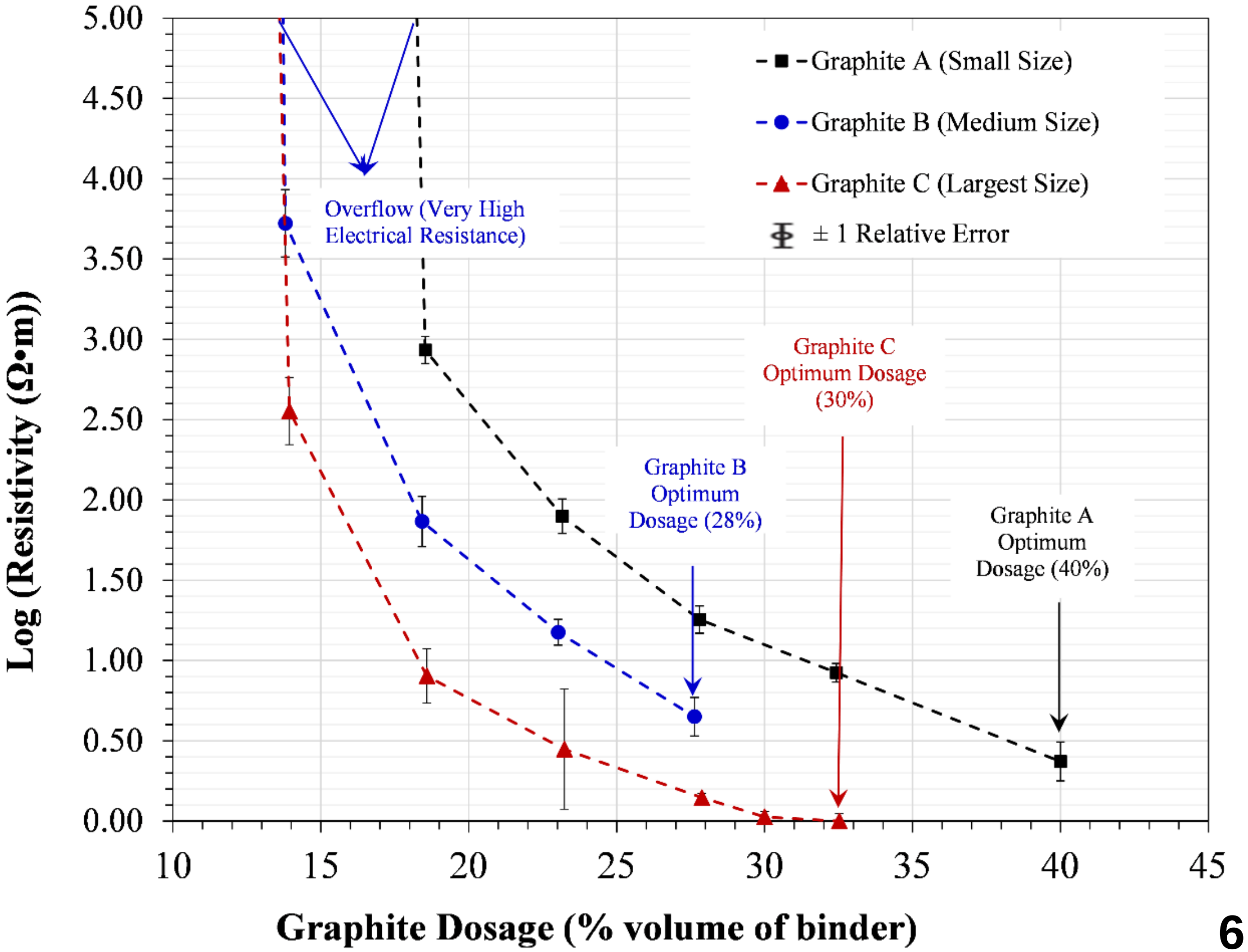

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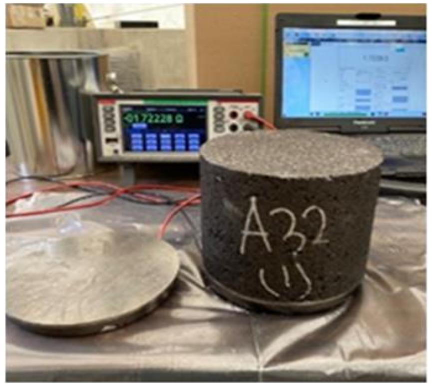

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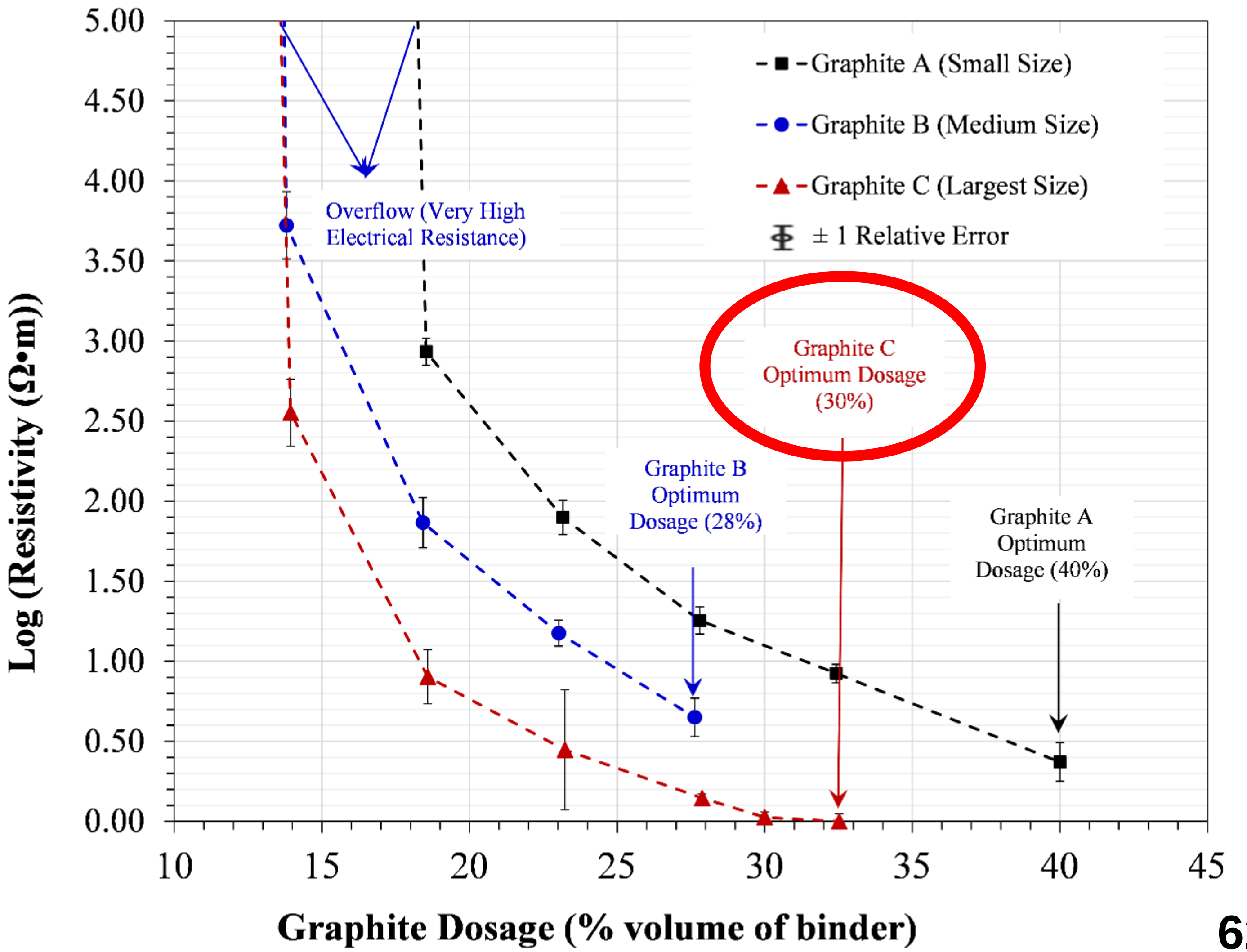
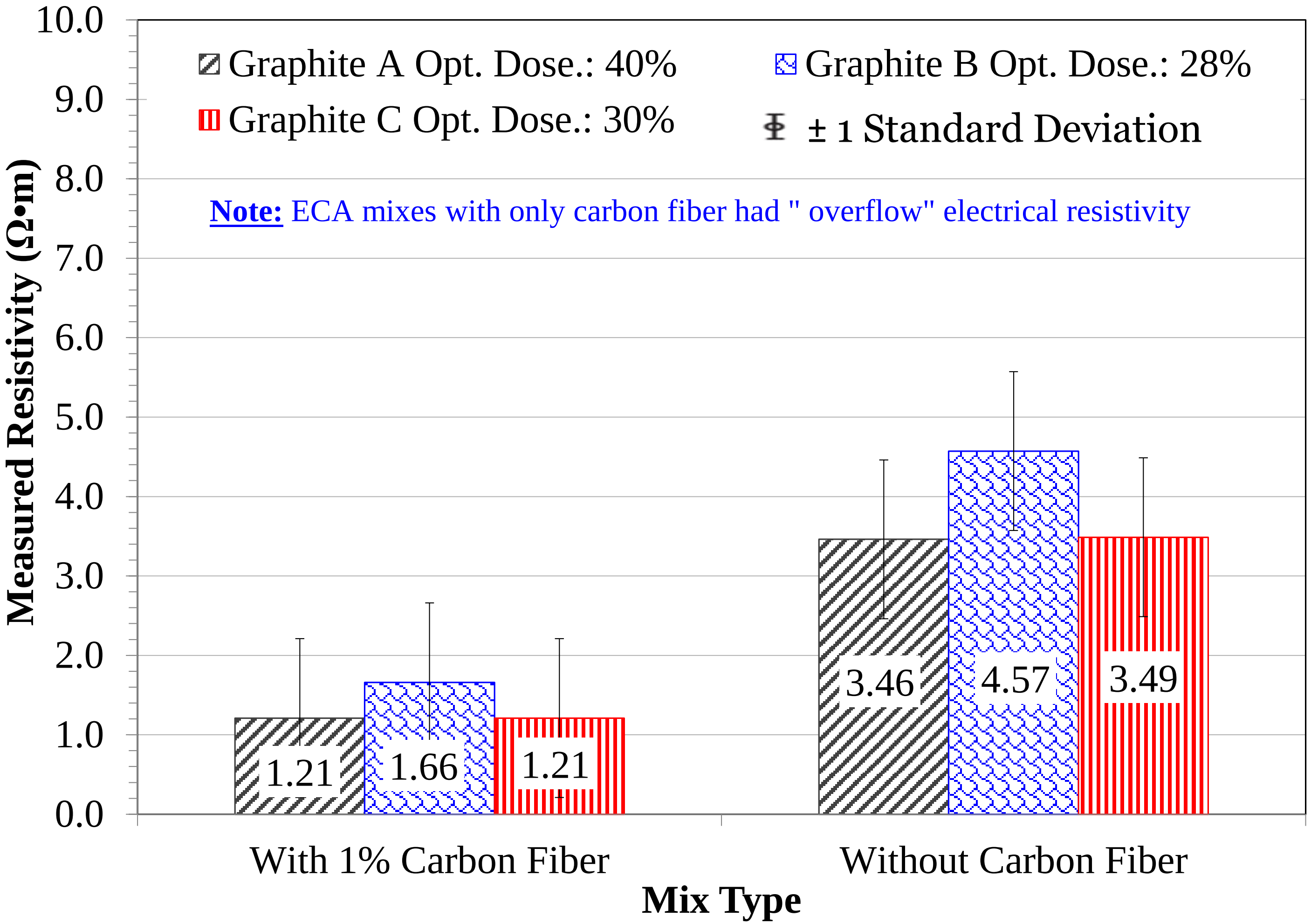


Impact of Carbon Fiber on Resistivity



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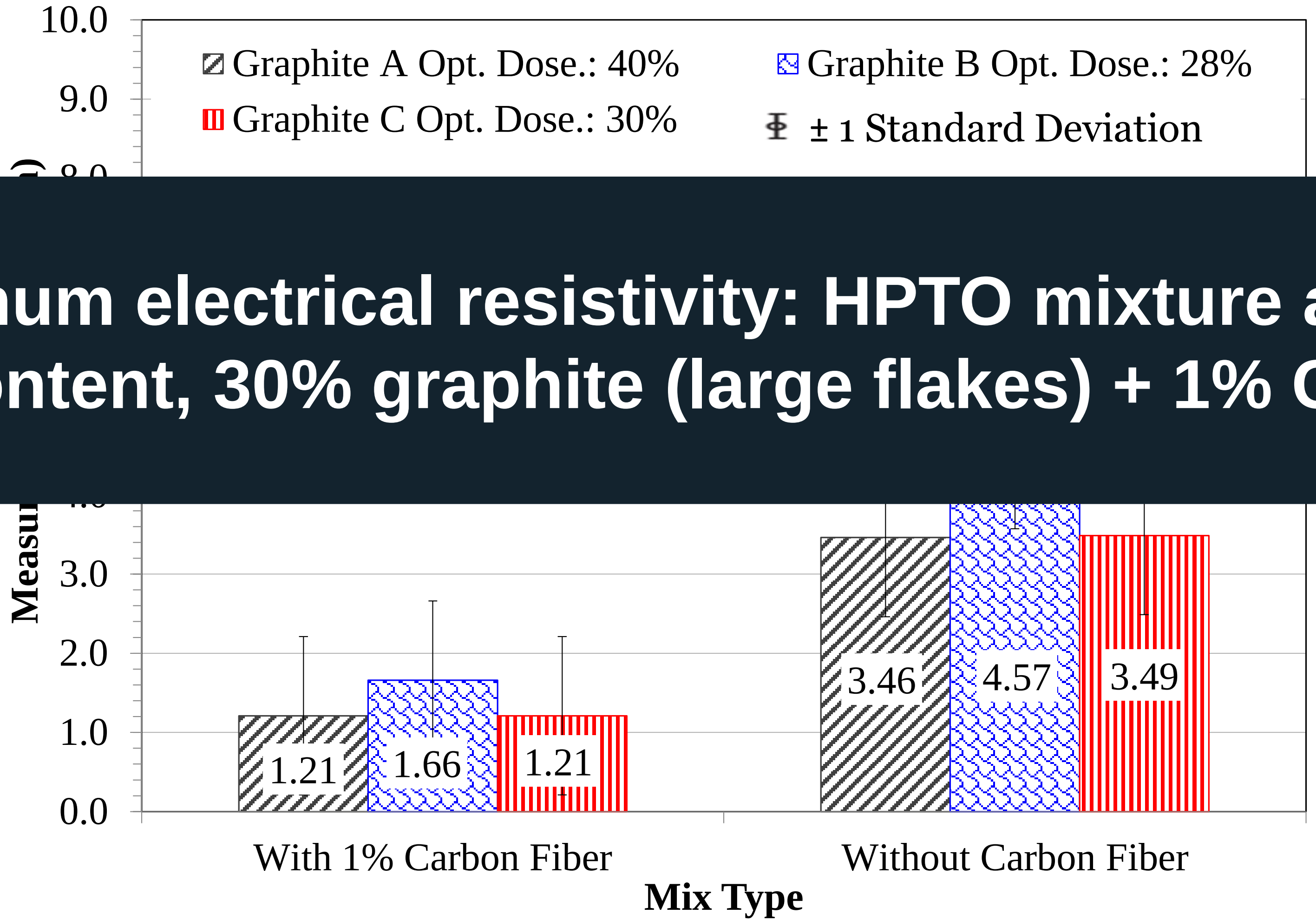
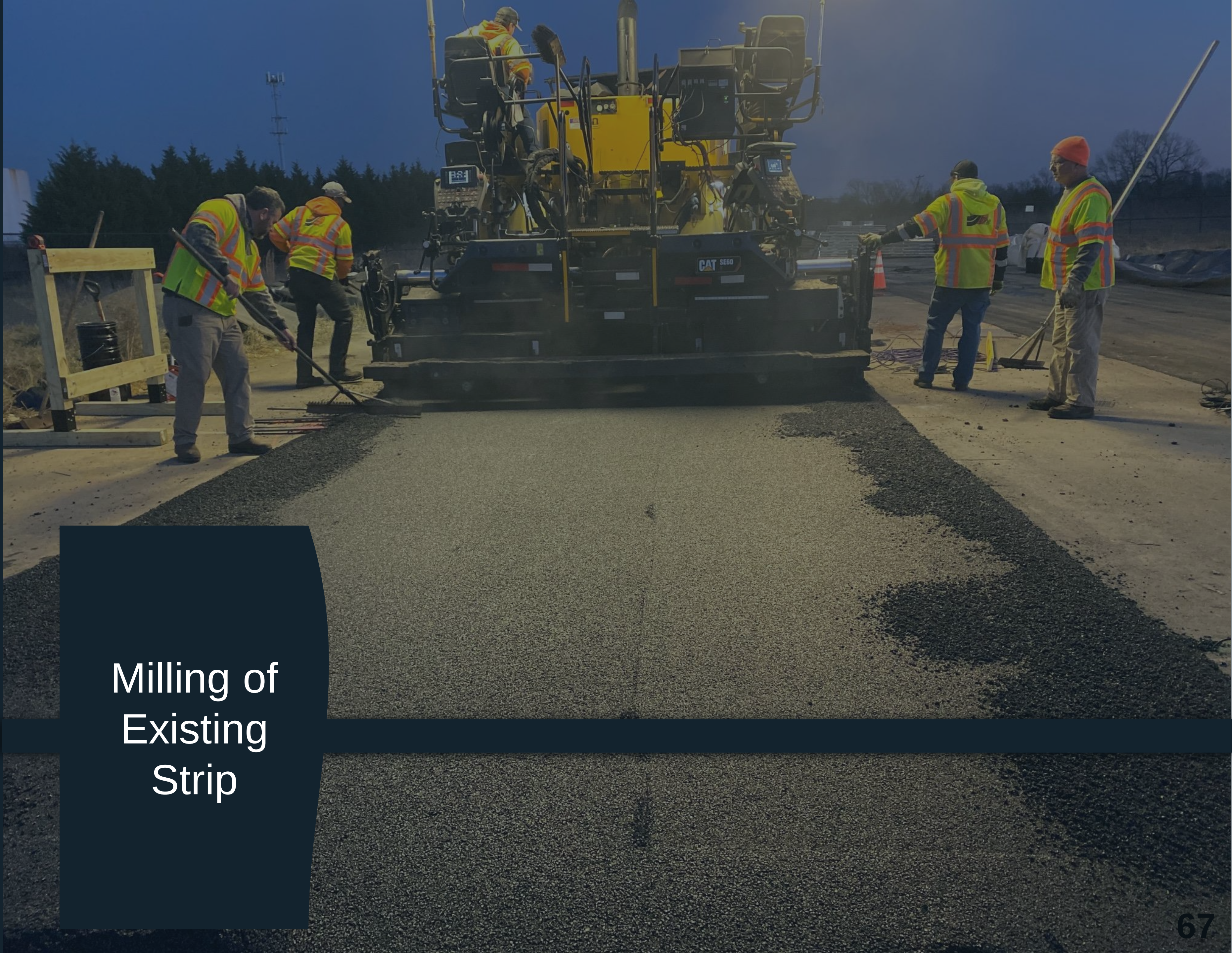


Mix with minimum electrical resistivity: HPTO mixture at 8.1 % binder content, 30% graphite (large flakes) + 1% CF

Construction of Full-Scale Test Strips

Construction Steps

Construction Steps



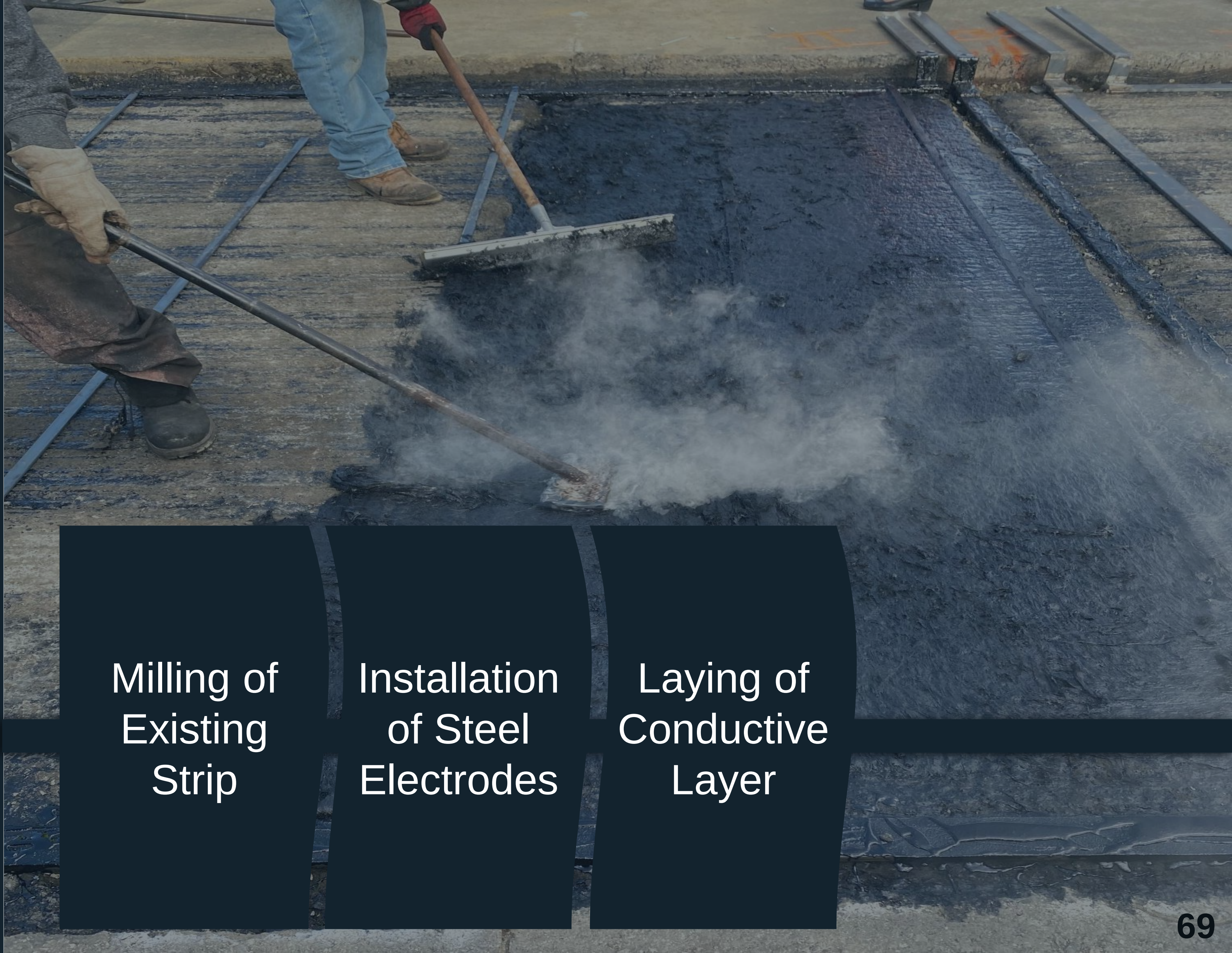
Milling of Existing Strip

Construction Steps

Milling of Existing Strip

Installation of Steel Electrodes

Construction Steps



- Milling of Existing Strip
- Installation of Steel Electrodes
- Laying of Conductive Layer

Construction Steps

Milling of Existing Strip

Installation of Steel Electrodes

Laying of Conductive Layer

Laying of Asphalt Capping Layer

Construction Steps

Milling of Existing Strip

Installation of Steel Electrodes

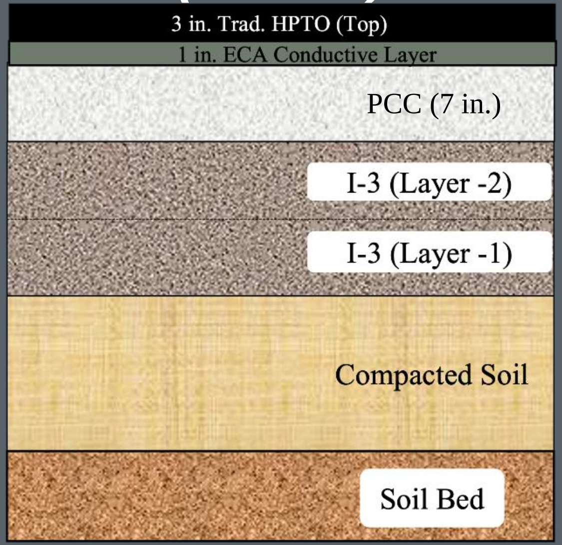
Laying of Conductive Layer

Laying of Asphalt Capping Layer

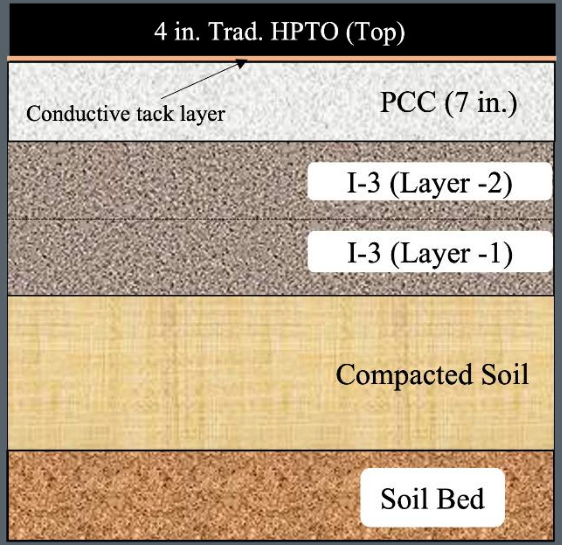
Pavement Strips' Structures

Pavement Strips' Structures

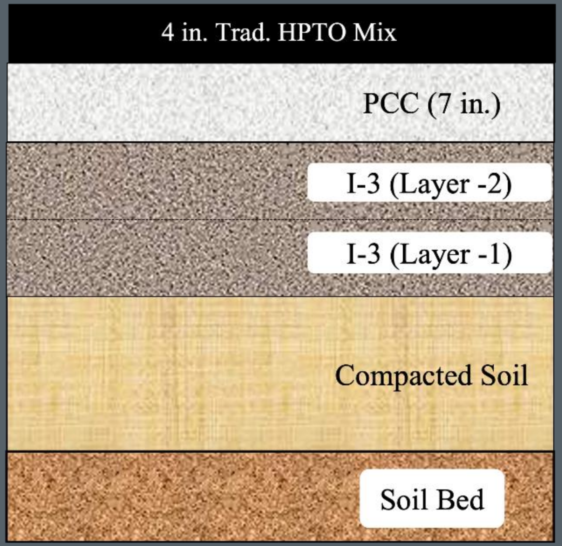
Conductive HPTO Mix *(Rowan)*



Proprietary Heated Pavement *(Heatpave)*



Control Section



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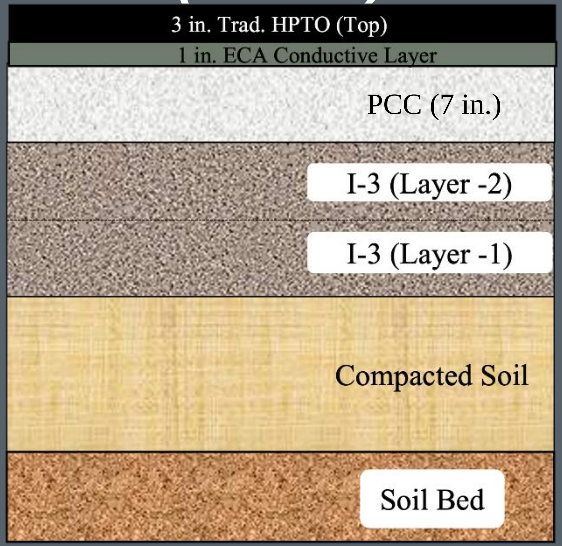

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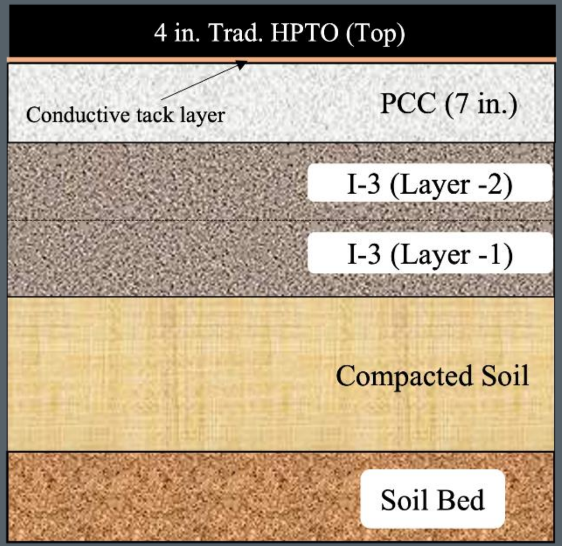

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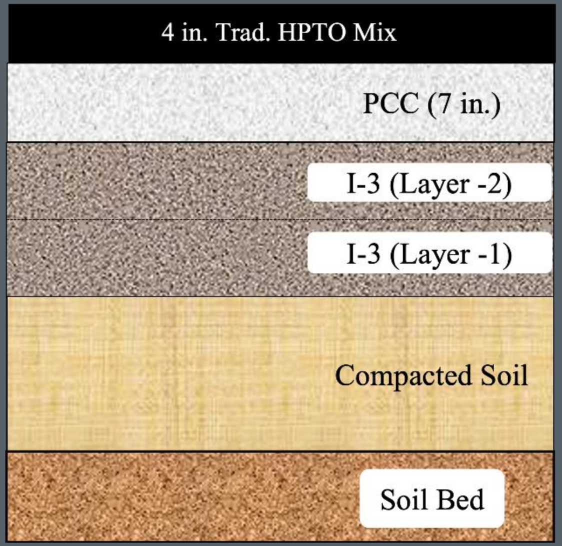

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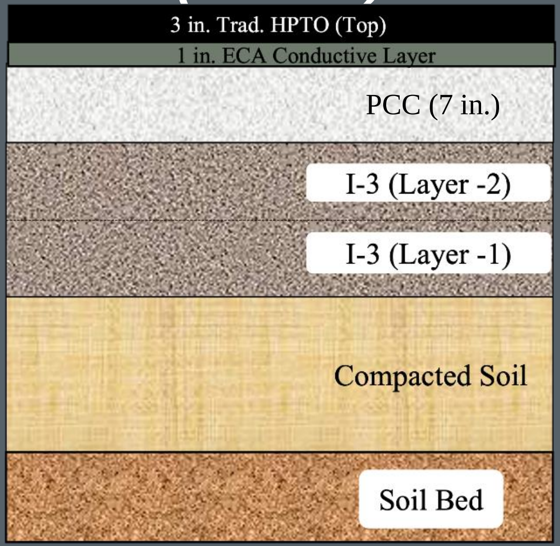

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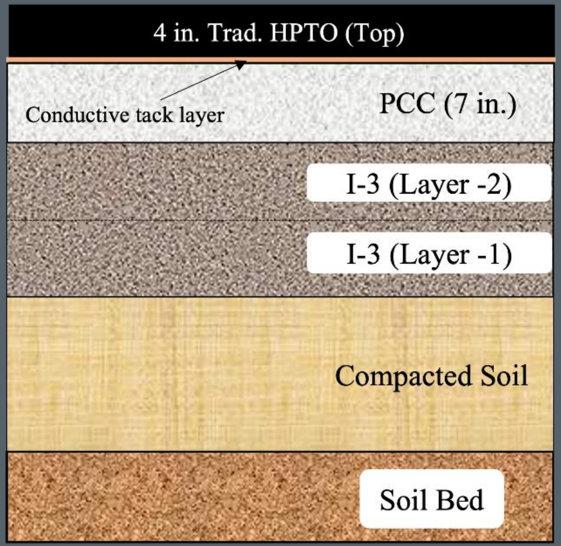

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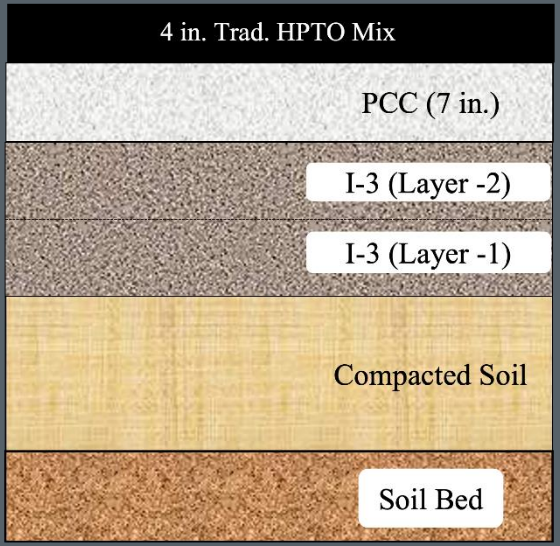

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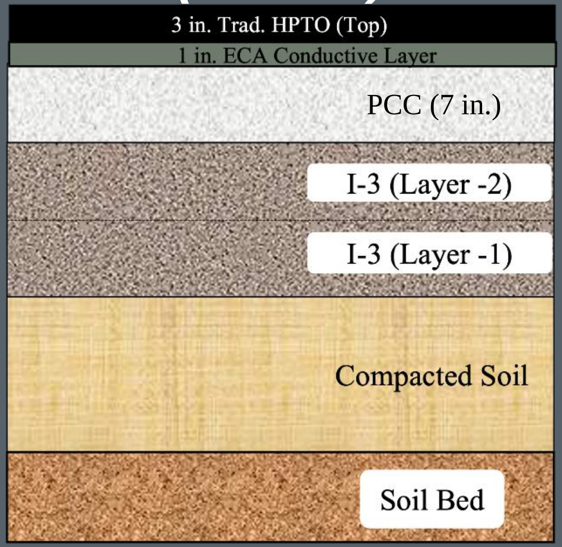

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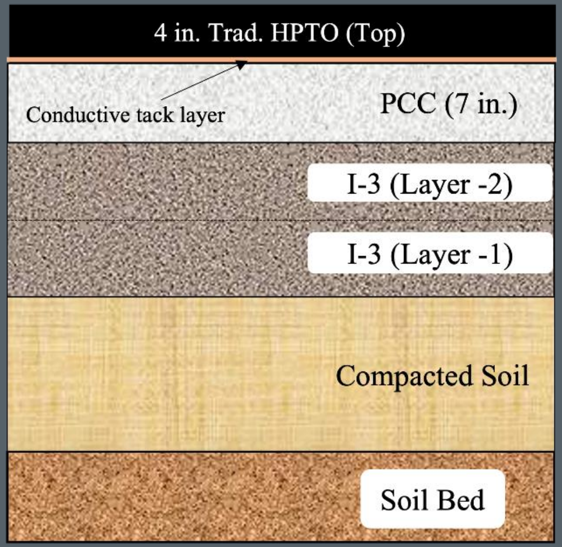

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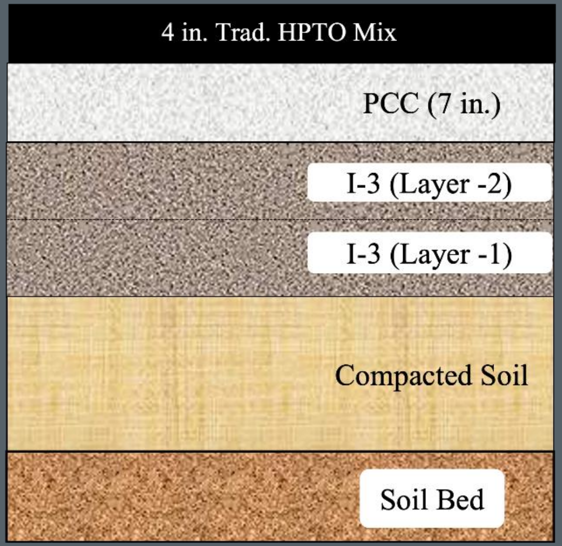

Electrode Installation and Spacing

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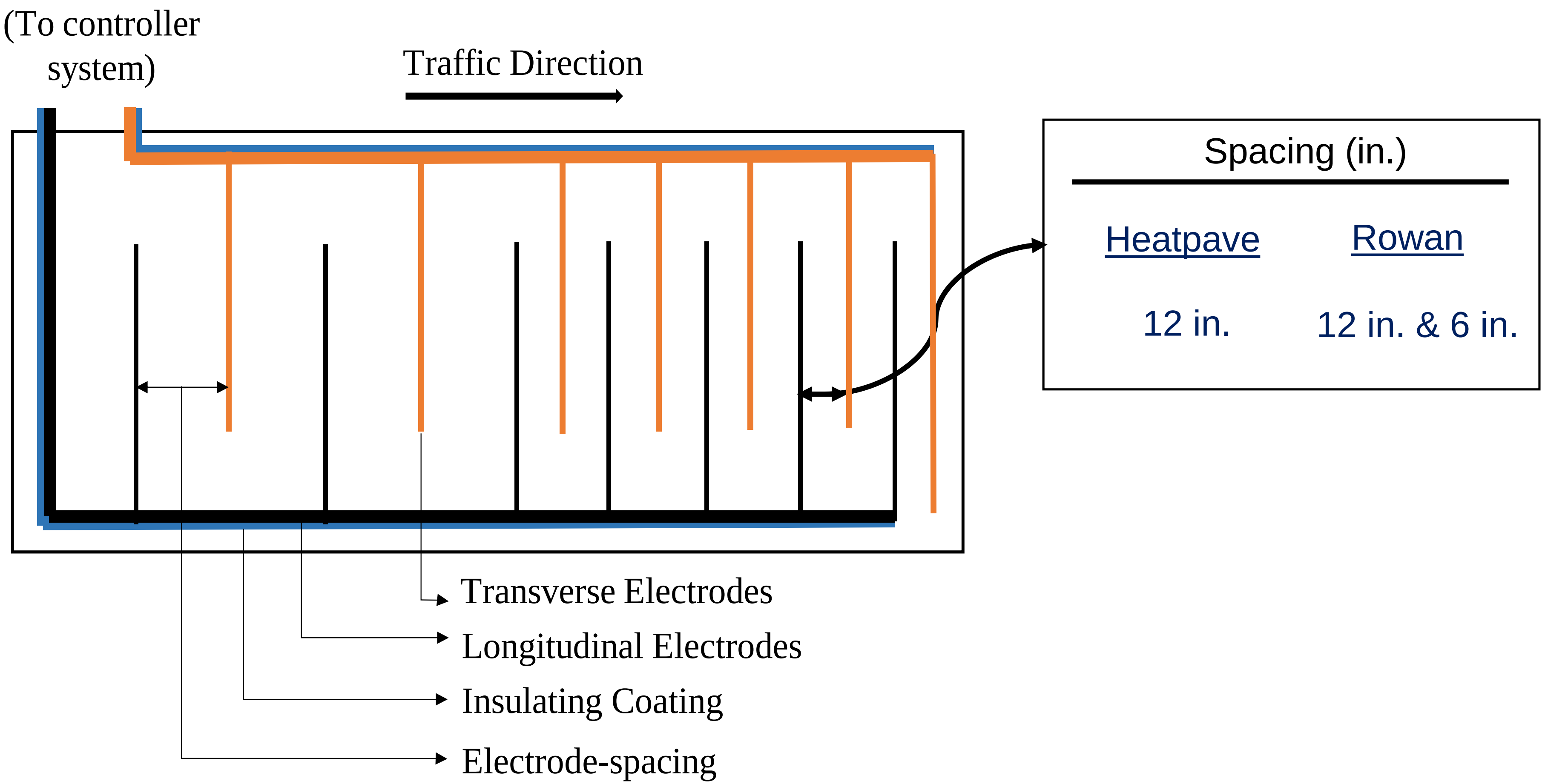
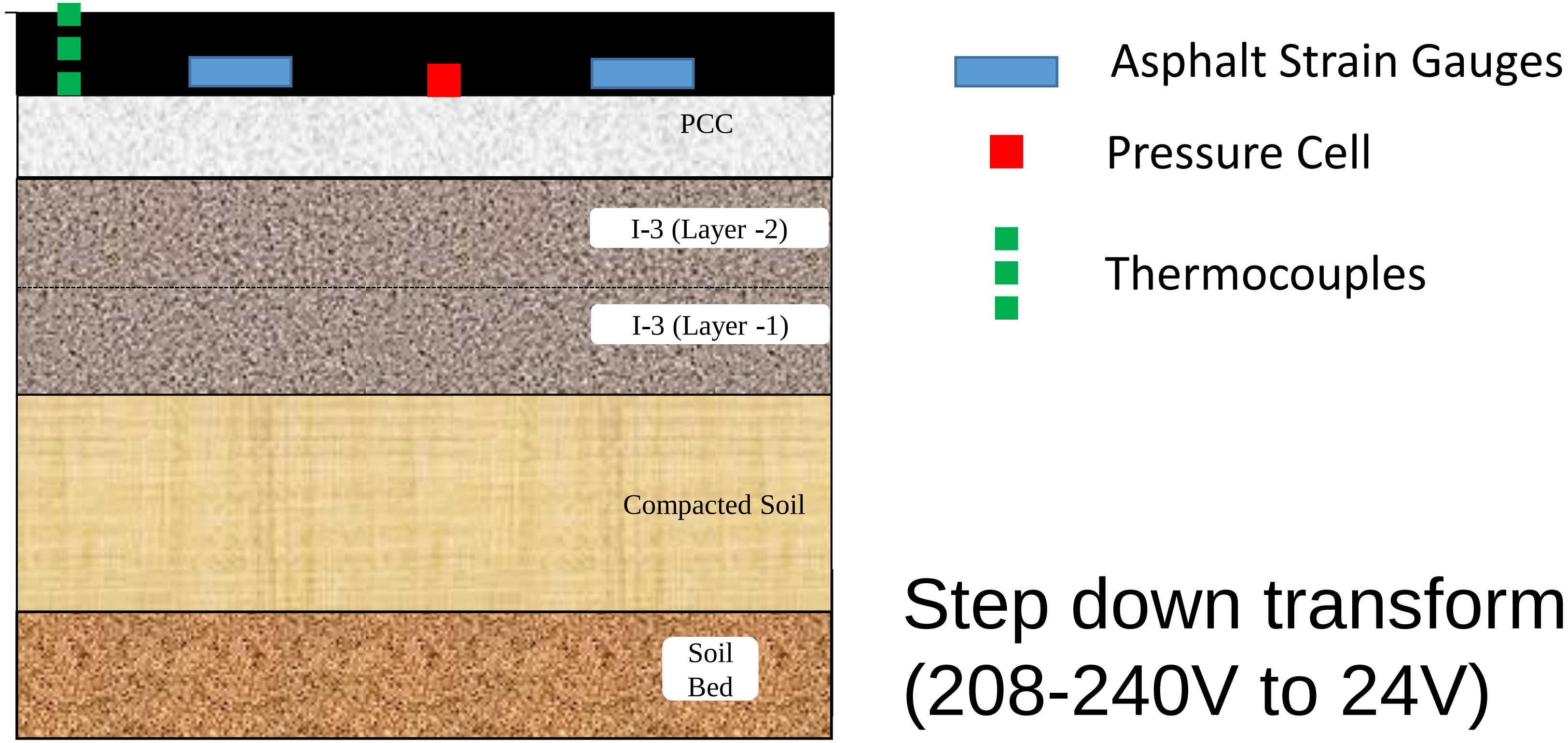


- Longitudinal electrodes: 2.5 in. wide and 0.5 in. thick steel
- Transverse electrodes are 1 in. wide and 0.125 in. thick steel

Instrumentation



Transverse Pavement Cross-Section

Step down transformers (208-240V to 24V)

Evaluate System Efficiency and Pavement Heating Performance

Methodology for Power Supply

Method 1:

Method 2:

Methodology for Power Supply

Method 1:

- System run manually
- Both the section was set ON at same time

Method 2:

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- Controlled by embedded sensor (controller)
- Heating is ON at 46º F and OFF at 52º F

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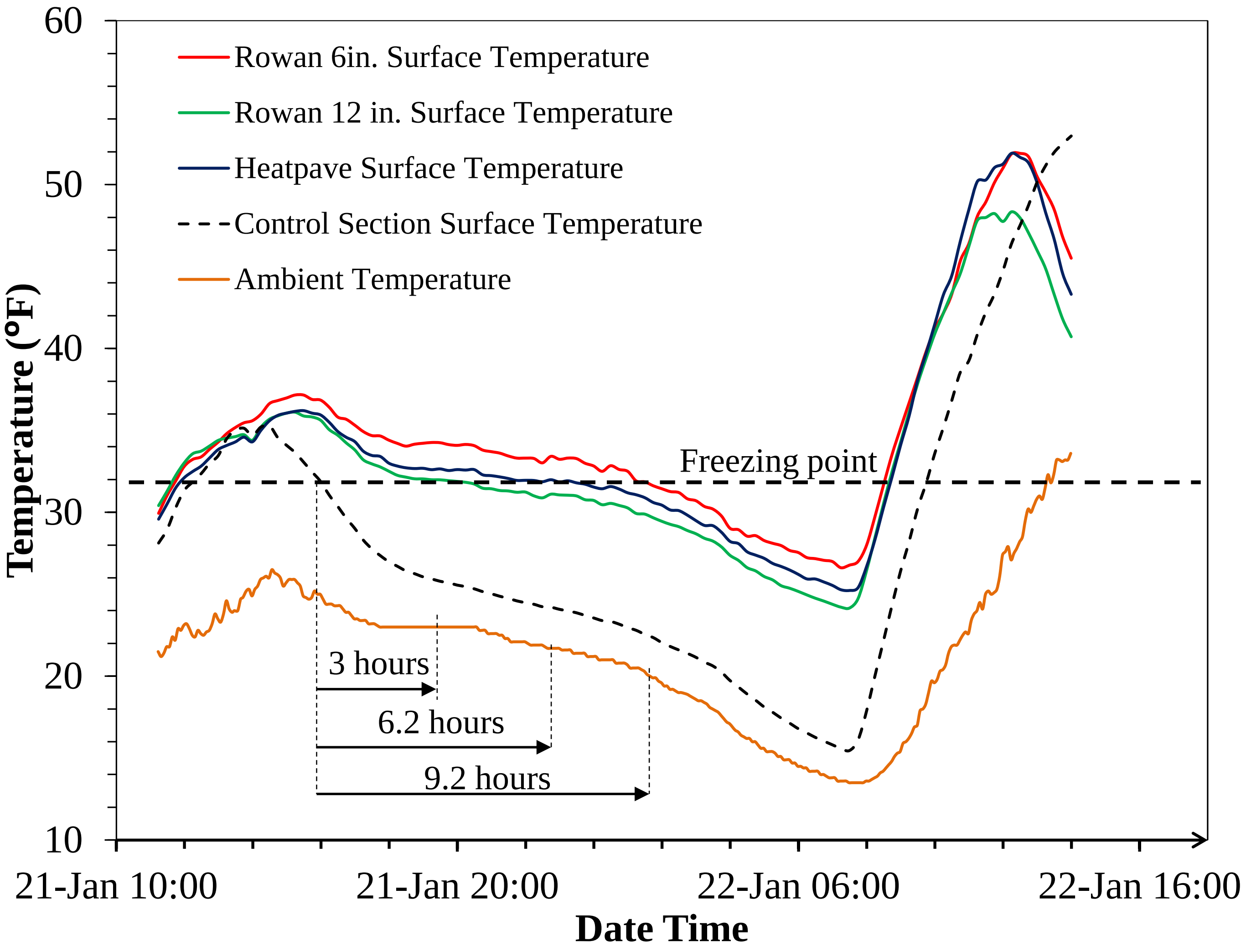
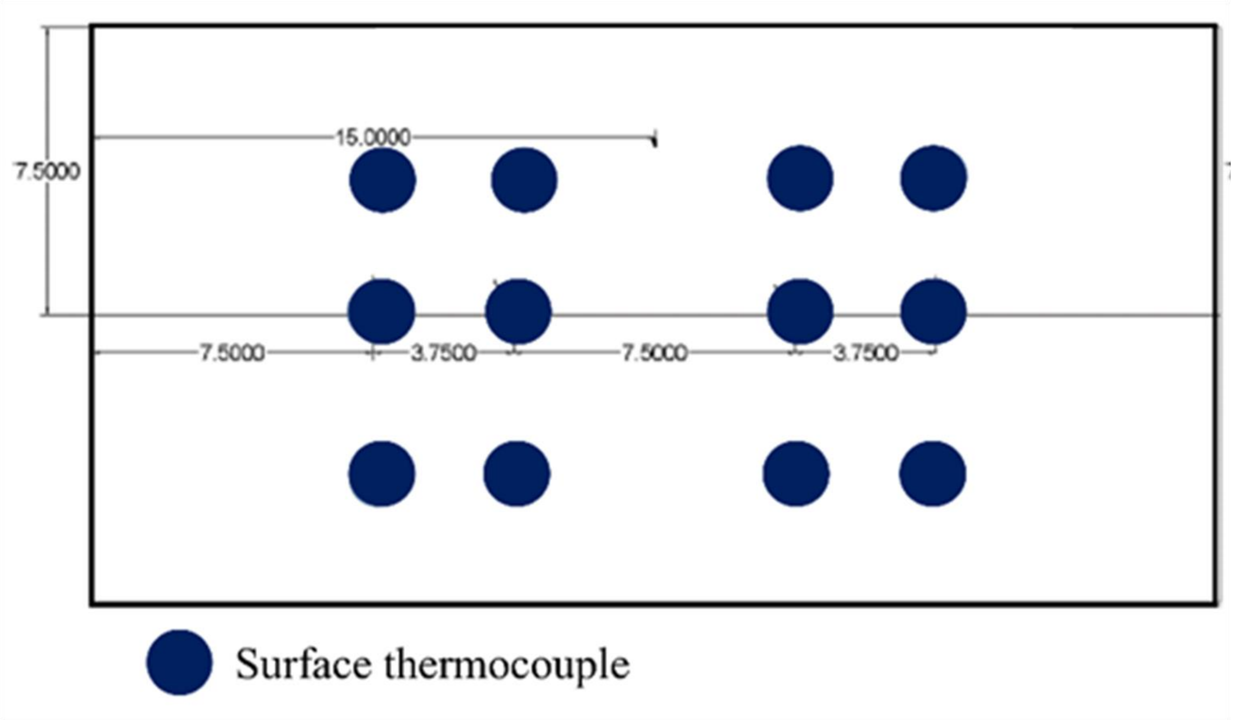
Surface Temperature Profile During Heating



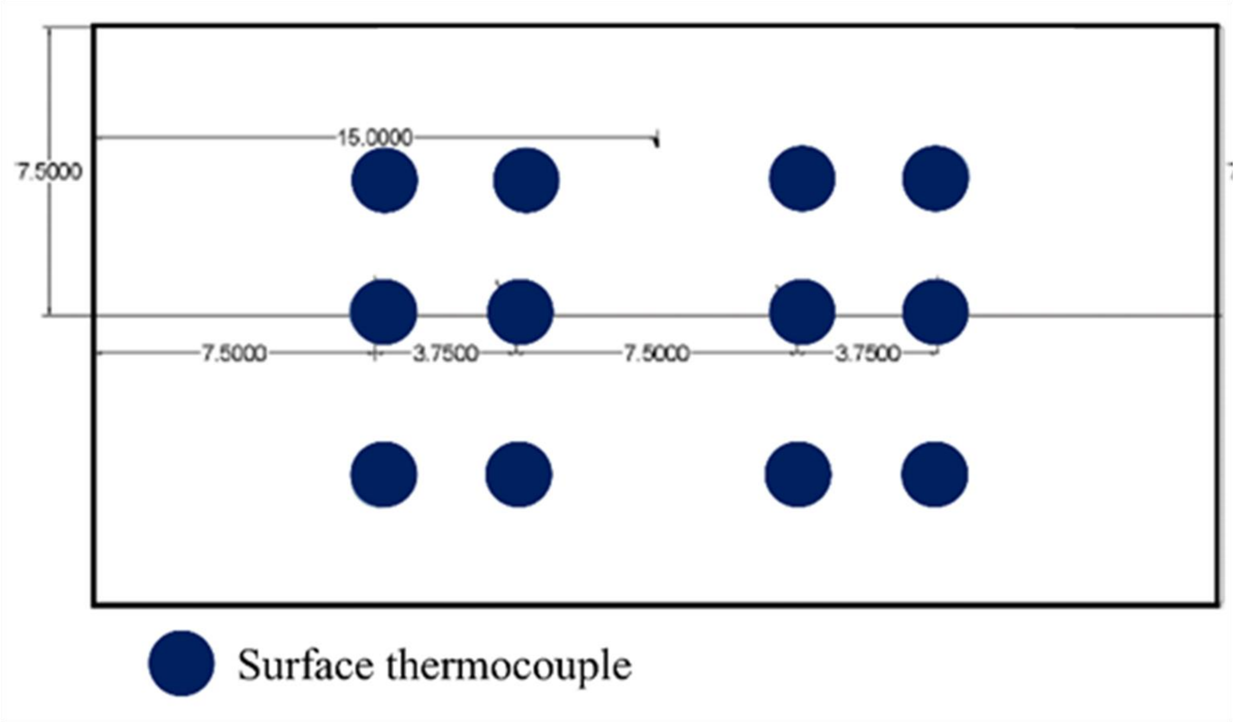
Sunrise time: 07:15 am

Surface Temperature Distribution



Surface Temperature Distribution

- Higher standard deviation indicates non-uniformity
- Rowan strip outperforms (better heat distribution) Heatpave
- Electrode spacing: No effect



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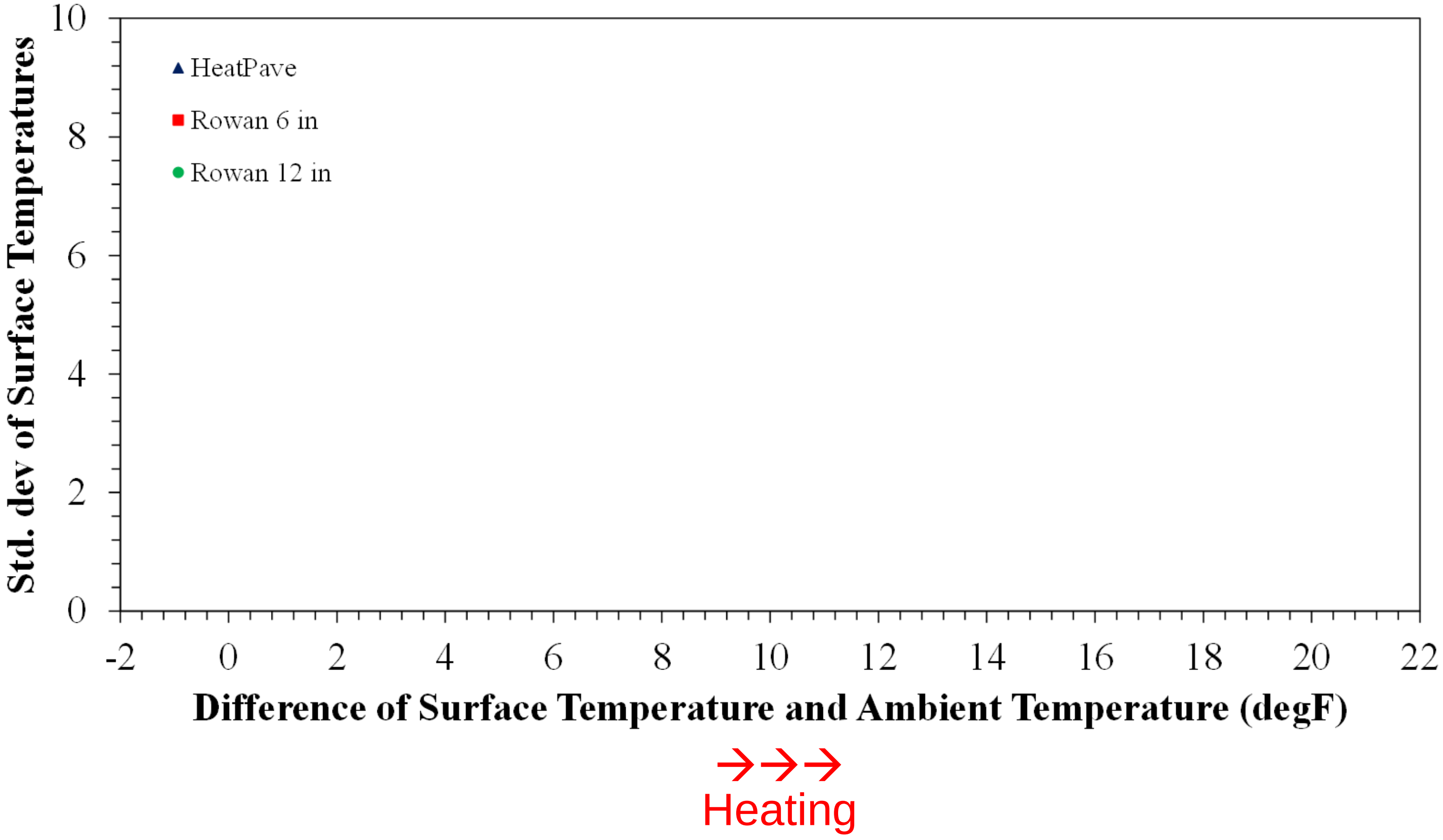

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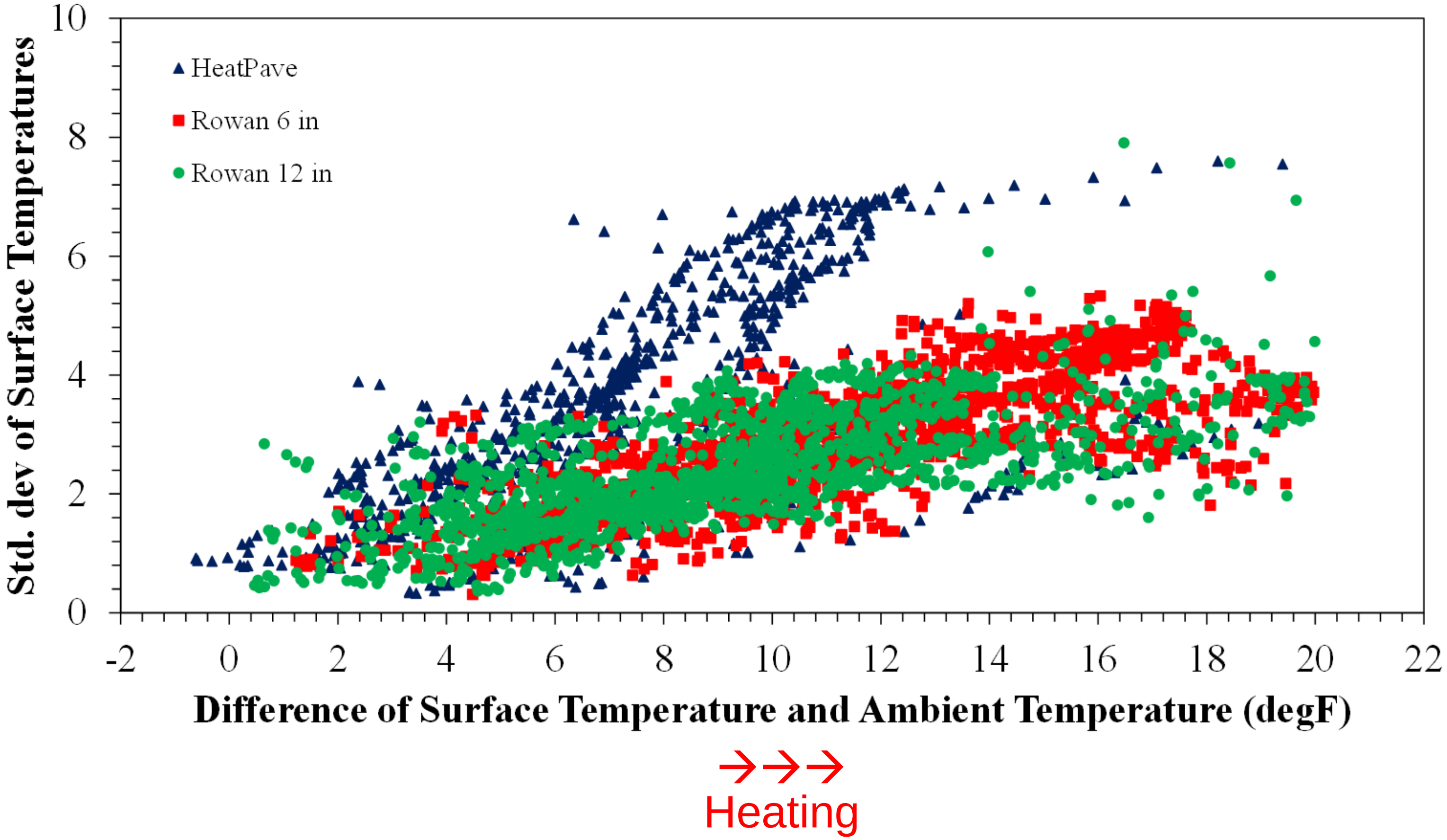

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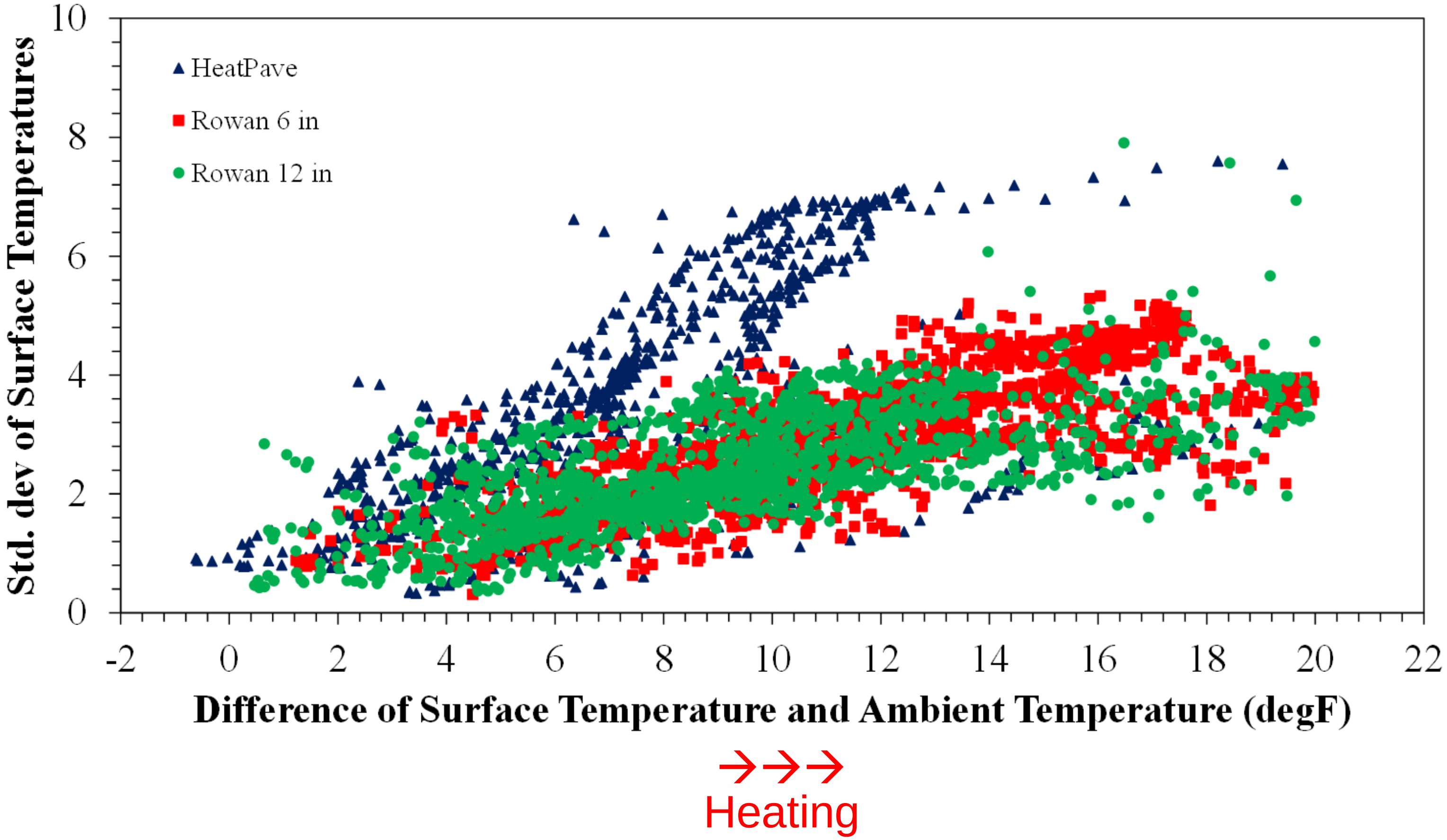

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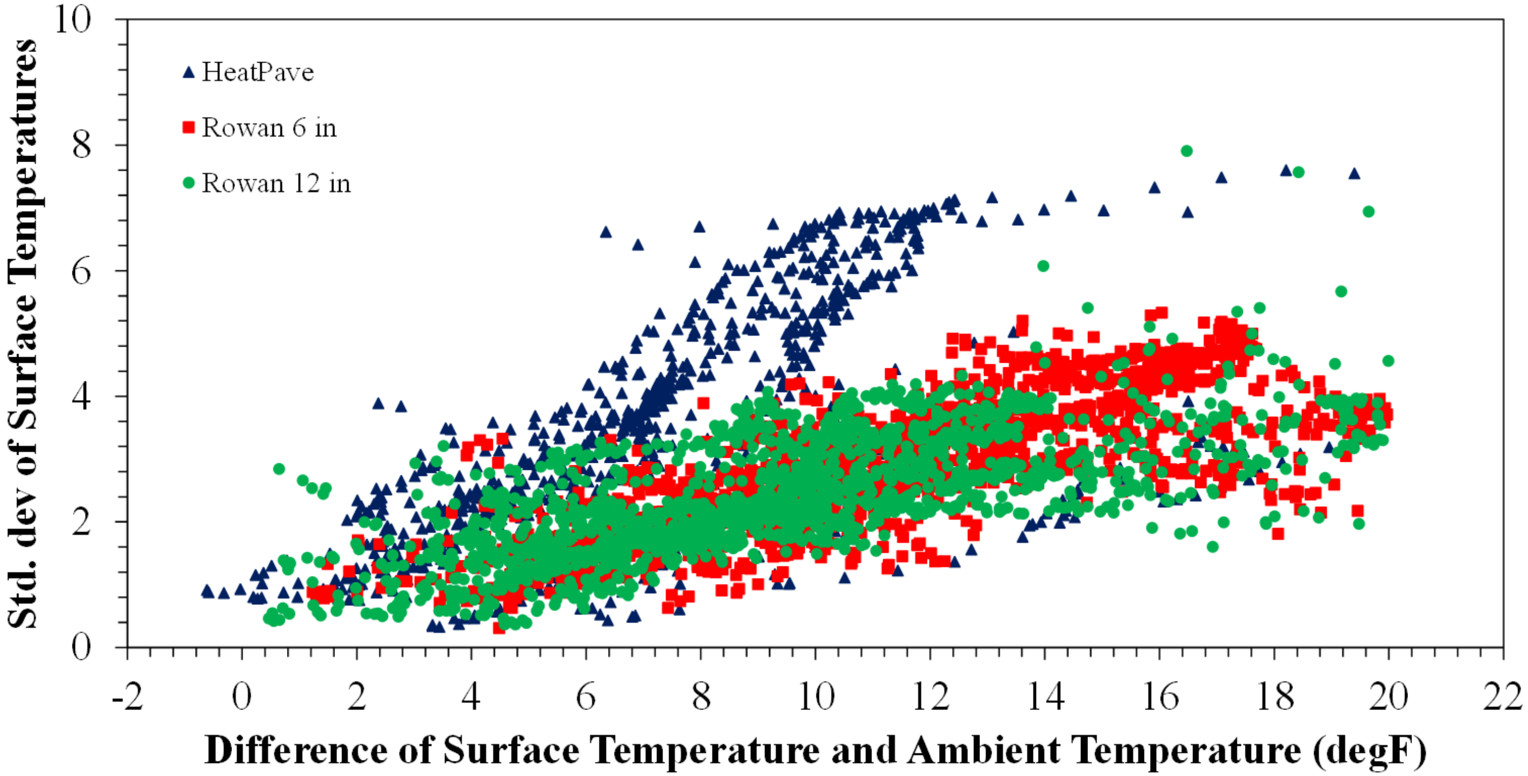
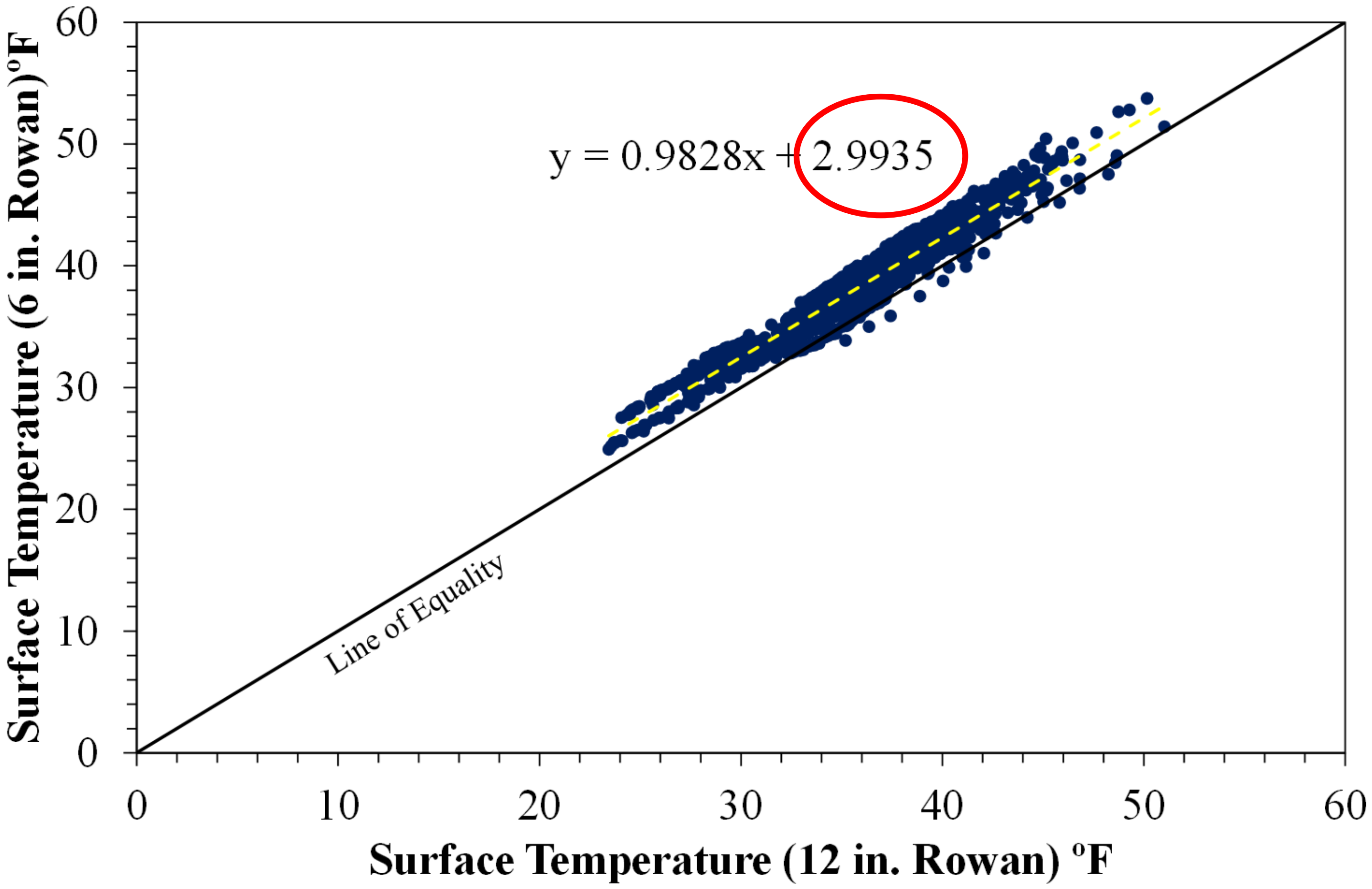


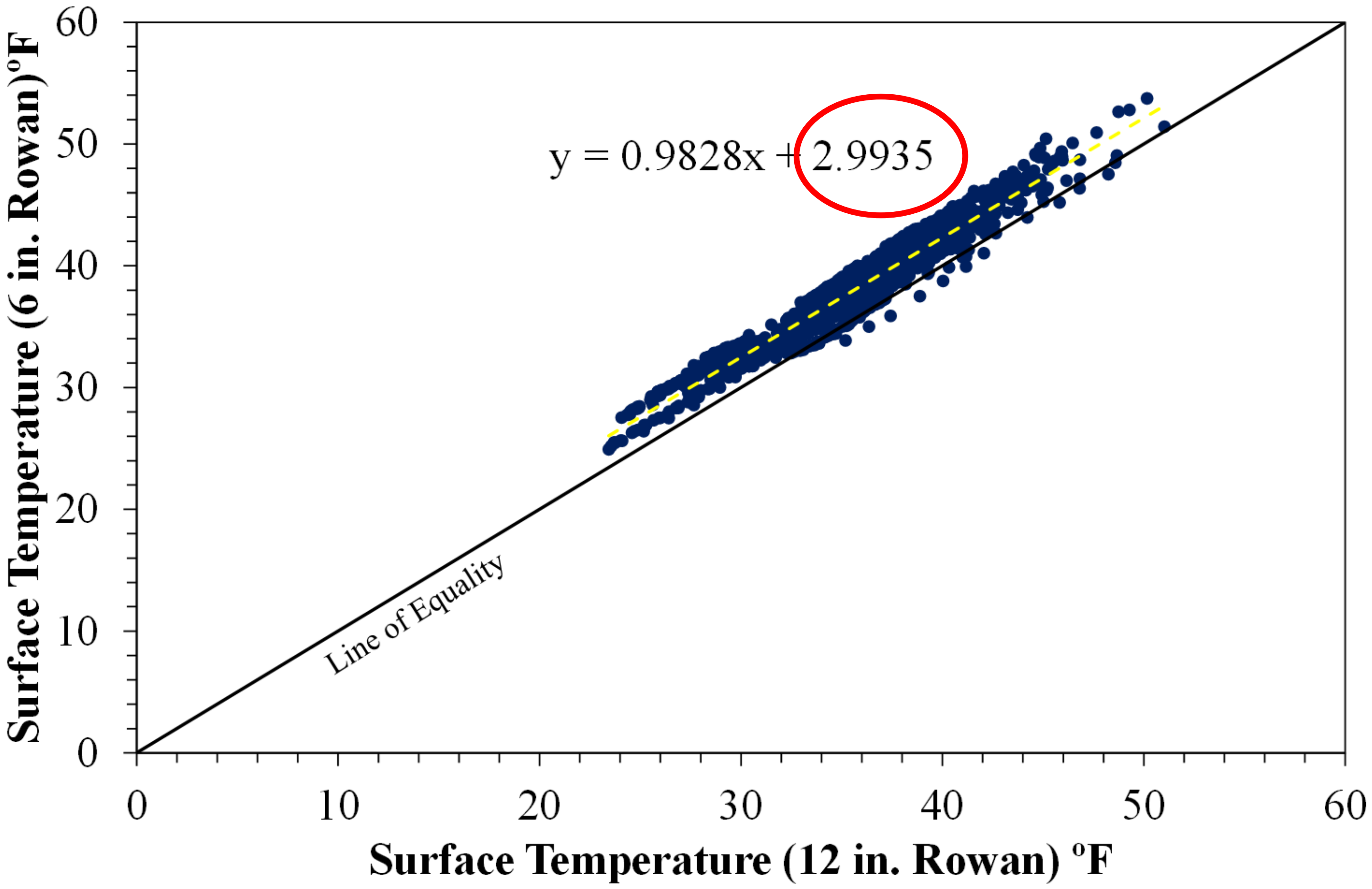
→→→
Heating

Electrode spacing 6in. Vs 12in. (Rowan Section)



Electrode spacing 6in. Vs 12in. (Rowan Section)

- 6in. electrode spacing shows higher average surface temperature(~ +3ºF)



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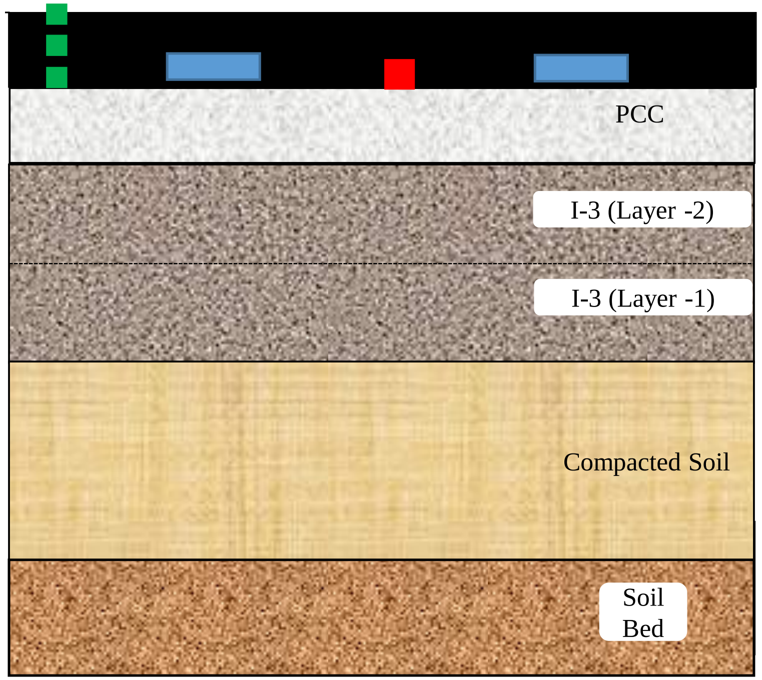

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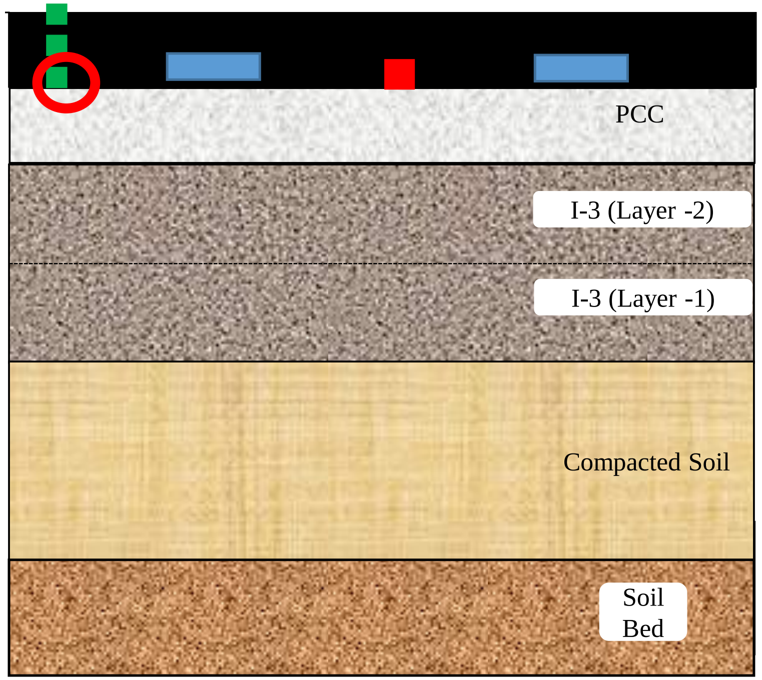

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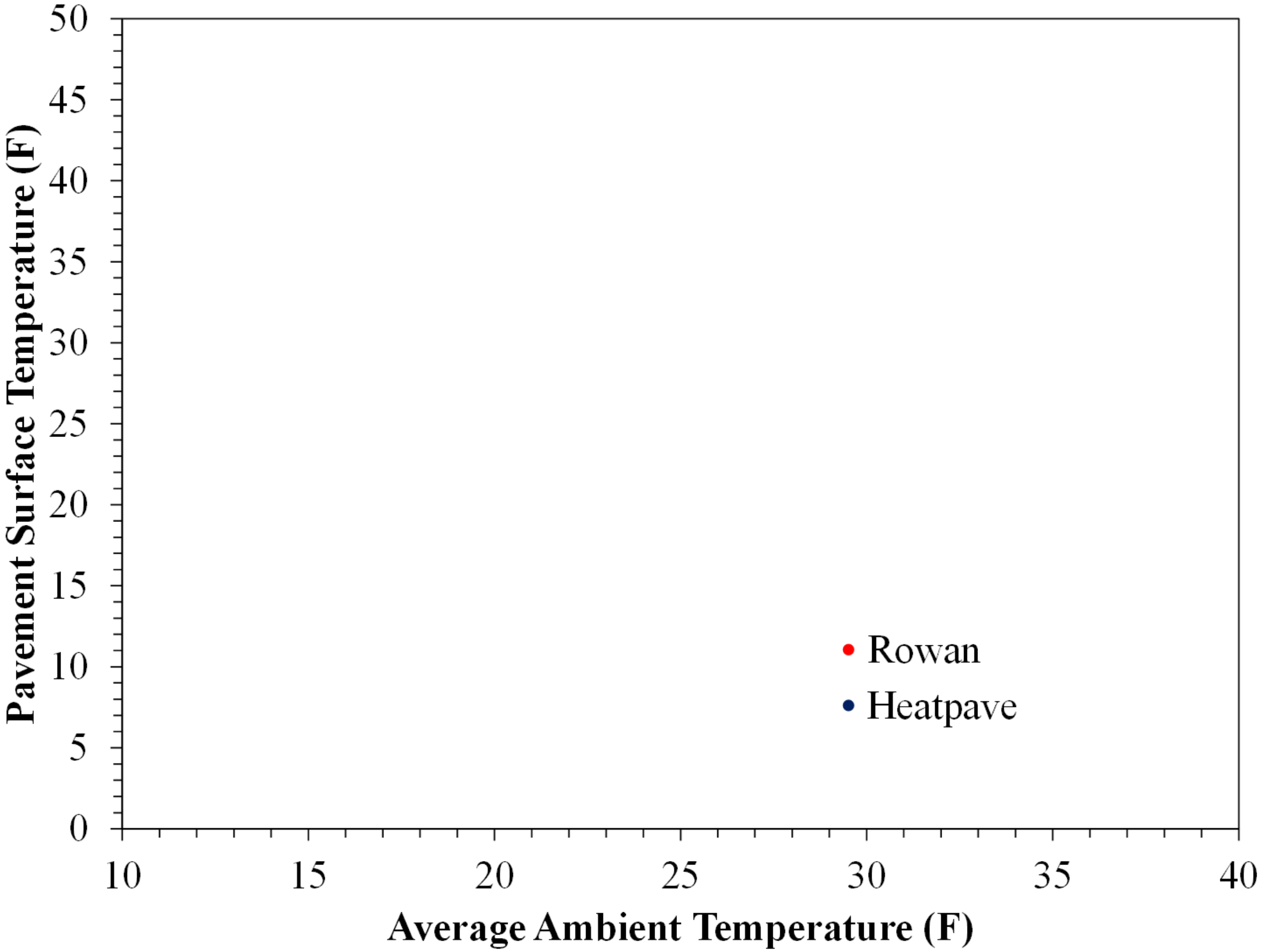
Temperature at System Trigger



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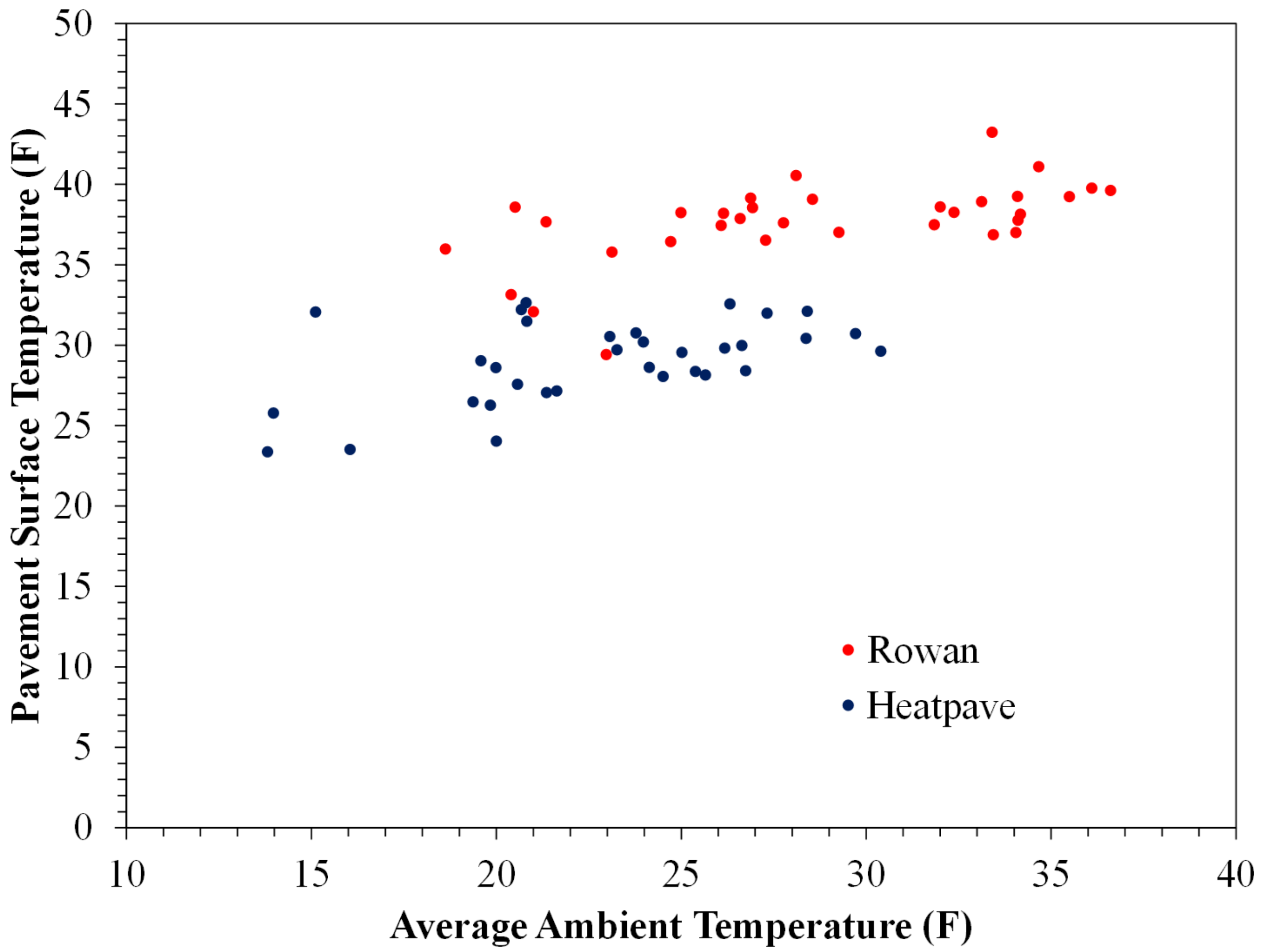


Temperature at System Trigger

- **Heatpave Section**

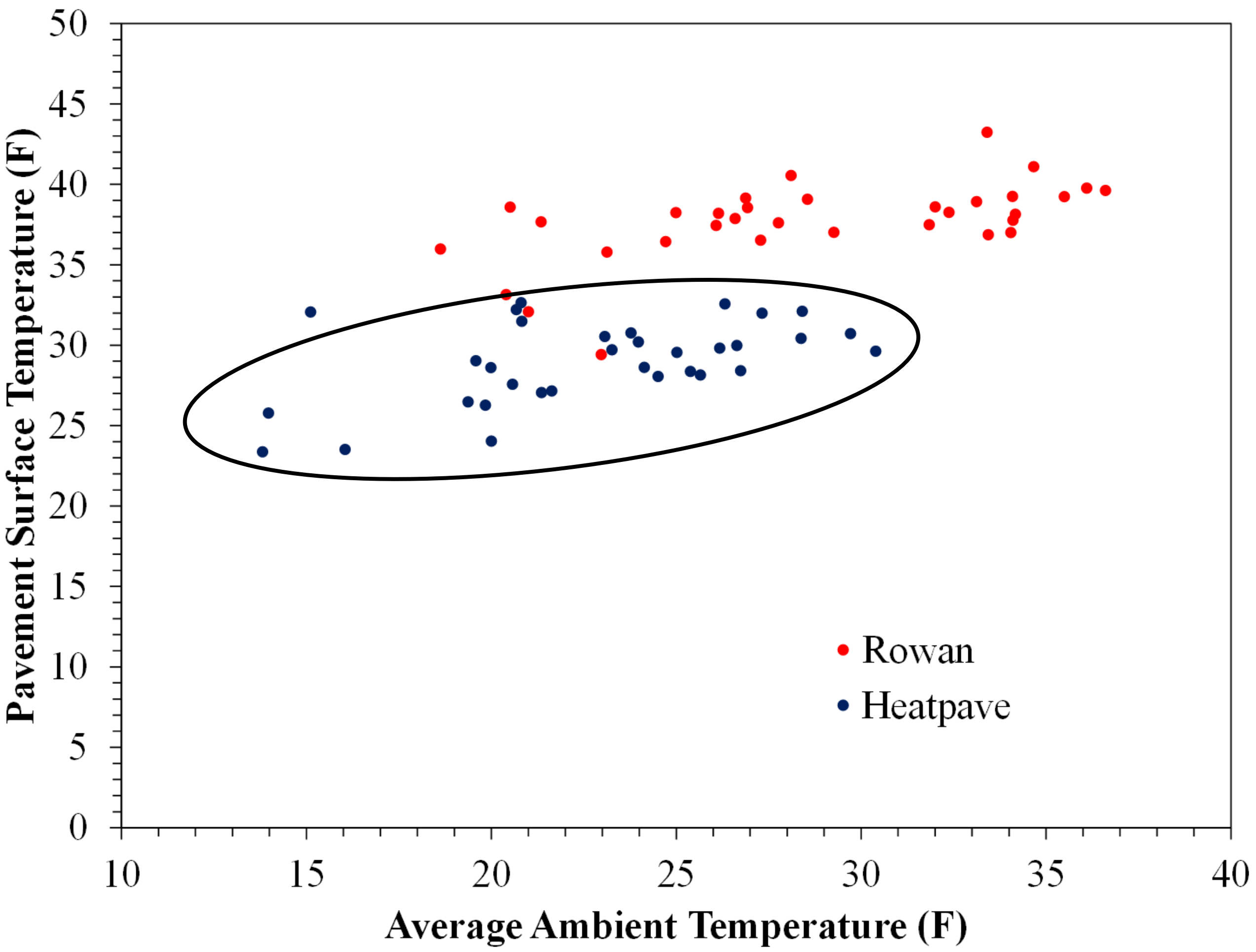
Ambient temperature range

(30ºF - 14ºF)

- **Rowan Section**

Ambient Temperature Range

(37ºF - 18ºF)



Temperature at System Trigger

➢ <u>Heatpave Section</u>

Ambient temperature range

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➢ <u>Rowan Section</u>

Ambient Temperature Range

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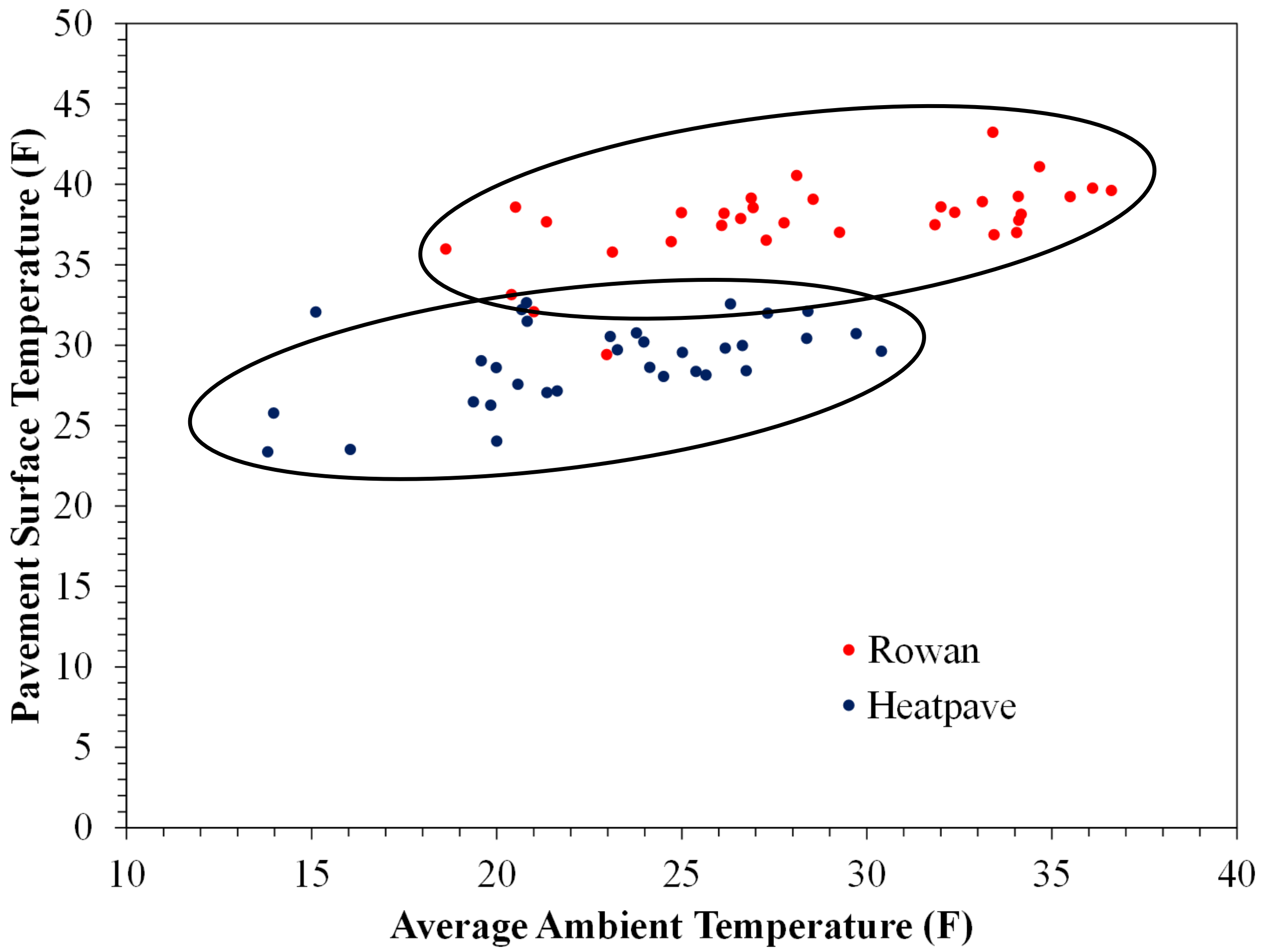
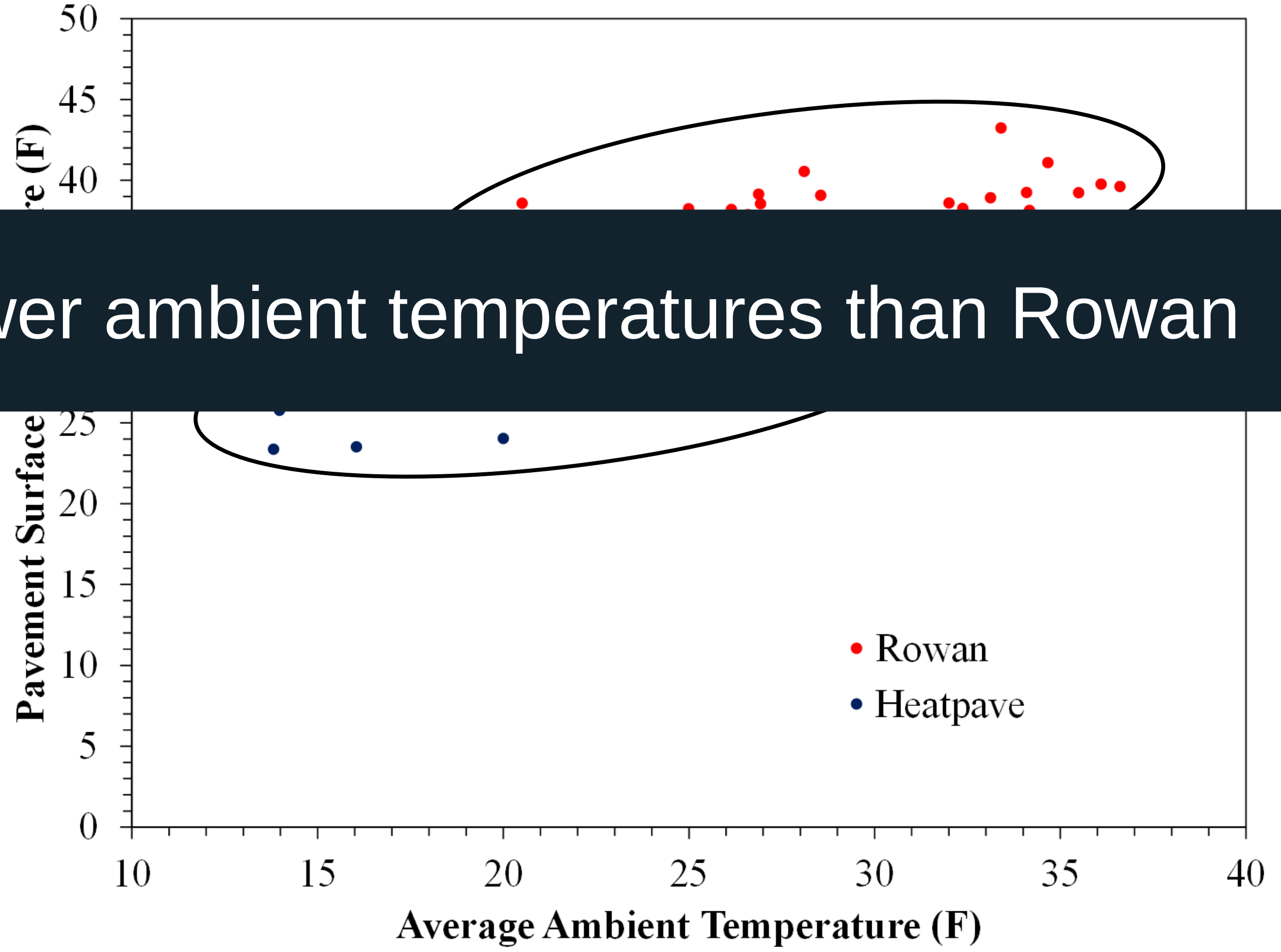


Temperature at System Trigger

➢ <u>Heatpave Section</u>

Ambient temperature range

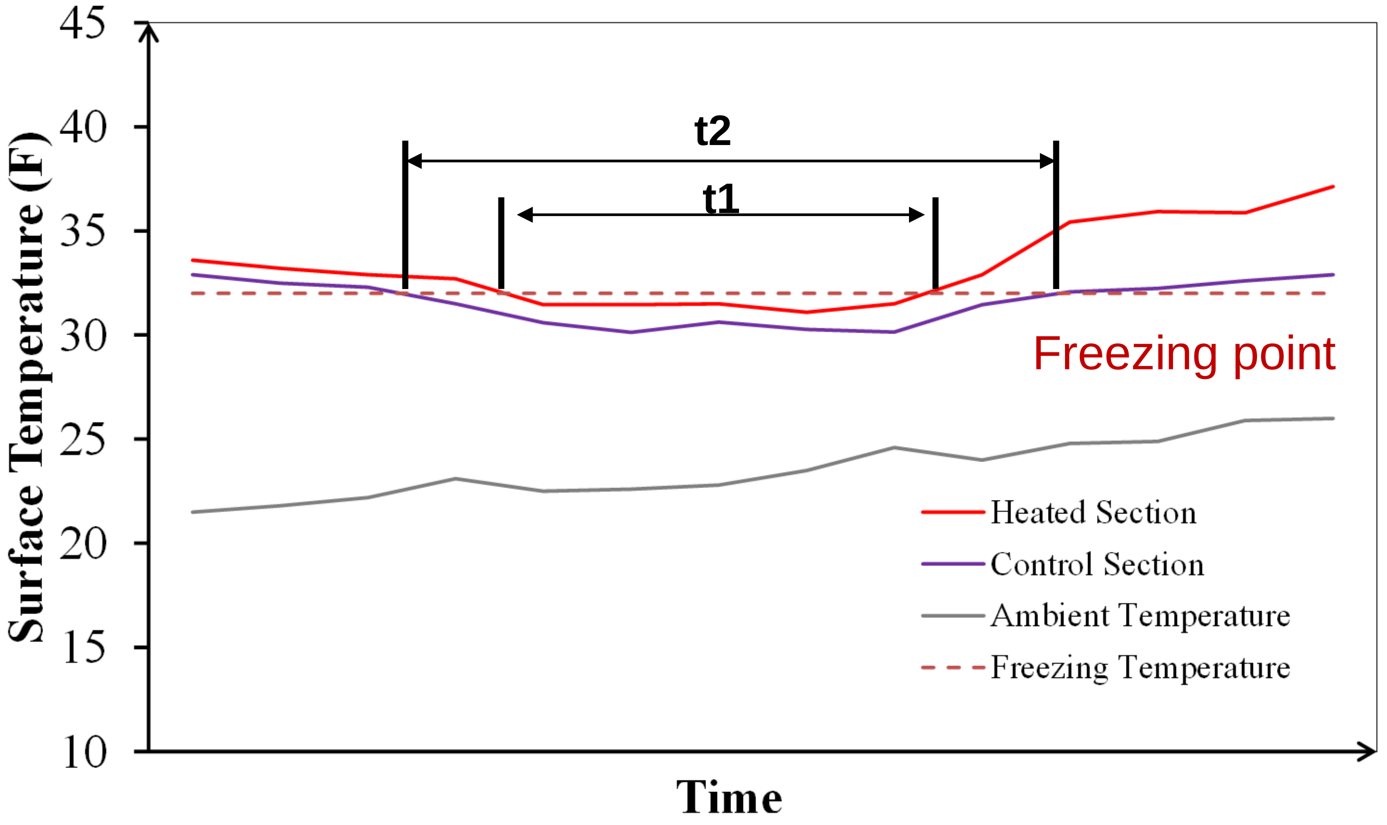


Heatpave started at lower ambient temperatures than Rowan

Ambient Temperature Range

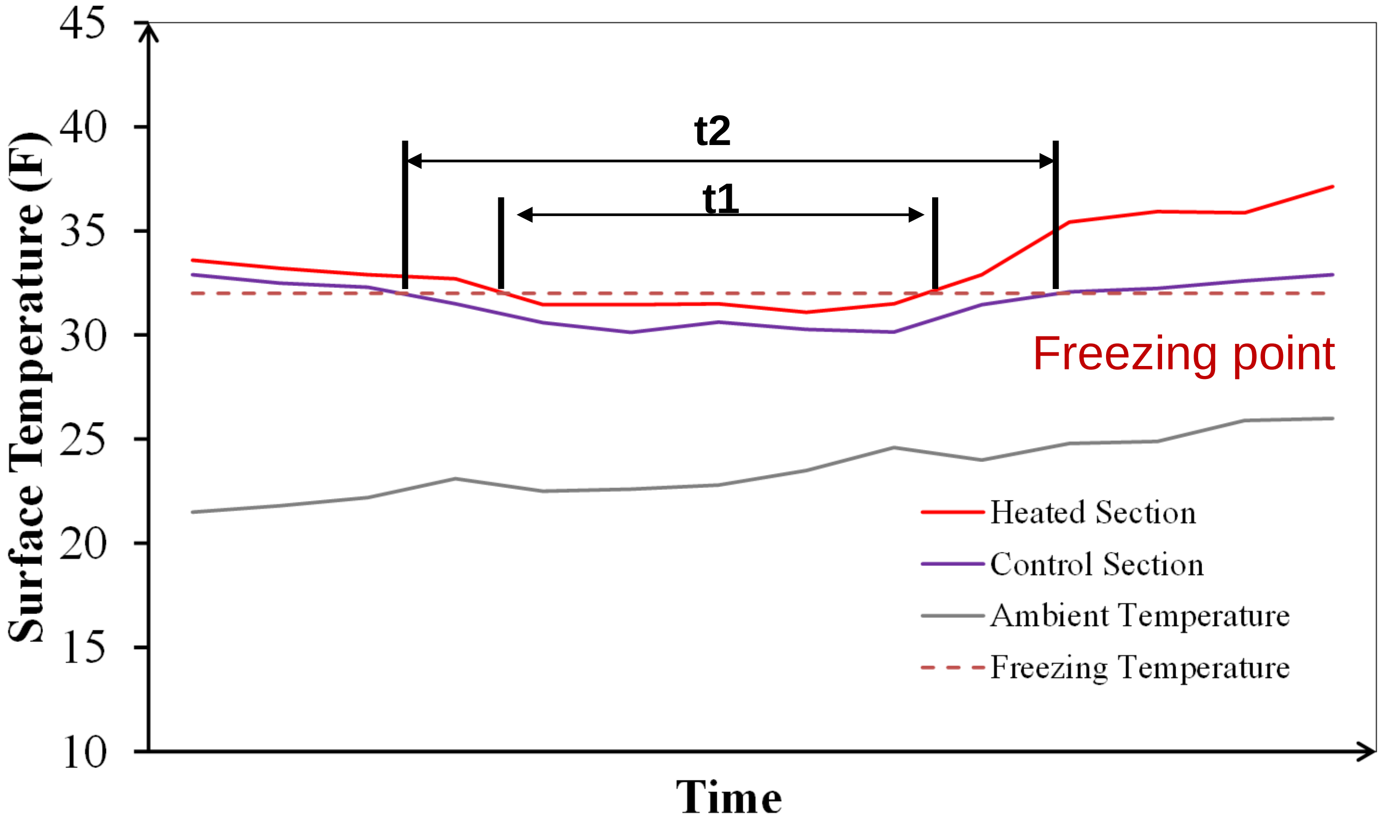
(37ºF - 18ºF)

Heating – Time Ratio (HTR)



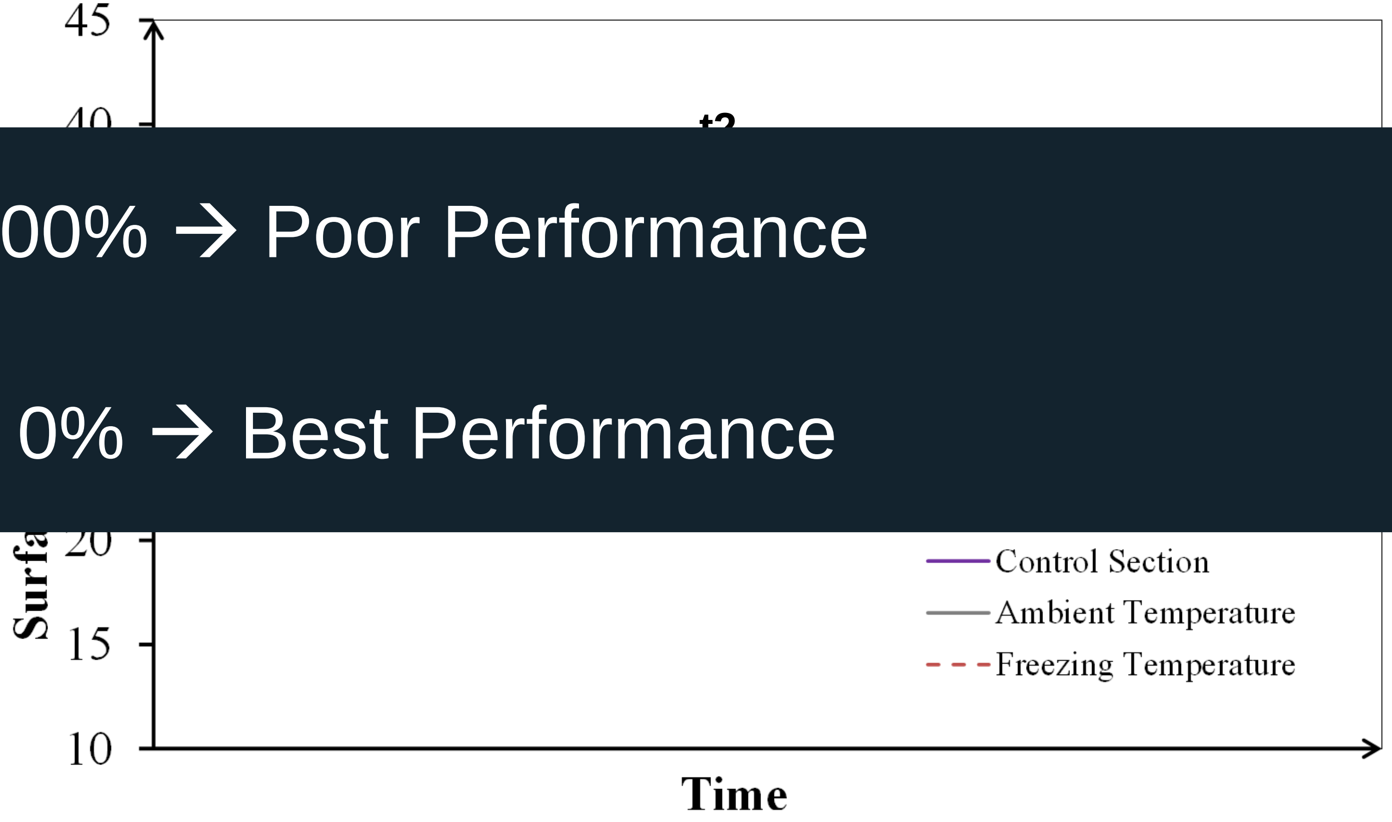
Heating – Time Ratio (HTR)

- Heating performance to maintain surface temperature above freezing point (32ºF)
- HTR (%)= $\frac{t1}{t2}$



Heating – Time Ratio (HTR)

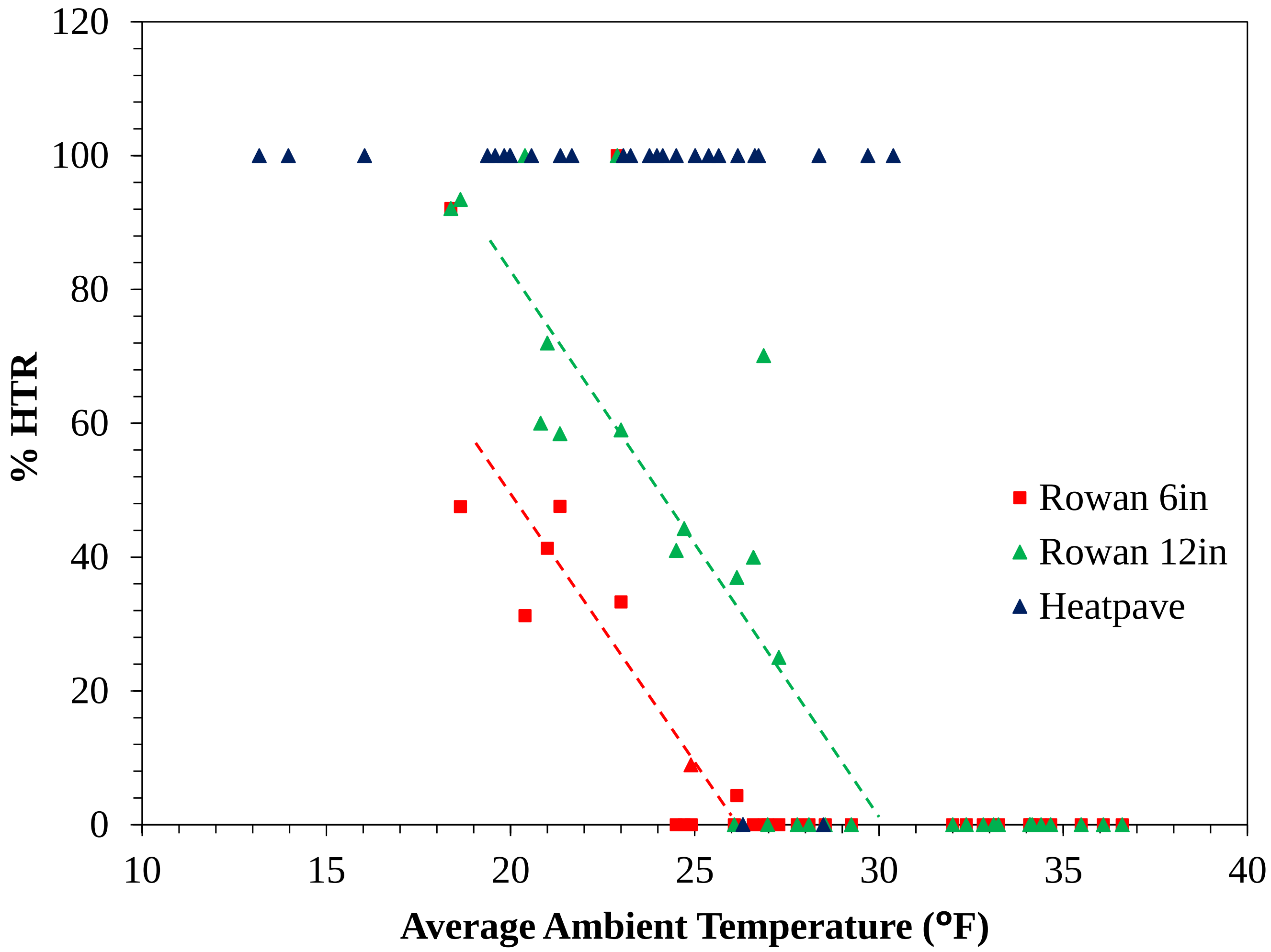
- ➢ Heating performance to maintain surface



HTR value100% → Poor Performance

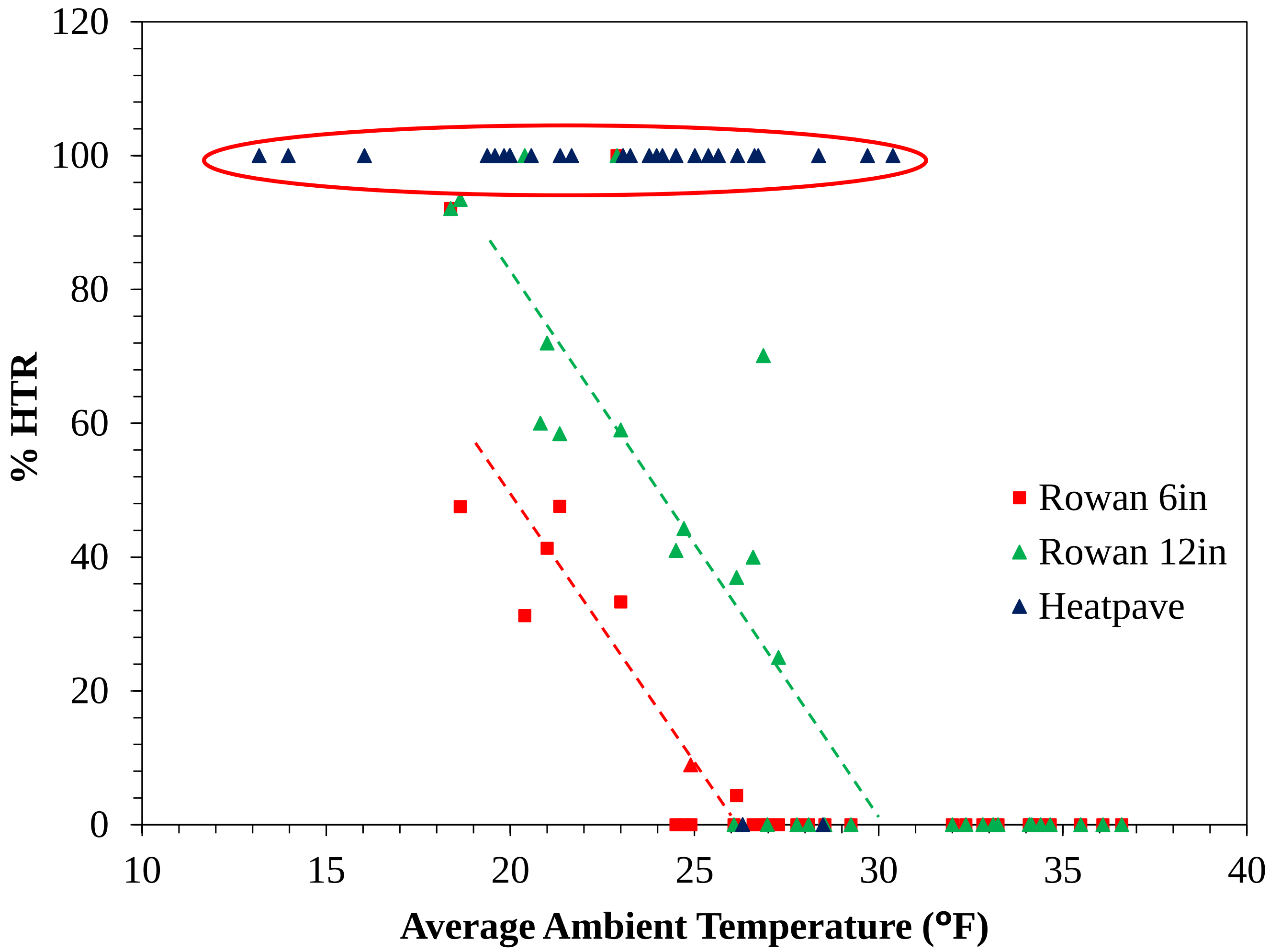
HTR Value 0% → Best Performance

HTR - Results



120
100
80
60
40
20
0
% HTR
10
15
20
25
30
35
40
Average Ambient Temperature (°F)
Rowan 6in
Rowan 12in
Heatpave

HTR - Results



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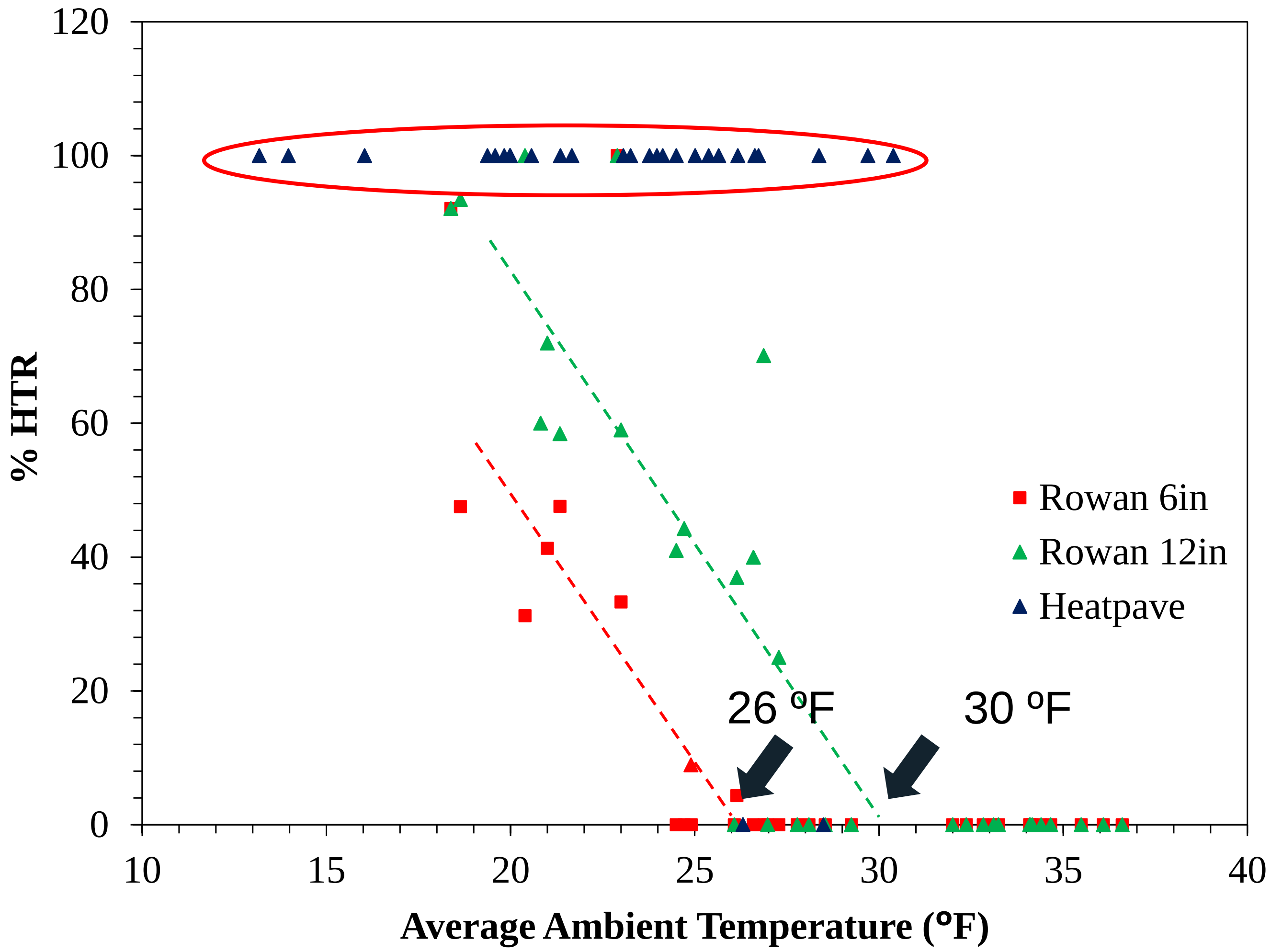

120
100
80
60
40
20
0
% HTR
10
15
20
25
30
35
40
Average Ambient Temperature (°F)
Rowan 6in
Rowan 12in
Heatpave
26 ºF
30 ºF

Power Consumption - Comparison

- Average of power consumed by each run cycles during time period of September 2021 – March 2022

Section	Average Power ($Watts/ft^2$)	Std. Deviation
Heat Pave	**19.75**	0.45
Rowan 6 in.	**11.90**	0.25
Rowan 12 in.	**5.95**	0.25

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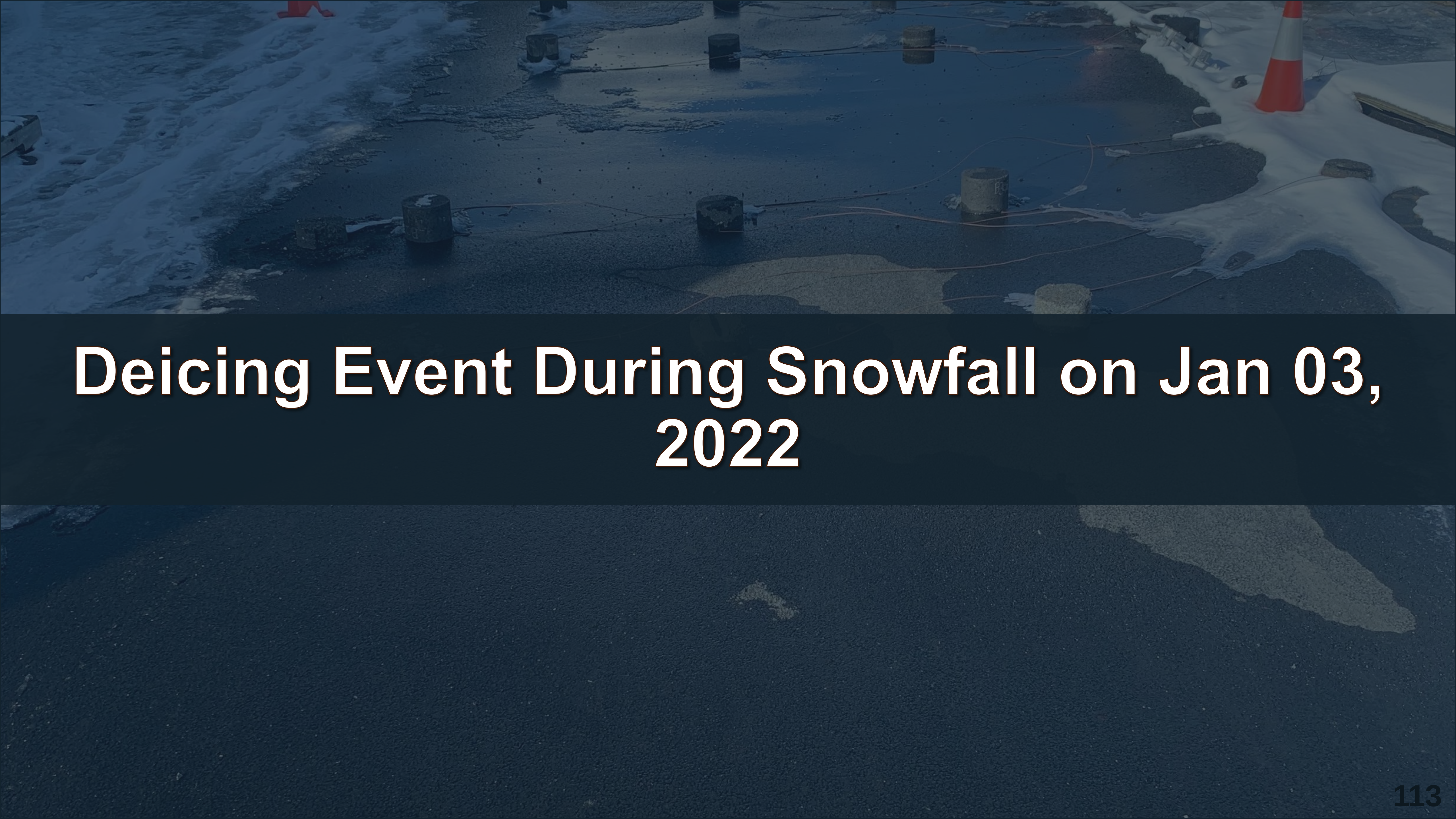

Deicing Event During Snowfall on Jan 03, 2022

Deicing Performance

01:00 PM Heatpave and Control

01:00 PM Rowan Section

Heating Duration: 7 hours

Average accumulated snow depth: 3.2 in.

Deicing Performance

03:30 PM Heatpave and Control

03:30 PM Rowan Section

Heating Duration: 9.5 hours

Summary of Findings

Performance Factors	Order of Sections		
	1	2	3
Surface Heating Performance	Rowan 6in.	Heatpave	Rowan 12 in
Surface Temperature Distribution	Rowan 6 in.	Rowan 12 in.	Heatpave
Power Consumption	Heatpave (highest)	Rowan 6 in.	Rowan 12 in.

Summary of Findings

- Heatpave generated more heat; however, that was not reflected on surface temperature – Conductive layer at higher depth
- Power consumption was the highest for Heatpave (~20 W/ft^2), followed by Rowan 6 in. spacing strip (~12 W/ft^2) and 12 in. spacing strip (~6 W/ft^2)
- Rowan section showed effective deicing performance (run time ~ 10 hours)

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- **Design of ECA mix**

  Use of combination of additives in fibrous and powder form for better conductivity

- **Ease of construction**

  Conductive asphalt mixture better than the conductive tack coat material

- **Construction challenge**

  Formation of fiber clumps (or hot spots)

- **Impact of electrode spacing**

  Shorter spacing → Better heating
  Less impact on surface temperature uniformity

Conclusions

➢ **Heating Efficiency**

ECA mixture performed better with a less power consumption

➢ **Electrical Supply**

Higher voltage (>20V) will be required for heating at lower ambient temperature conditions (<10ºF)

➢ **Control of Power Supply**

Based on embedded thermocouple is not recommended for strip comparison

➢ **Other factors to consider**

- ❖ Thermal conductivity of ECA layer
- ❖ Thickness ratio of asphalt capping layer and ECA layer

Long-Term Performance

Heavy Vehicle Simulator (HVS) loading in progress

Thank You!

Acknowledgements:

Dr. Yusuf Mehta (CREATES)
Dr. Ayman Ali (CREATES)
Dr. Ahmed Saidi (CREATES)
Rahaf Hasan (CREATES)
Dr. Mohammed Elshaer (ERDC)
Christopher Decarlo (ERDC)

Questions and Answers

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