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DEVELOPING ELECTRICALLY HEATED FLEXIBLE PAVEMENTS FOR SELF DEICING APPLICATION

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US Army Corps of Engineers®

CRREL

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In This Presentation…

- Background & problem statement
- Research objectives
- Materials and design of ECA mixtures
- Construction of Pavement Test Strips
- Heating and Field Performance of ECA
- Conclusions & recommendations

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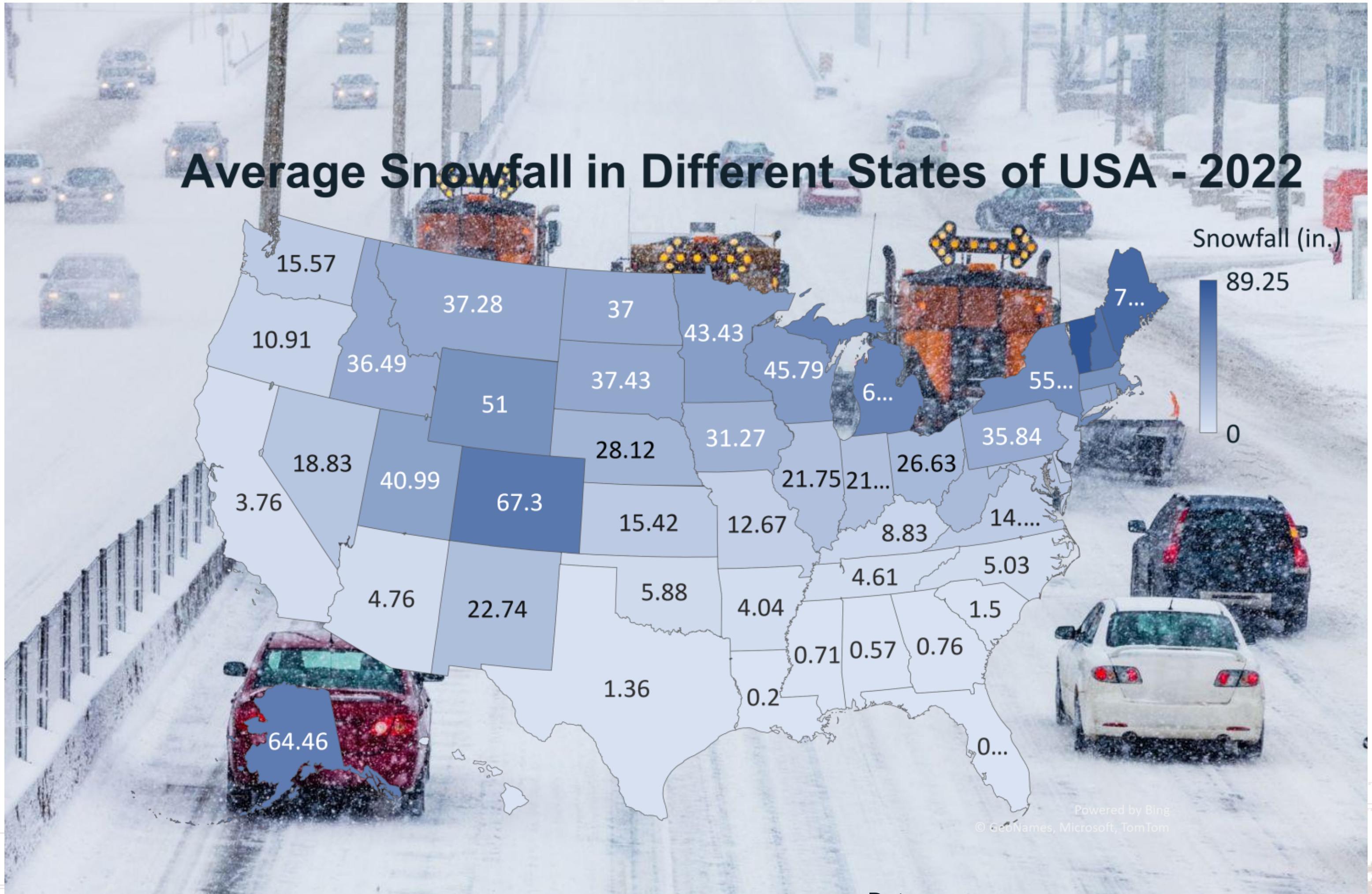
Background & Problem Statement

Background



Data source: www.usa.com

Snow & Ice Mitigation Techniques

Use of chemicals and salts

Source: Willowpix/iStock

Snow plowing

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

Problem Statement

- Labor intensive and time-consuming techniques
  Operational delays, safety concerns
- Deteriorating pavement structures → Durability issues
- Increased salinity → Groundwater contamination

Research Goal

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

Research Objectives

- Develop electrically-conductive asphalt (ECA) mixtures using different dosages of conductive additives
- Construct full-scale pavement test strips using selected electrically-conductive mixtures
- Monitor heating performance and power consumption for each test strip
- Evaluate the field performance of ECA mixtures

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Materials and Design of Conductive Asphalt Mix

Design Parameters

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

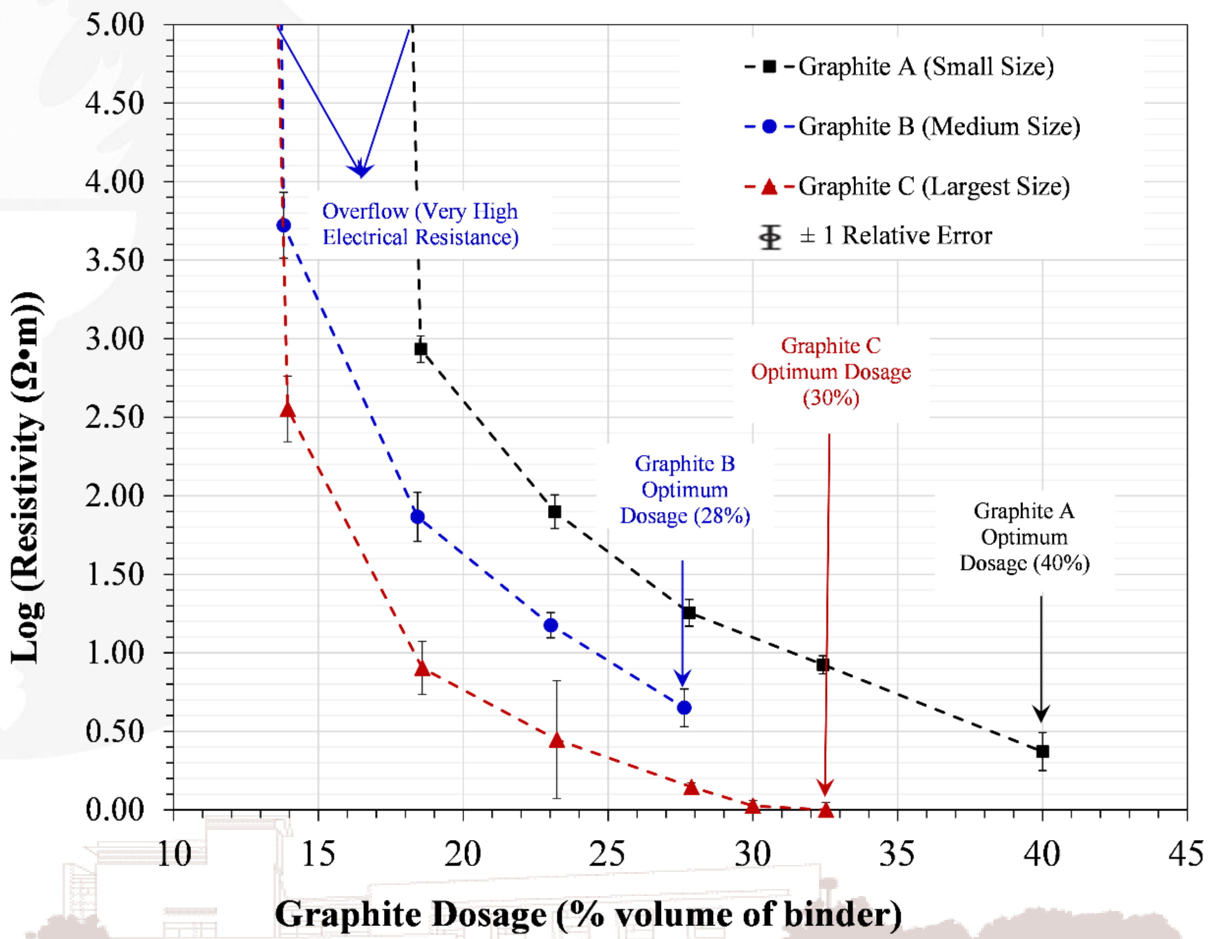
ECA Mix Preparation


Asphalt

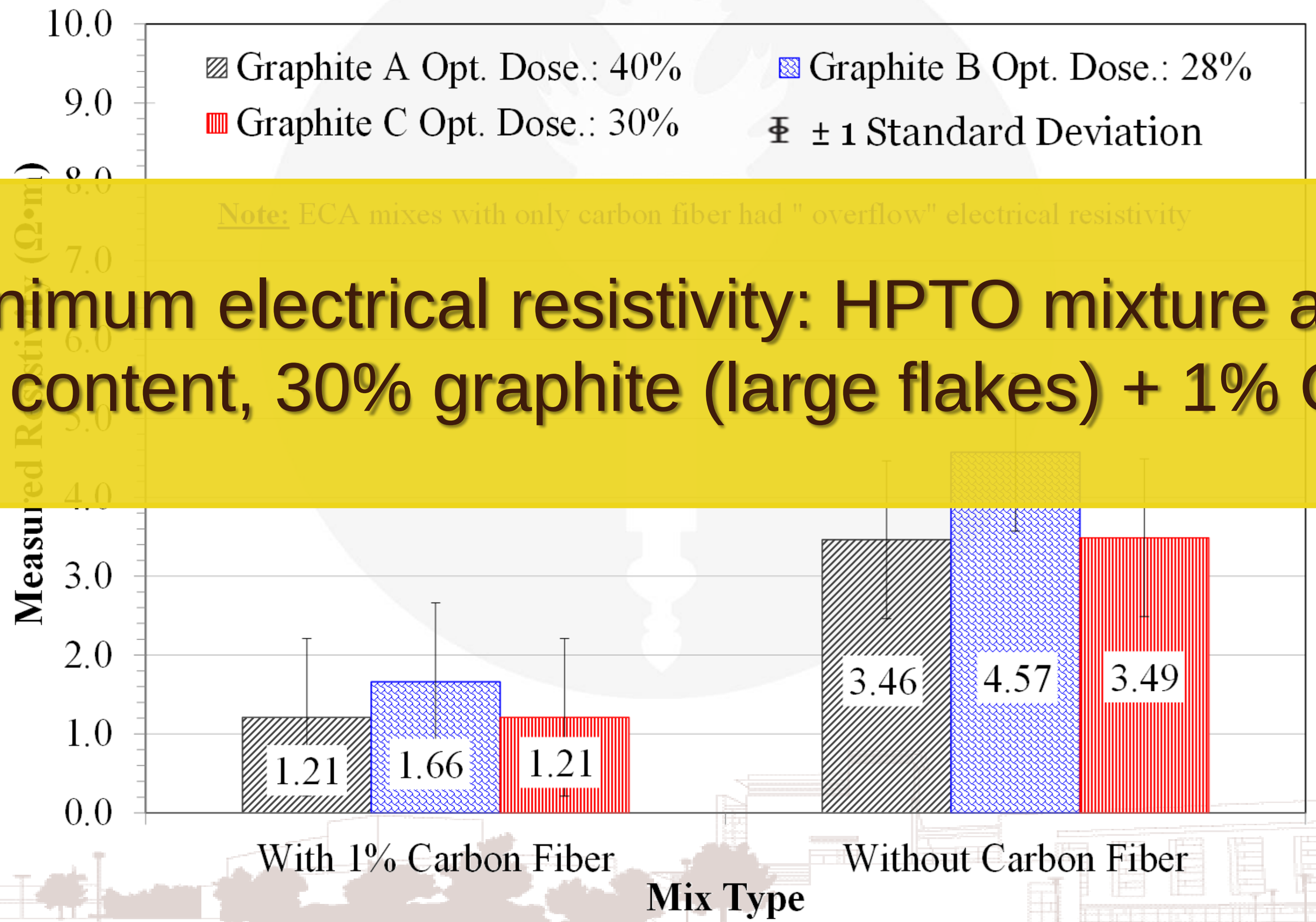
Until achieved
3.5% Air Voids




Resistivity Testing and Results



Resistivity Testing and Results



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

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Construction of Pavement Test Strips

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Construction Steps

Milling of Existing Strip

Installation of Steel Electrodes

Laying of Conductive Layer

Laying of Asphalt Capping Layer

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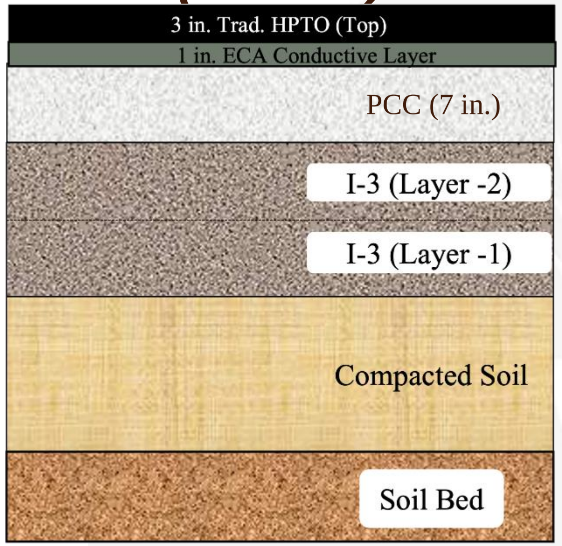
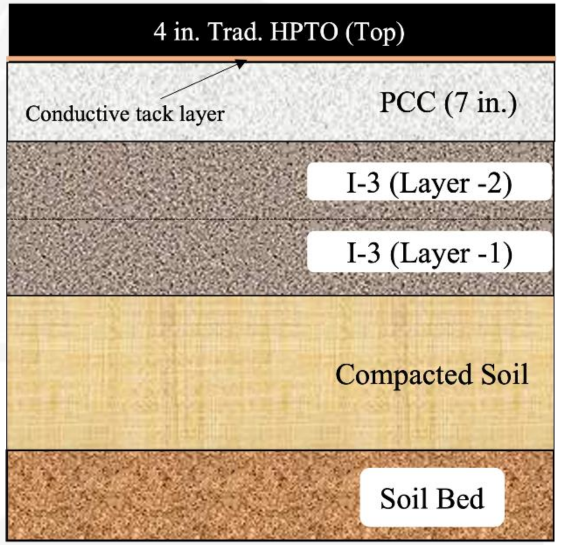
Pavement Strips' Structures

Conductive HPTO Mix *(Rowan)*



Proprietary Heated Pavement *(Heatpave)*



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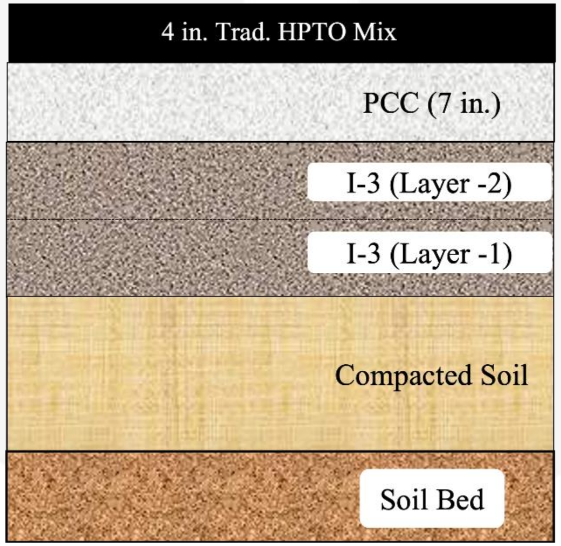
Control Section



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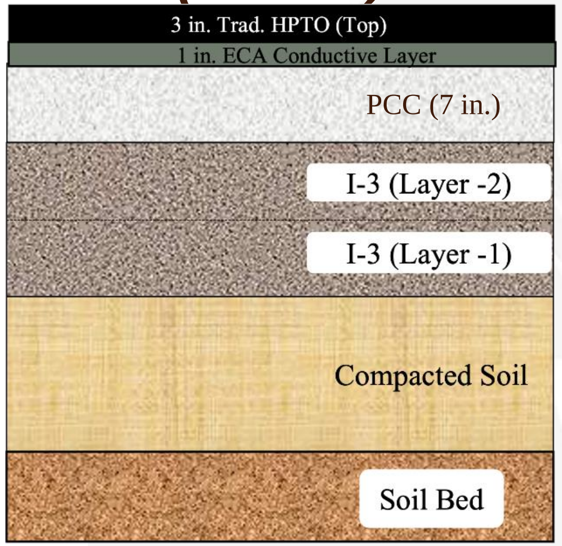

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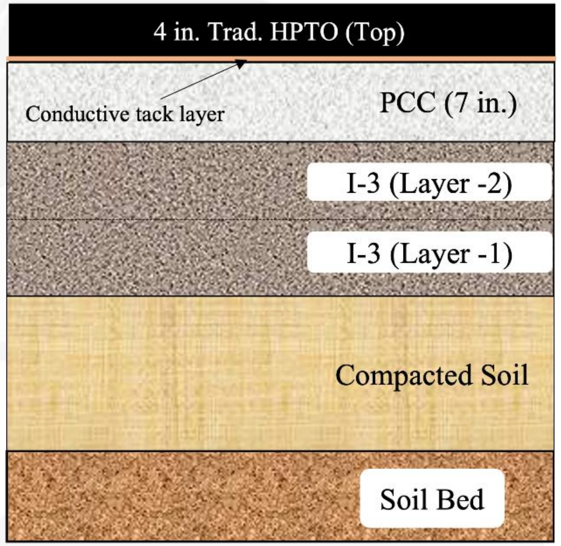

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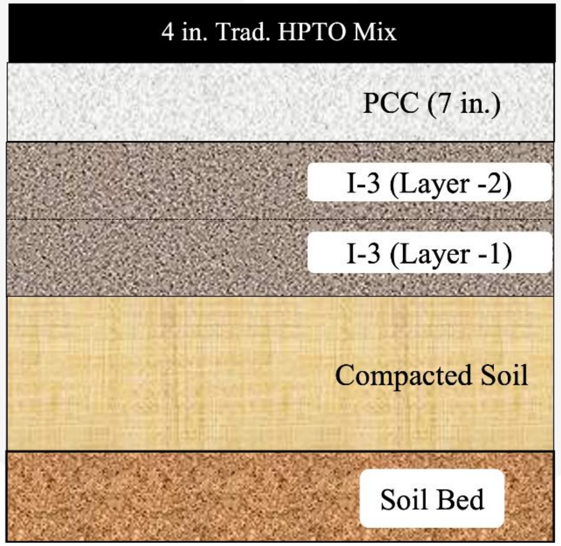

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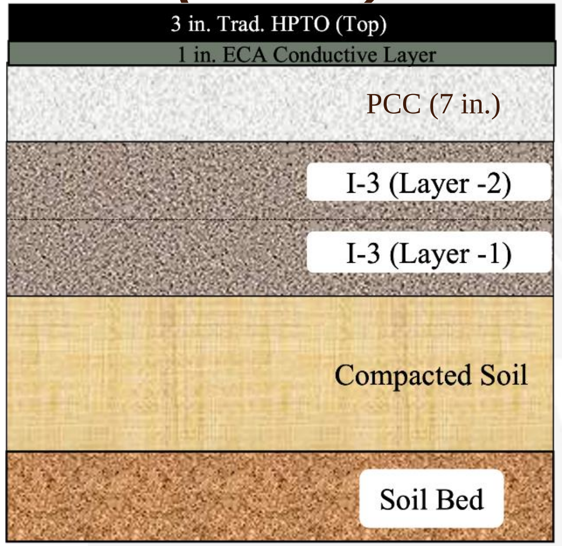

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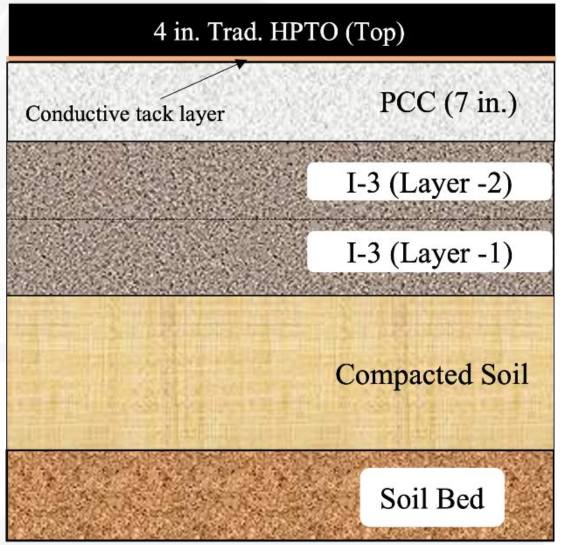

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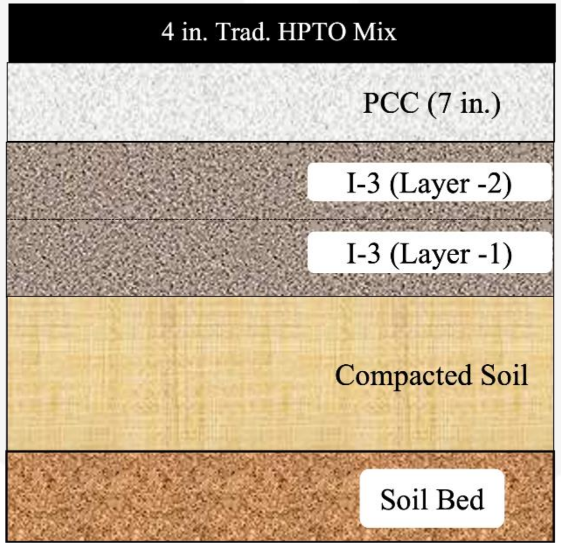

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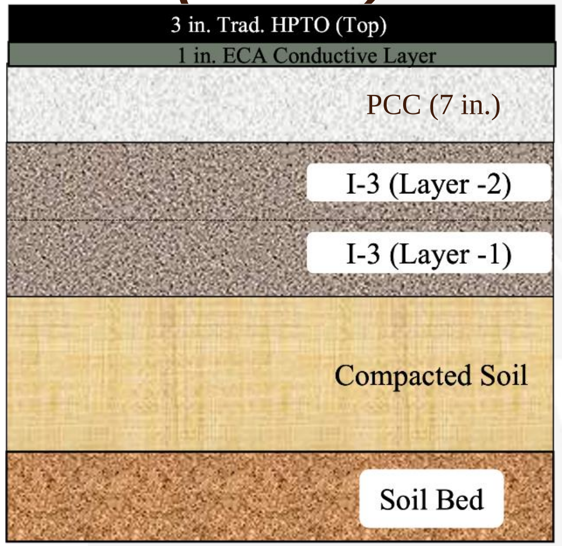

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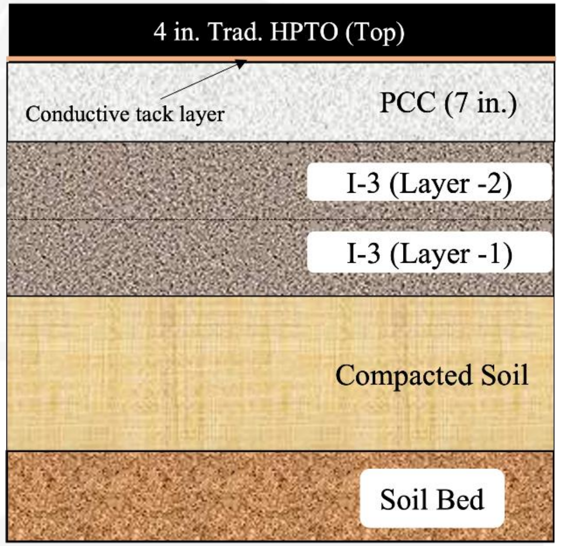

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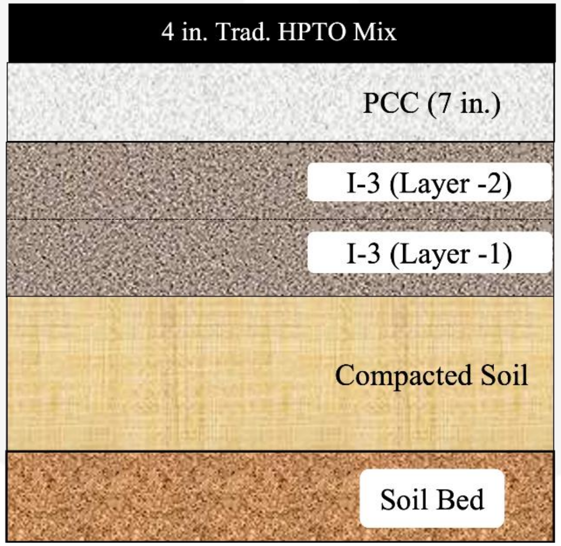

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Electrode Installation & Spacing

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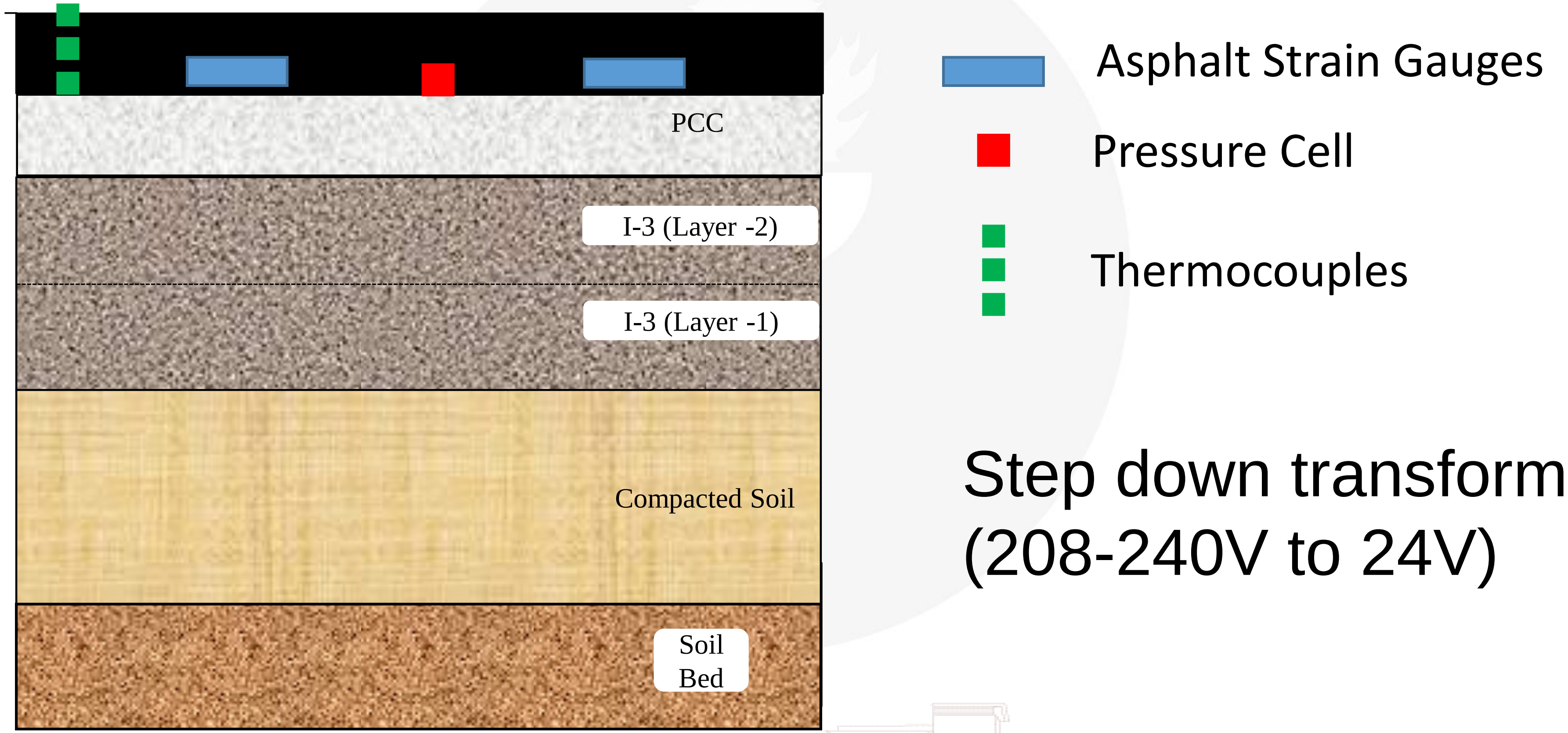
Strip Instrumentation



Transverse Pavement Cross-Section

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

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Heating Performance of ECA Pavement Strips

Methodology for Power Supply

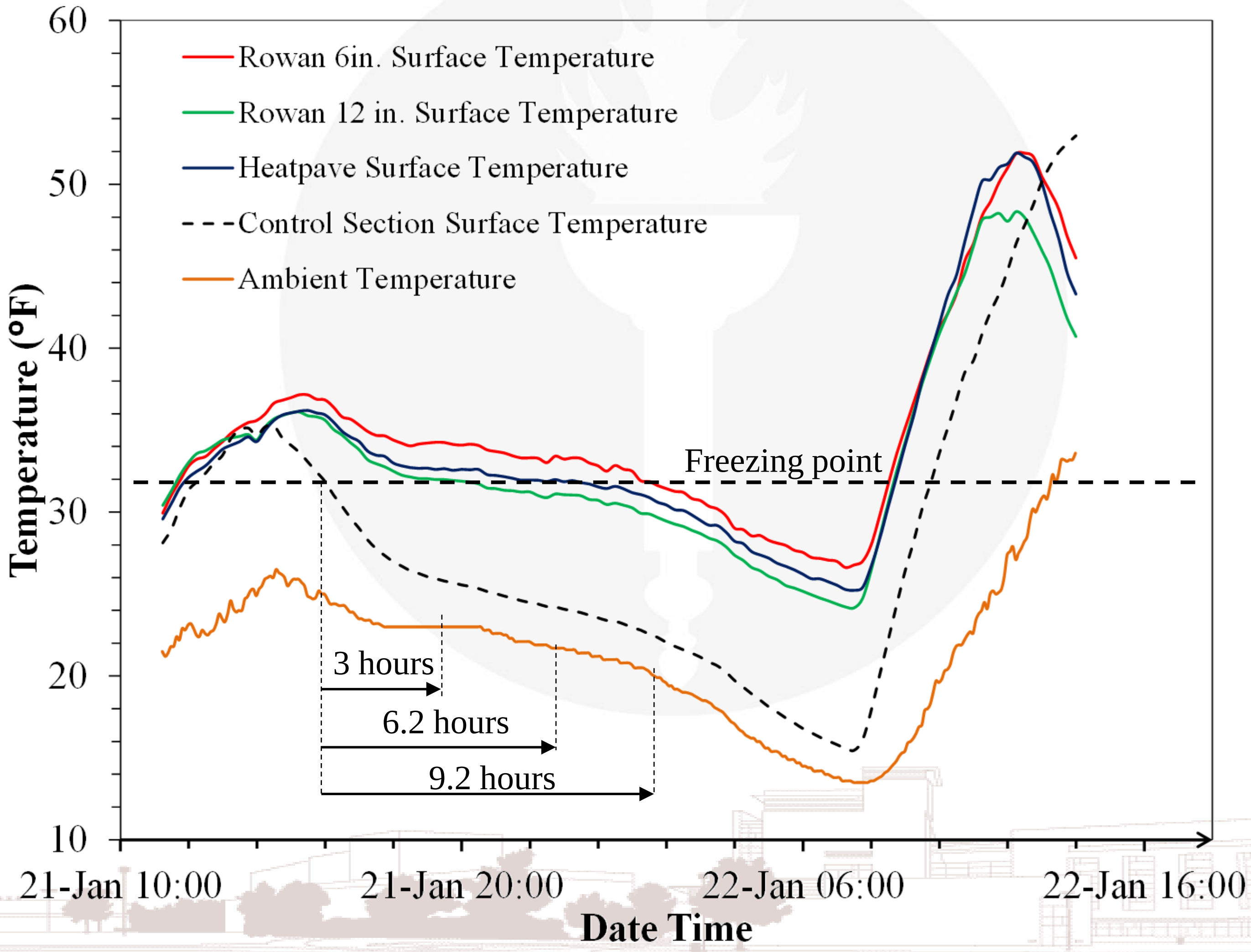
Method 1:

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

Method 2:

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

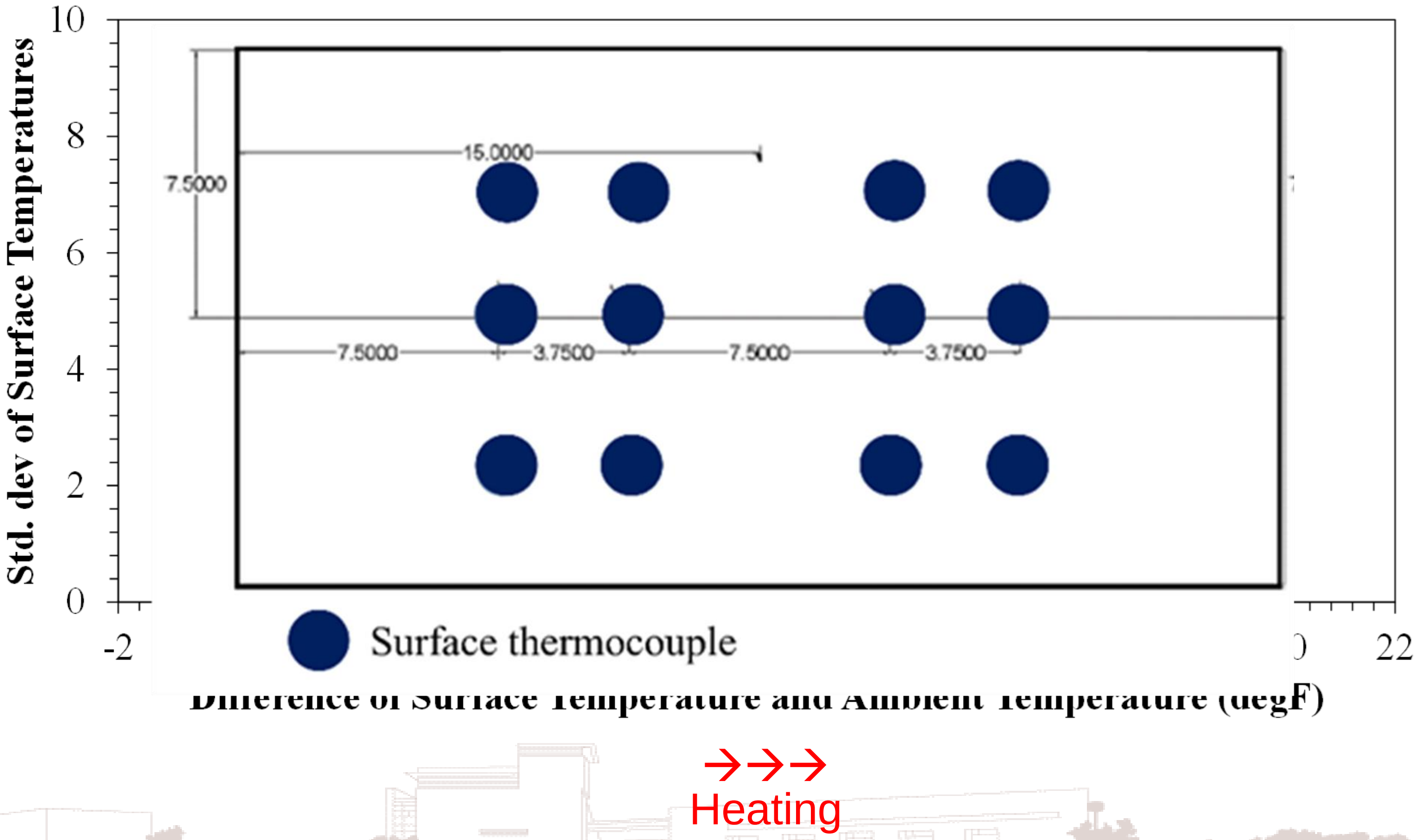
Surface Temperature Profile



Sunrise time: 07:15 am

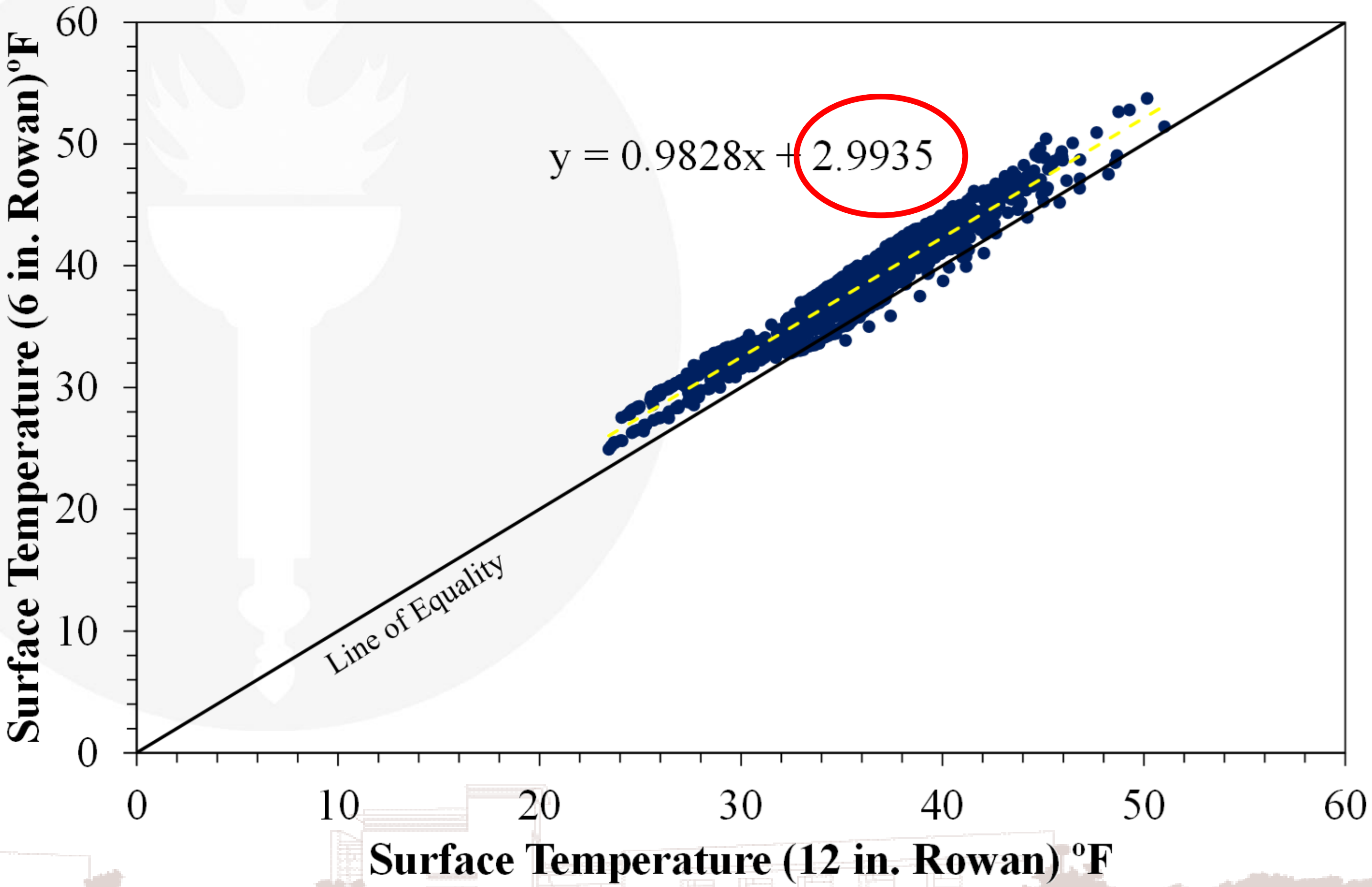
Surface Temperature Distribution

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



Electrode spacing 6 in. Vs 12 in.

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



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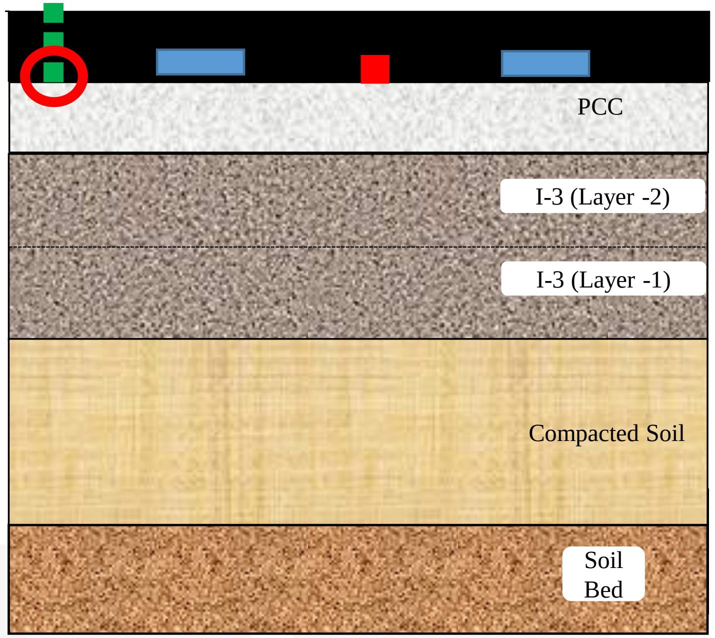


Method 2:

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

Temperature at System Trigger

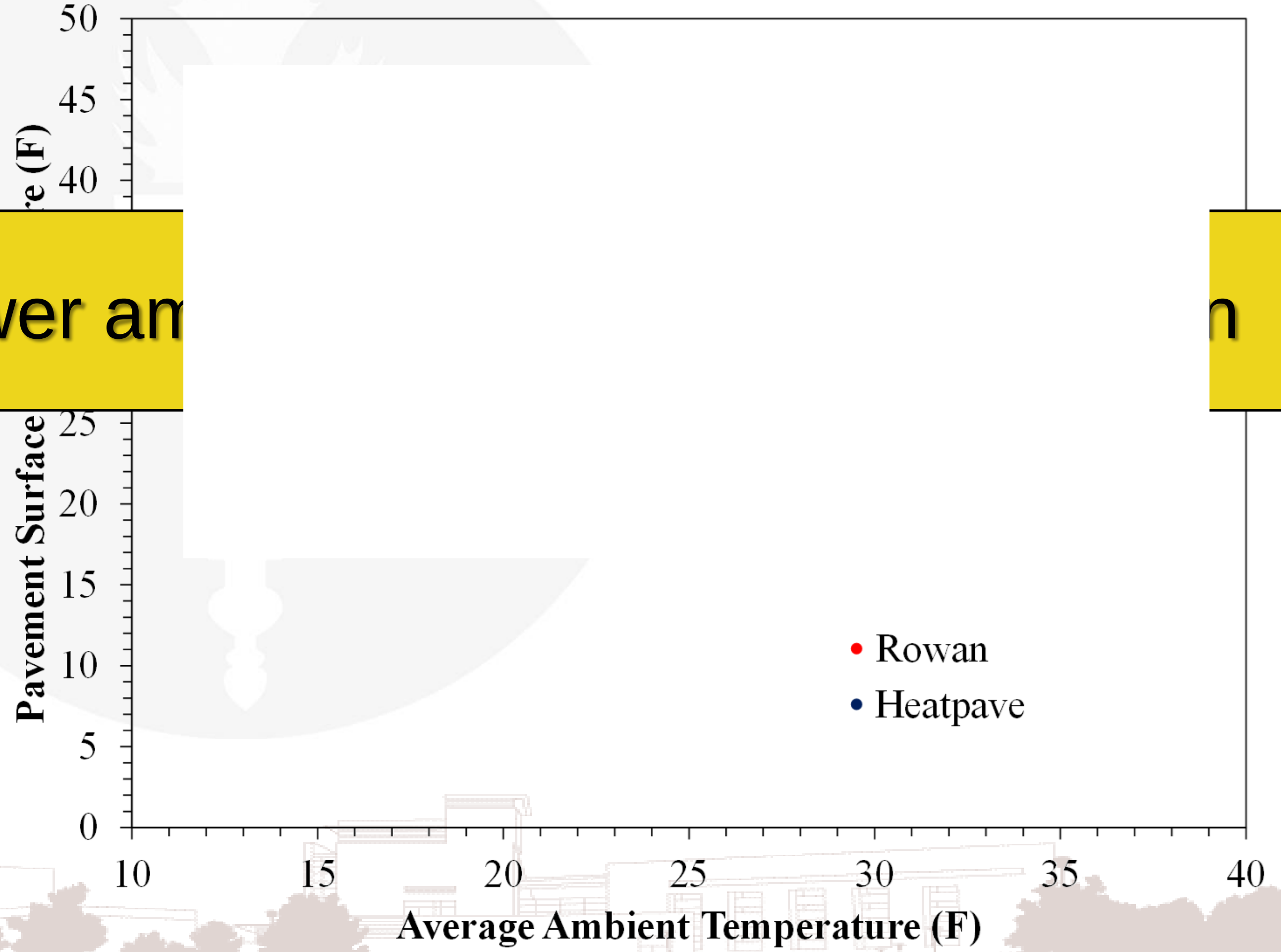
- <u>Heatpave Section</u>

Ambient temperature range

Heatpave started at lower am n

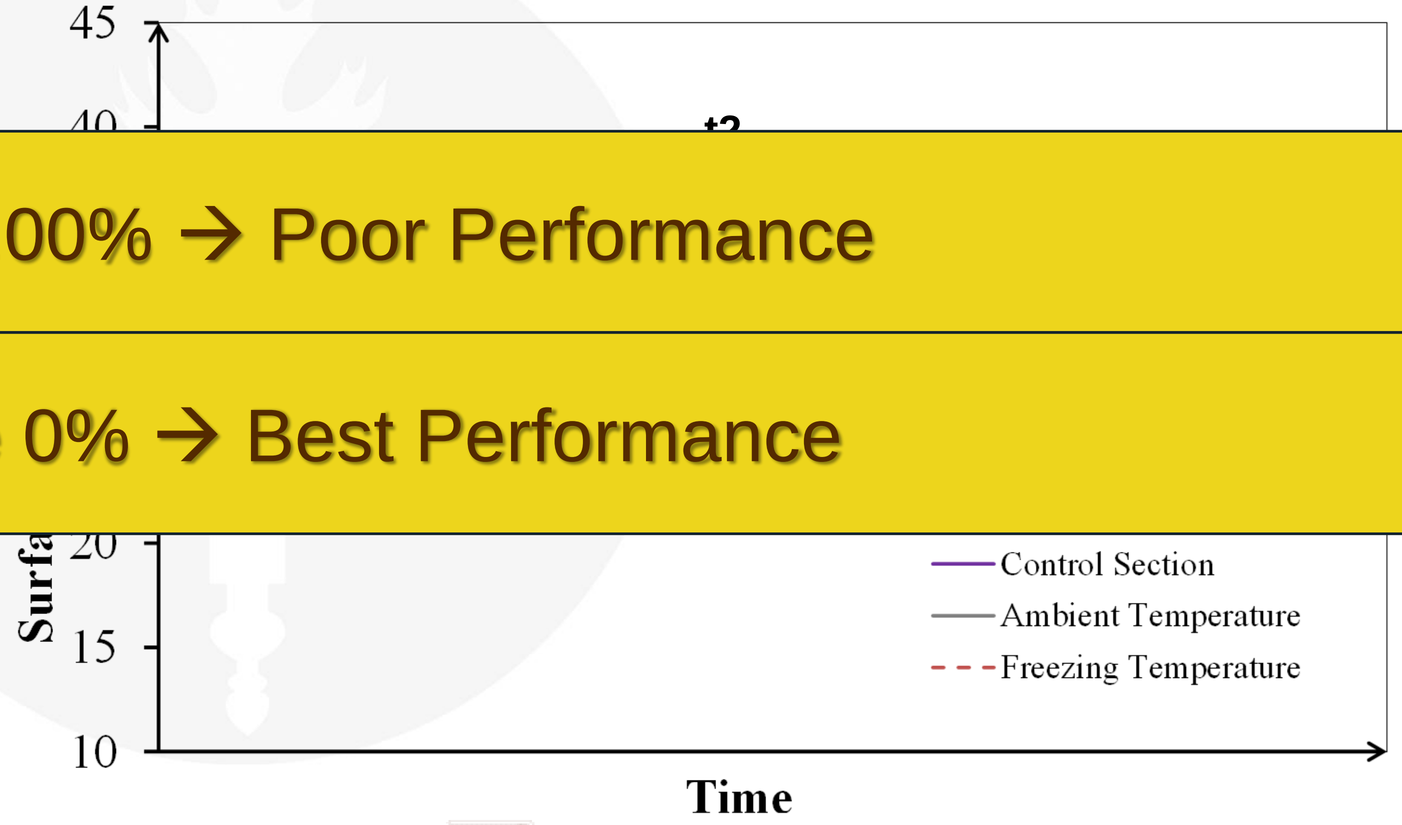
Ambient Temperature Range

(37ºF - 18ºF)



Heating – Time Ratio (HTR)

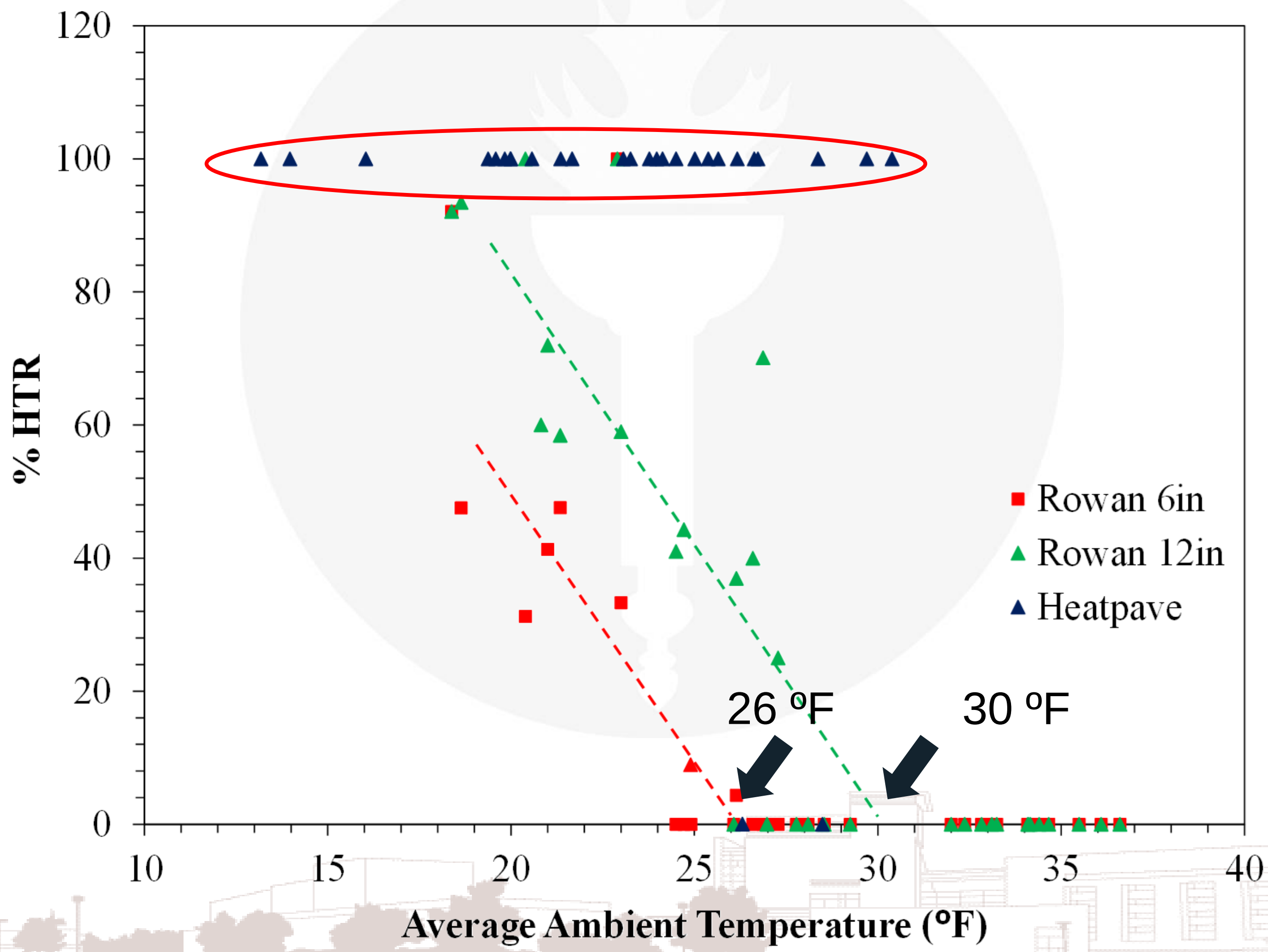
- Heating performance to maintain surface



HTR value100% → Poor Performance

HTR Value 0% → Best Performance

Heating – Time Ratio (HTR)



Power Consumption

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

Section	Average Power (Watts/ft^2)	Std. Deviation	Operating Cost (¢/ft2.hr)
Heat Pave	**19.75**	0.45	0.25
Rowan 6 in.	**11.90**	0.25	0.15
Rowan 12 in.	**5.95**	0.25	0.07

- Operating Heatpave with an area of 100,000 ft2 for 1 hour will cost $252 (considering ¢12.78/kWh – Commercial rate in NJ)

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System Efficiency during Snowfall New Jersey, January 3rd 2022

03:30 PM Heatpave and Control

03:30 PM Rowan Section

Heating Duration: 9.5 hours

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ECA Field Performance

Accelerated Pavement Testing

- APT program: CREATES Heavy Vehicle Simulator (HVS)
- Target no. of passes: 300,000
- Load: 40 kN (Truck)
- Tire pressure: 100 psi
- Sensors: 2 asphalt strain gauges & 2 pressure cells
- Loading mode: Bi-directional
- Wander: Yes; 8 inches
- Test temperature: 50ºF

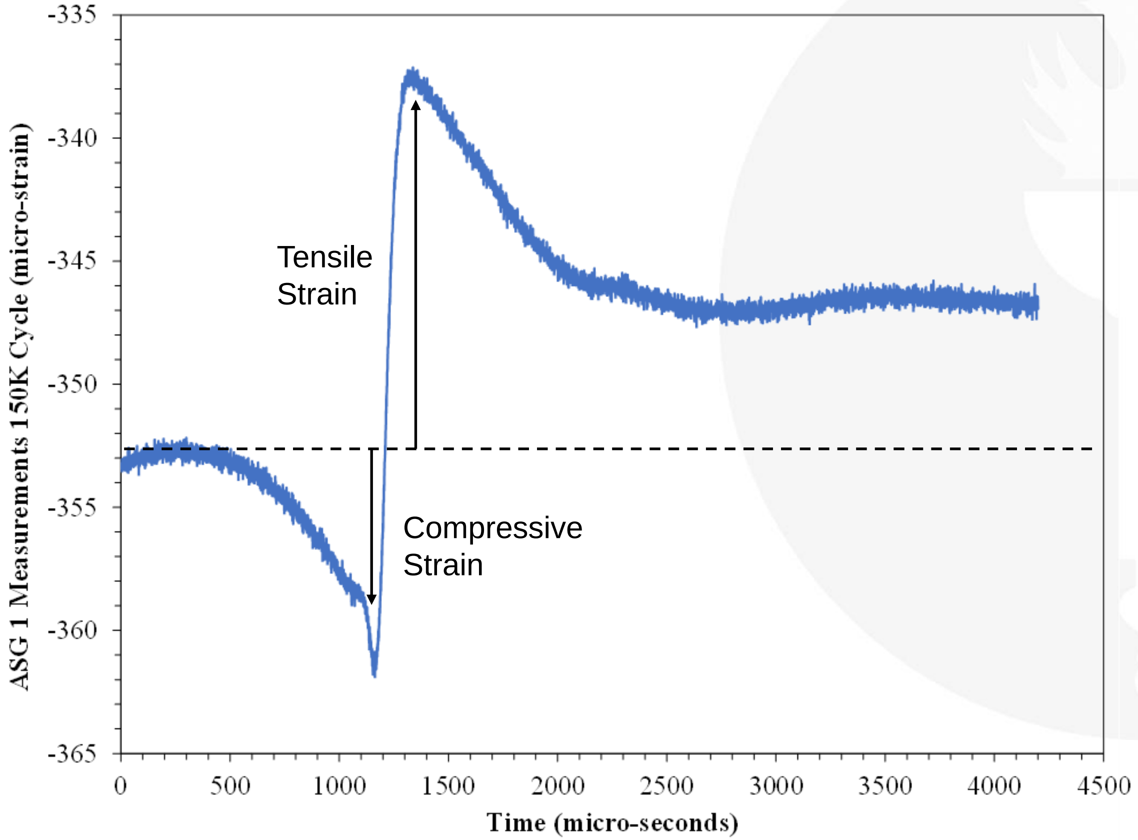
Test Strips after HVS Loading

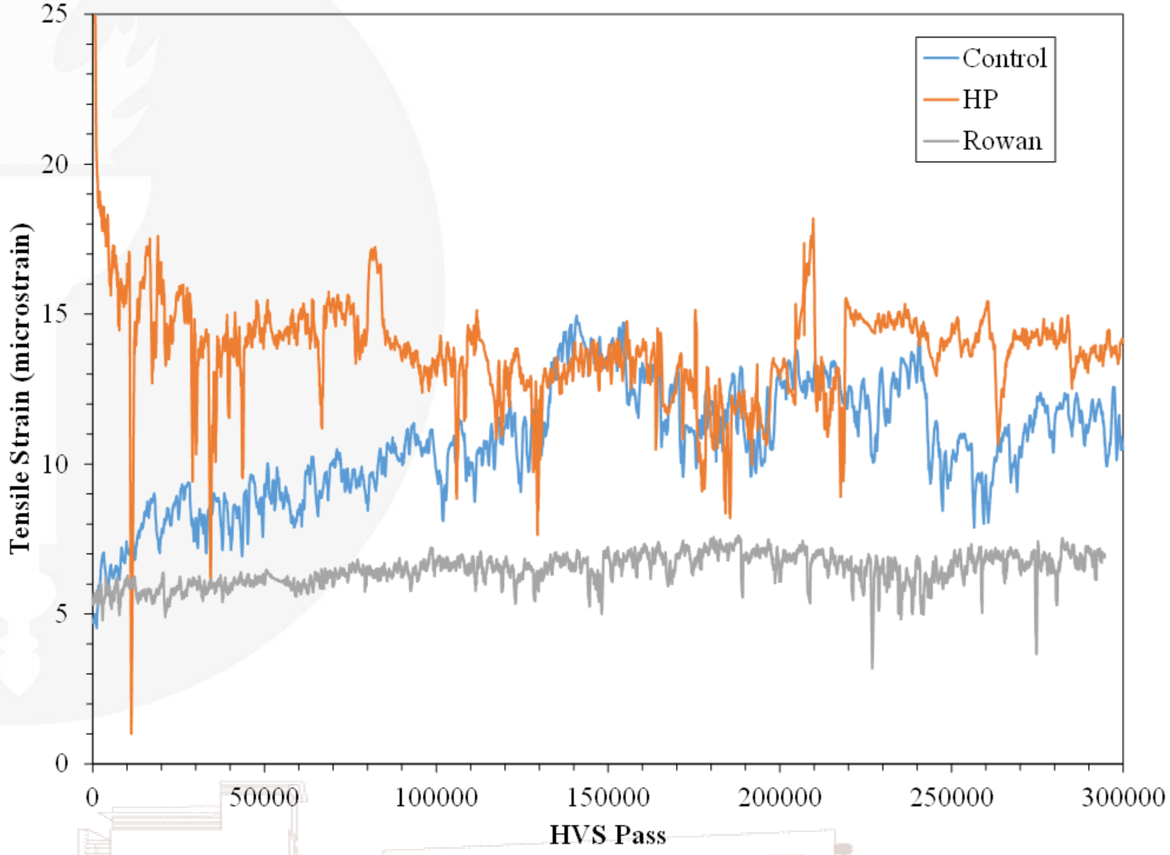
Control

Heatpave

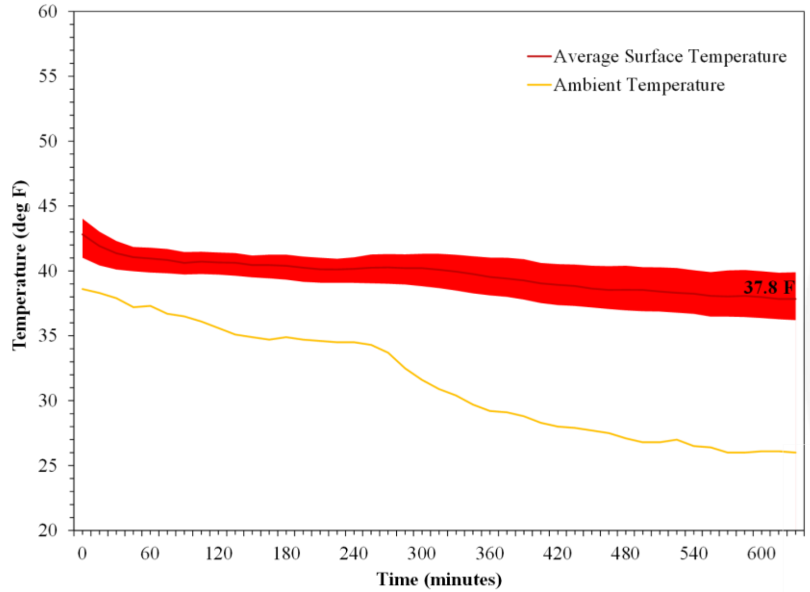
Rowan

Mechanistic Responses



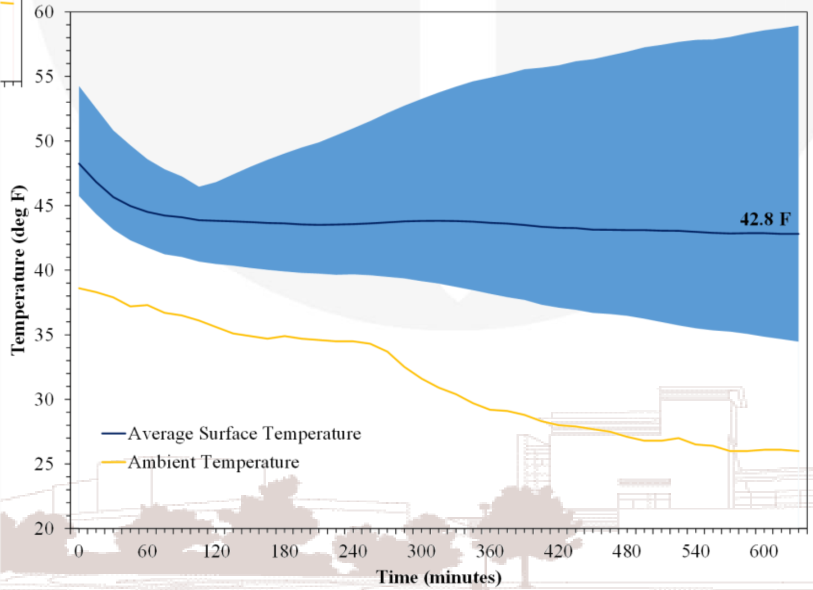


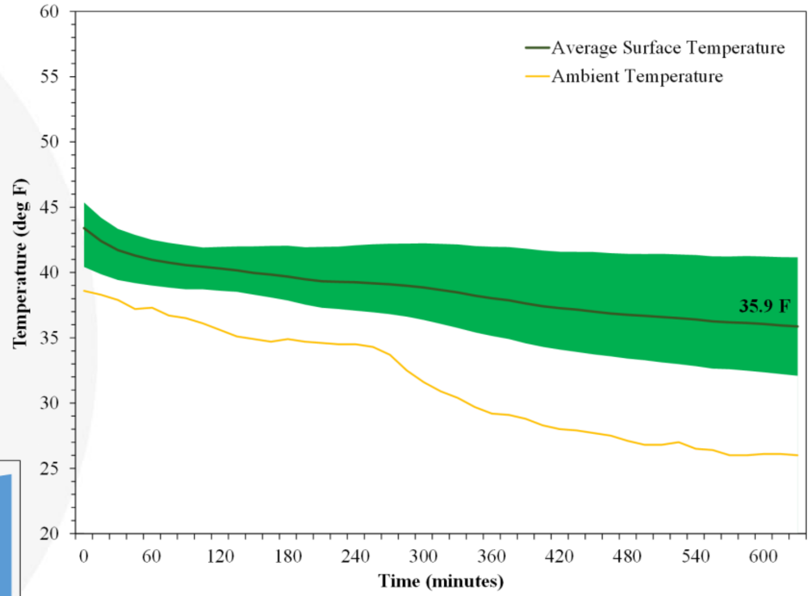
Heating Performance - Post Loading



Rowan 6 in.

Heat Pave





Rowan 12 in.

Power Consumption

Strip	Before Loading (Watts/ft^2)	After Loading (Watts/ft^2)	% Change
Heat Pave	19.75	18.82	- 4.7%
Rowan 6 in.	11.90	11.53	- 3.1%
Rowan 12 in.	5.95	5.76	- 3.2%

Summary of Findings

Performance Factors	Ranking of sections based on performance		
	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)
- Reduction in power consumption of test section was observed after HVS loading (3% - 5%)

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Conclusions & Recommendations

Conclusions & Recommendations

- **Design of ECA mix**

Use of combination of graphite and carbon fibers ensures better conductivity

- **Ease of construction**

Conductive asphalt mixtures are easier to work with compared to 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 & Recommendations

- **Heating Efficiency**

ECA mixtures showed best heating performance along with a less power consumption

- **Electrical Supply**

Higher voltage (>20V) is required when ambient temperature is <10ºF

- **Control of Power Supply**

Automatic control is recommended

- **Other factors should be considered in future studies**

  - Thermal conductivity of ECA layer
  - Thickness ratio of asphalt capping layer and ECA layer
  - Calibrate and validate the finite element model of ECA pavements
  - Assess the performance of ECA pavements in Alaska (CRREL test facility)

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Thank You!

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