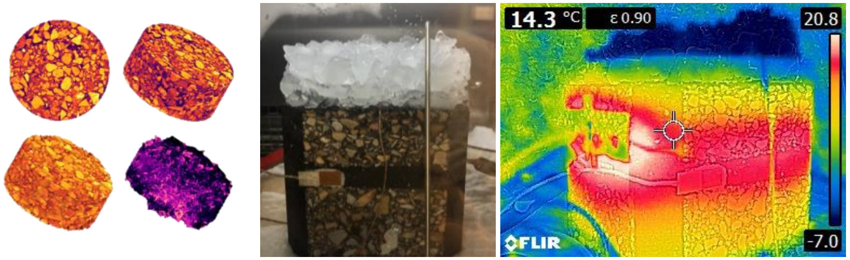
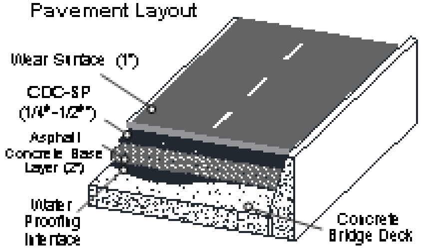
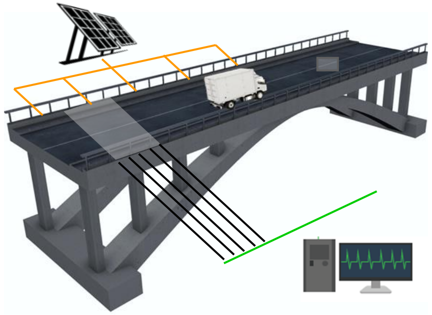
DE-FE0031983

Utilizing coal-derived solid carbon materials towards next-generation smart and multifunction pavements



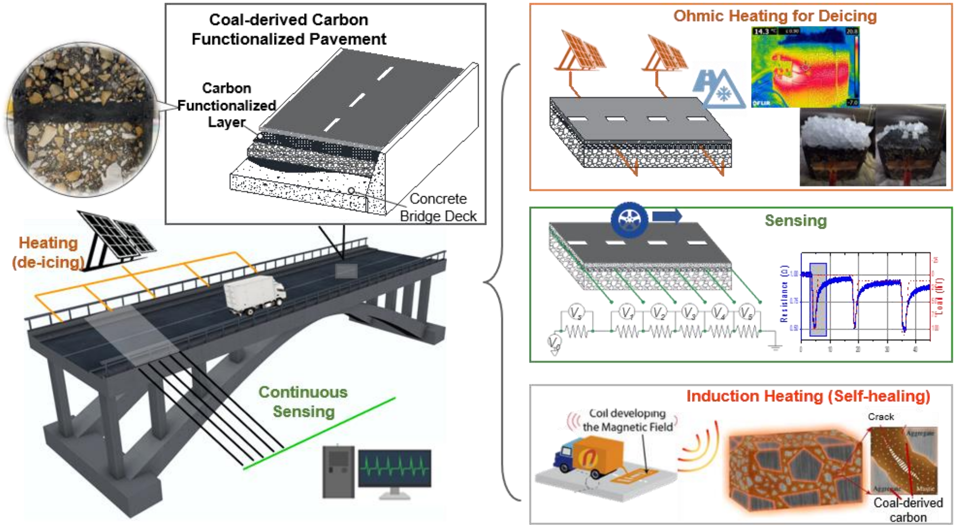




Hongyu 'Nick' Zhou, Ph.D., Associate Professor
Department of Civil and Environmental Engineering
University of Tennessee, Knoxville

Project Review Meeting
April 3rd, 2024

Project Overview



Project Funding:
$430,000 (DOE), $107,500 (Cost-share)
Expenditure to date: $ 428,768.86 (DOE), $107,692 (Cost-share)

Project Performance Period:
01/05/2021 – 03/31/2024 (including NCE)

Project Manager:
Mark Render

Technology Manager:
Dr. Joseph Stoffa

Overall Project Goal

Develop and demonstrate a field deployable, multifunctional smart pavement system made from domestic coal-derived soli carbon materials. This research will demonstrate the use of coke-like coal char, a key byproduct of the coal pyrolysis process, in the design and construction of a prototype multifunctional pavement system that could provide roadways with the capability for self-sensing, self-heating (deicing), and self-healing.

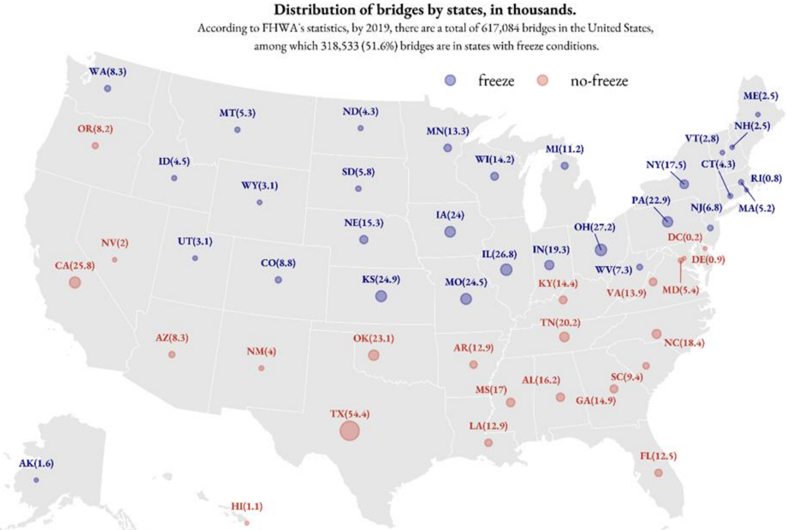
Specific Objectives

(1) Establish processing-structure-property relationships of multifunctional coal-derived pavement materials
(2) Gather experimental data to evaluate its engineering performance and assess the feasibility for scale up
(3) Test and assess the performance of a prototype
(4) Techno-economic analysis (TEA)

Technology Background

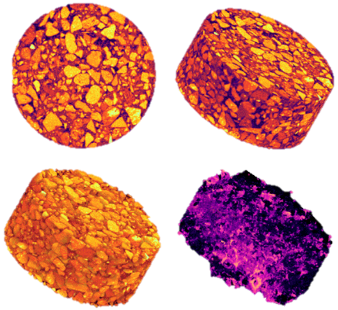
Distribution of Bridge of States, in thousands

According to FHWA's statistics by 2019, there are a total of 617,084 bridges in the U.S., among which 318,533 (51.6%) bridges are in states with freeze conditions.



The U.S. spends about $2.3 billion each year to remove highway snow and ice. Most de-icing is accomplished by **mechanical methods** (scraping, pushing or plowing) or by applying **chemicals** and/or sand as an abrasive.

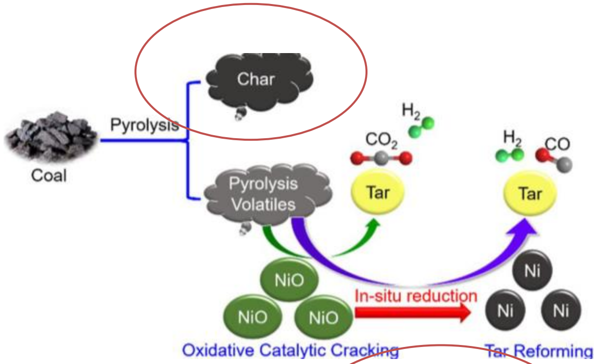
Mechanical deicing causes damage/ wear to pavement surfaces. Chloride-based salts as deicers resist break down in the environment and are corrosive to bridges, other metal structures, especially aluminum, and to the metal parts of vehicles, especially underneath the car. Damage from salt corrosion costs the U.S. up to about $19 billion per year.

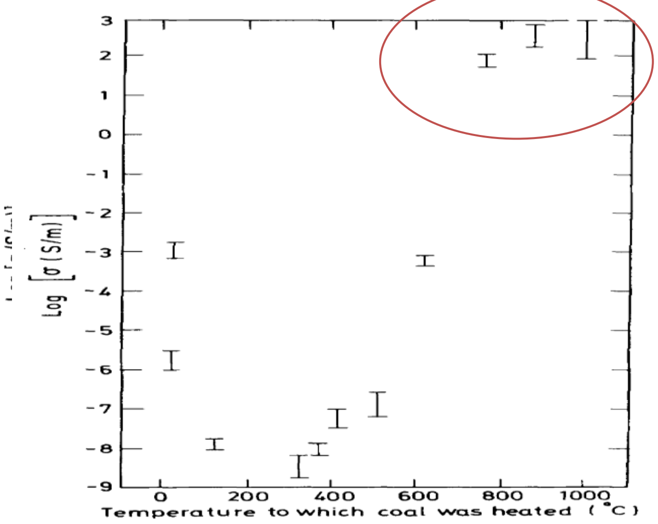


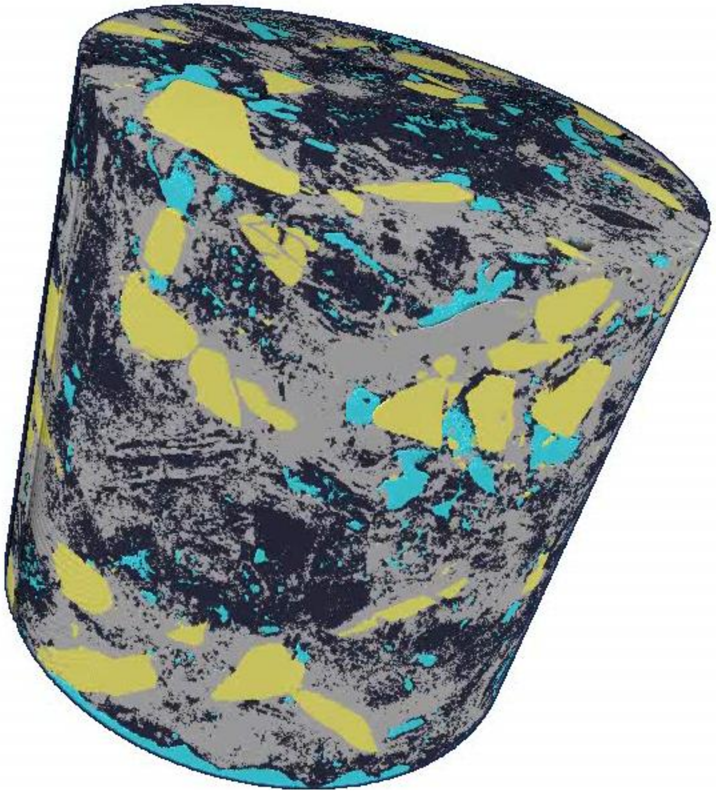
Current 'self-heating pavements' are difficult to build and 'non-recyclable', the embedment of carbon fiber (for heating) lead to rapid deterioration of asphalt binder

Technology Background

University of Tennessee, Knoxville (UTK) is developing a new class of multifunctional asphalt materials using coal-derived solid carbon. The percolated network formed by coal char within the aggregate system provide conductive pathway to enable pavement deicing, damage sensing, and potentially self-healing.



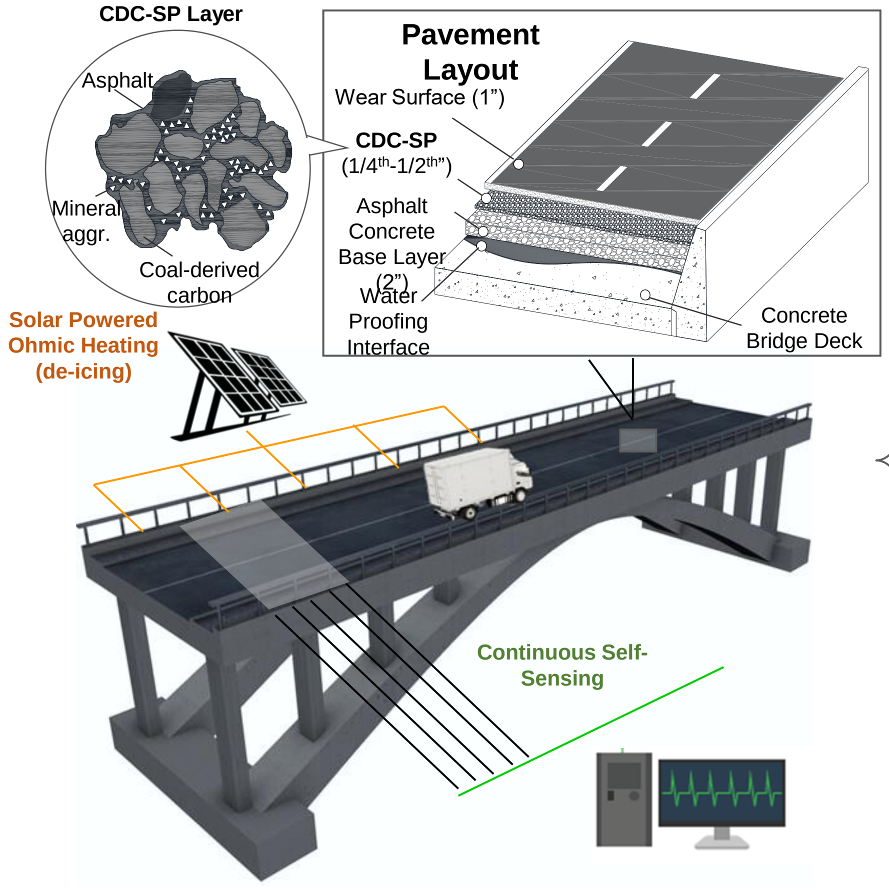


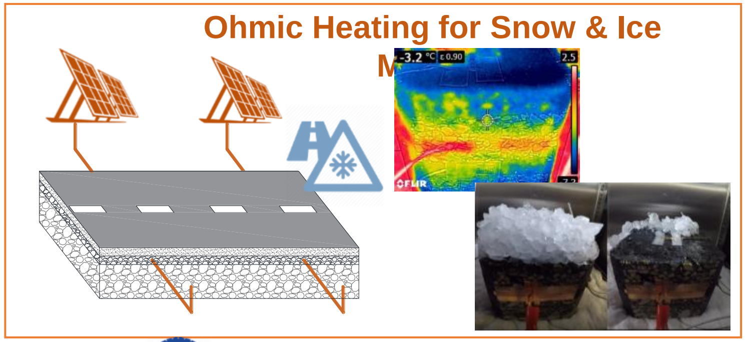


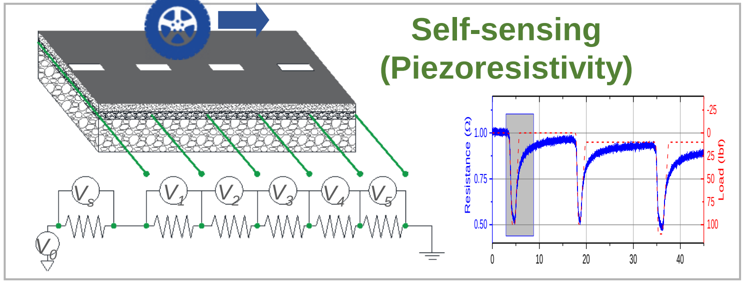
Limestone skeleton

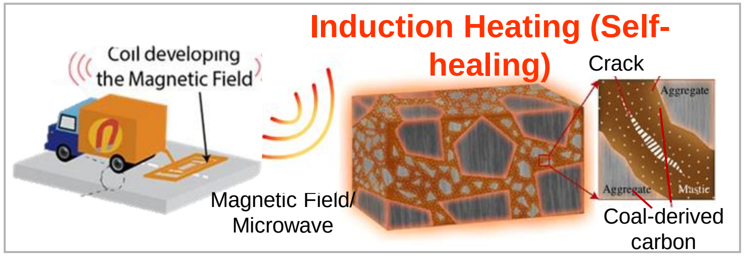
Technology Background

The **‘one-stop-shop’ smart pavement solution** for **Ohmic heating (deicing)**, **self-sensing**, and **self-healing.**




Ohmic Heating for Snow & Ice M

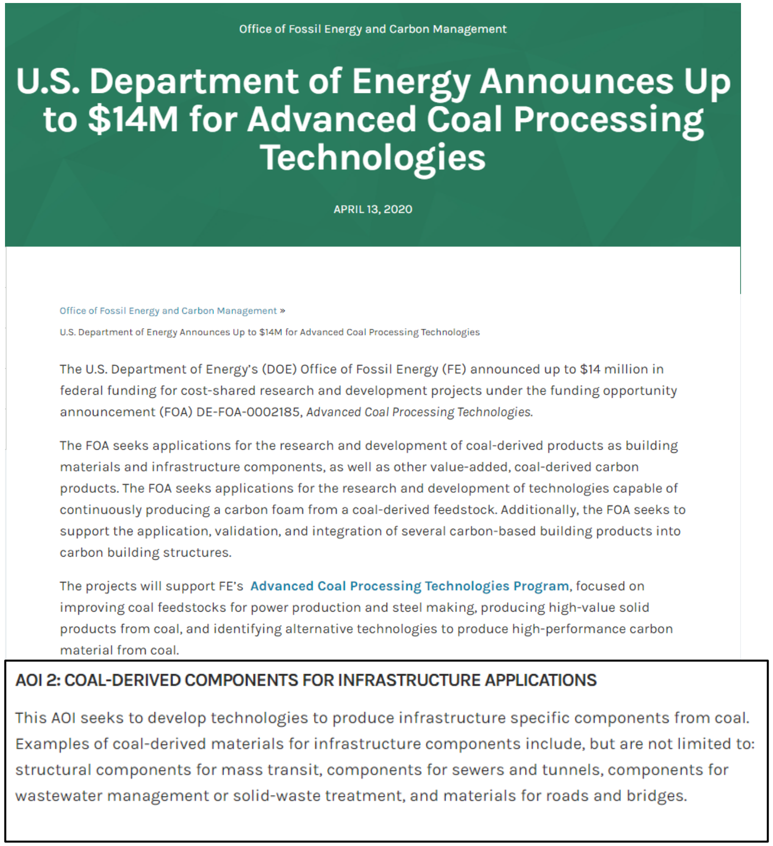

Self-sensing (Piezoresistivity)


Induction Heating (Self-healing)

Background

Strategic Alignment to FECM Objectives

- This new strategy enables the production of multifunctional smart pavements at costs comparable to those of regular pavements.
- Market benefits include the utilization of domestic coal resources in the infrastructure sector to enable multifunctionalities of future smart pavement systems.
- Impacts is significant in terms of the time and cost savings for winter roadway operations, reducing traffic delay and improving safety, reducing corrosion and environmental impacts caused by de-icing chemicals.



Office of Fossil Energy and Carbon Management

U.S. Department of Energy Announces Up to $14M for Advanced Coal Processing Technologies

APRIL 13, 2020

Office of Fossil Energy and Carbon Management »

U.S. Department of Energy Announces Up to $14M for Advanced Coal Processing Technologies

The U.S. Department of Energy's (DOE) Office of Fossil Energy (FE) announced up to $14 million in federal funding for cost-shared research and development projects under the funding opportunity announcement (FOA) DE-FOA-0002185, *Advanced Coal Processing Technologies.*

The FOA seeks applications for the research and development of coal-derived products as building materials and infrastructure components, as well as other value-added, coal-derived carbon products. The FOA seeks applications for the research and development of technologies capable of continuously producing a carbon foam from a coal-derived feedstock. Additionally, the FOA seeks to support the application, validation, and integration of several carbon-based building products into carbon building structures.

The projects will support FE's **Advanced Coal Processing Technologies Program**, focused on improving coal feedstocks for power production and steel making, producing high-value solid products from coal, and identifying alternative technologies to produce high-performance carbon material from coal.

AOI 2: COAL-DERIVED COMPONENTS FOR INFRASTRUCTURE APPLICATIONS

This AOI seeks to develop technologies to produce infrastructure specific components from coal. Examples of coal-derived materials for infrastructure components include, but are not limited to: structural components for mass transit, components for sewers and tunnels, components for wastewater management or solid-waste treatment, and materials for roads and bridges.

Research Team

Research Team

Dr. Hongyu 'Nick' Zhou
Associate Professor, Civil and Environmental Engineering
University of Tennessee, Knoxville

Dr. Baoshan Huang, PhD, PE
Edward Burdette Professor, Civil and Environmental Engineering
University of Tennessee, Knoxville

Hongyu 'Nick' Zhou
PI @ UTK

Baoshan Huang
Co-PI @ UTK

Industrial Partners

Mr. Jon Niebel
General Manager, ET Construction
Rogers Group Inc.

ROGERS GROUP INC.

Mr. Ryan Weir
Director of Research and Technical Services
Asbury Carbons

ASBURY CARBONS

Ms. Heather Hall
Director, Materials & Tests
Tennessee Department of Transportation

TN TDOT Department of Transportation

Dr. Gaylon Baumgardner
Senior Vice President
Ergon Asphalt & Emulsions, Inc.

Ergon Asphalt & Emulsions, Inc.
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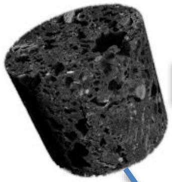
Technology Approach

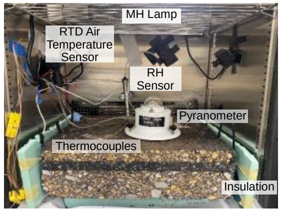
From Laboratory to Field

Coal char (feedstock)

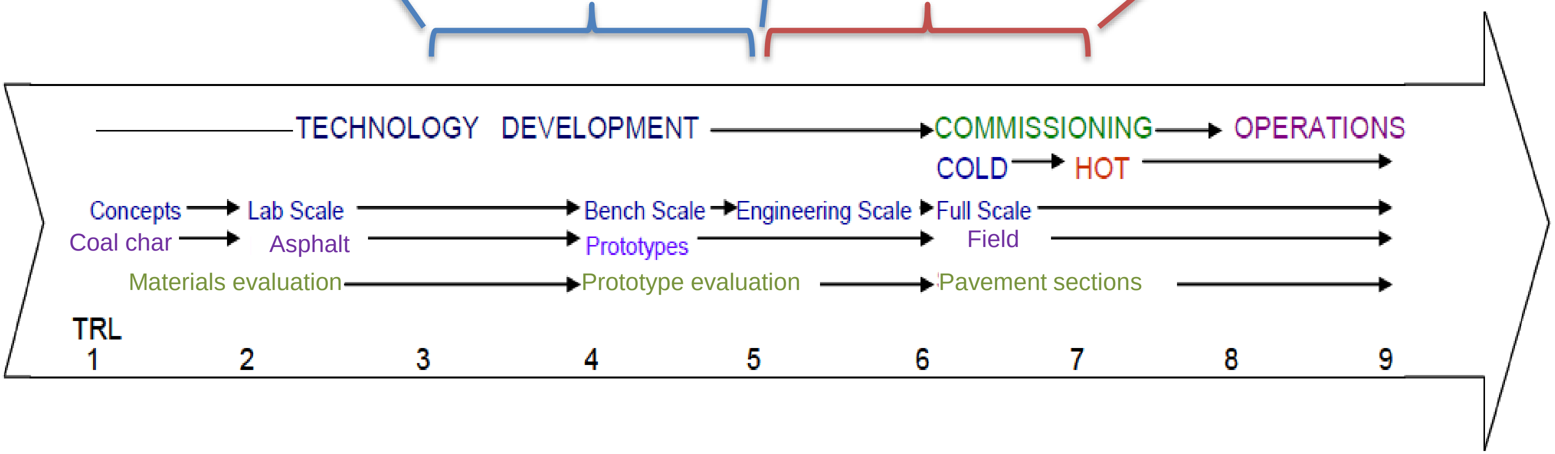


Pavement Materials

Prototype Demonstration



Field Construction



Phase I Research
(2021.1 - 2023.8)

NCE
(2023.9 - 2024.3)

TECHNOLOGY DEVELOPMENT → COMMISSIONING → OPERATIONS

COLD → HOT →

Concepts → Lab Scale → Bench Scale → Engineering Scale → Full Scale →

Coal char → Asphalt → Prototypes → Field →

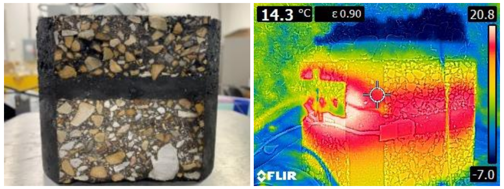
Materials evaluation → Prototype evaluation → Pavement sections →

TRL
1 2 3 4 5 6 7 8 9

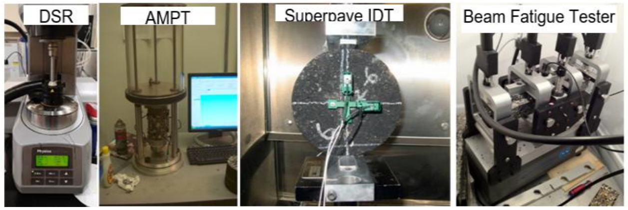
Research Tasks

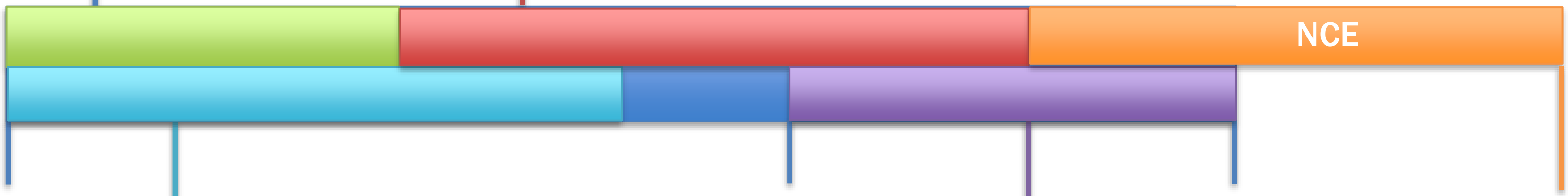
Research Tasks

Task I & II – Project Planning & Market Analysis



Task IV – Developing Multifunctional Coal Char Bearing Multifunctional Asphalt Mixture





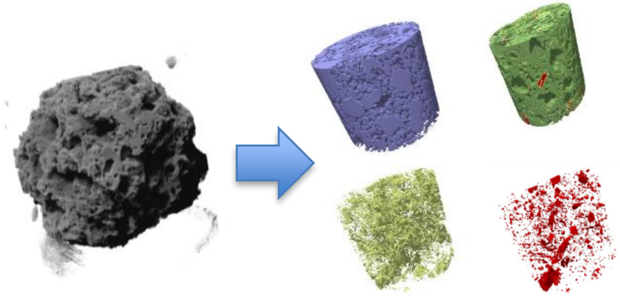
2021.1

2022.10

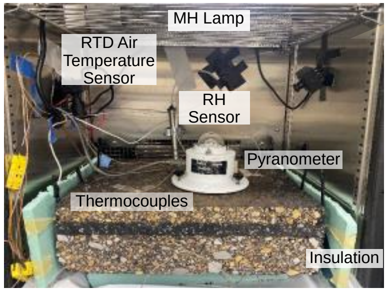
2023.8

2024.3

Task III – Characterization and Processing of Coal Char for Multifunctional Pavement

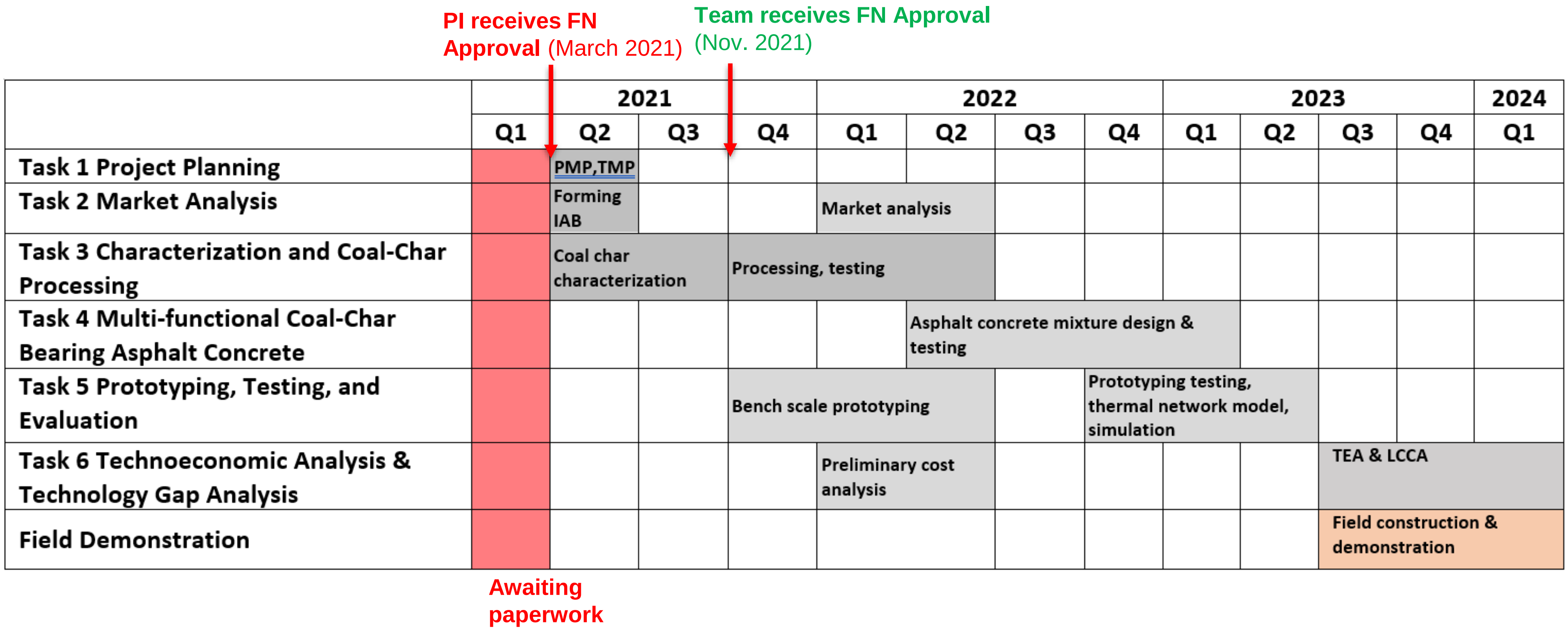


Task V – Prototype development and test



Field Demonstration

Project Execution Timeline



PI receives FN Approval (March 2021)

Team receives FN Approval (Nov. 2021)

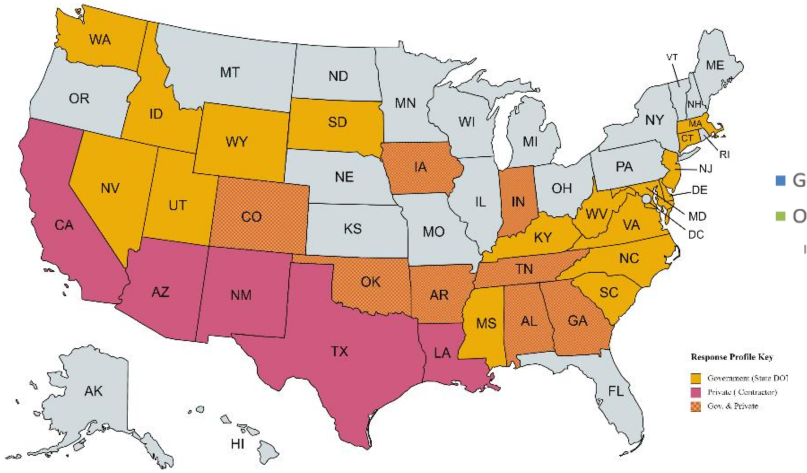
	2021				2022				2023				2024
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Task 1 Project Planning	🟥	PMP,TMP											
Task 2 Market Analysis	🟥	Forming IAB			Market analysis								
Task 3 Characterization and Coal-Char Processing	🟥	Coal char characterization		Processing, testing									
Task 4 Multi-functional Coal-Char Bearing Asphalt Concrete	🟥					Asphalt concrete mixture design & testing							
Task 5 Prototyping, Testing, and Evaluation	🟥			Bench scale prototyping				Prototyping testing, thermal network model, simulation					
Task 6 Technoeconomic Analysis & Technology Gap Analysis	🟥				Preliminary cost analysis						TEA & LCCA		
Field Demonstration	🟥										Field construction & demonstration		

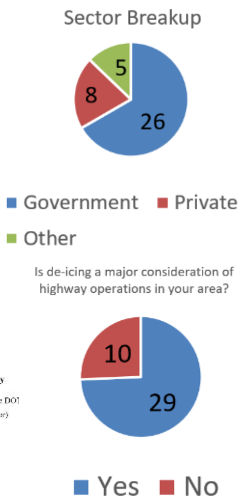
Awaiting paperwork

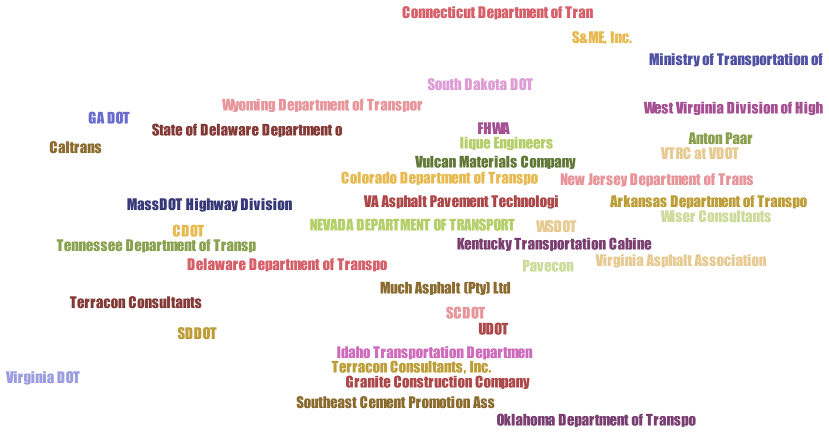
Accomplishments

Task 2 Market Analysis

A comprehensive survey was prepared to help understand the potential market, technological, and economical challenges of the proposed smart pavement technology.





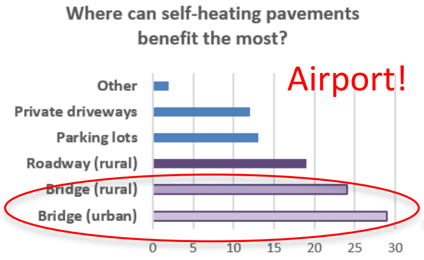


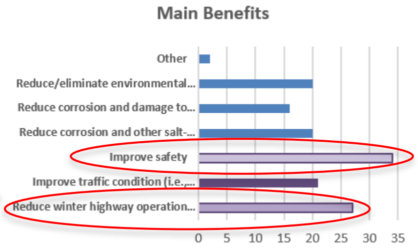
~200 Emails/Mails were distributed. 39 responses received by March 30th 2022, covering 30 US states, 2 Canadian Provinces, and South Africa.

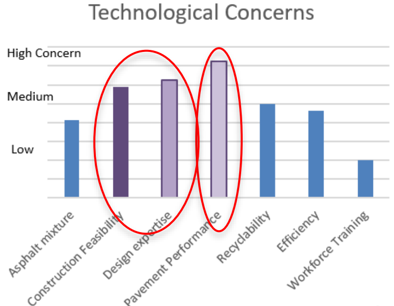
Accomplishments

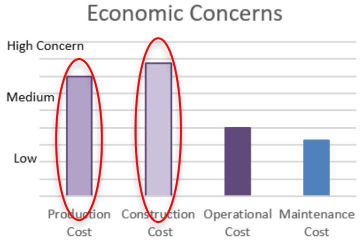
Task 2 Market Analysis

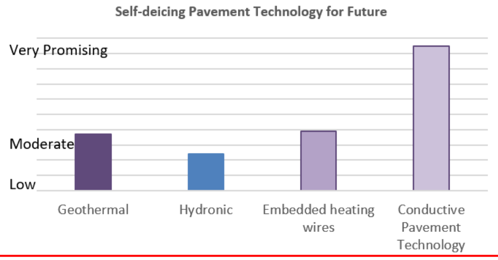
A comprehensive survey was prepared to help understand the potential market, technological, and economical challenges of the proposed smart pavement technology.

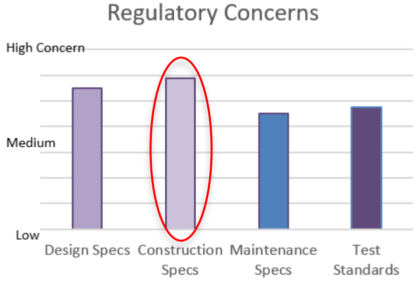










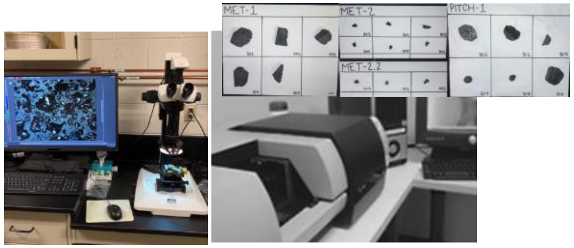


Key Takeaways:

- Stakeholders (both government and industry) have **high level of interest** as compared to competing technologies.
- Most think that it will benefit the **bridge (urban and rural)** and **airport** most. Key benefits include: **improving safety** and **reducing winter roadway maintenance cost**.
- Main perceived technological barriers: **pavement performance**, **design expertise**, **construction**.
- Main perceived economic barriers: **Construction cost** and **production cost**.
- Main perceived regulatory barriers: **Construction** and **Design Specifications**.

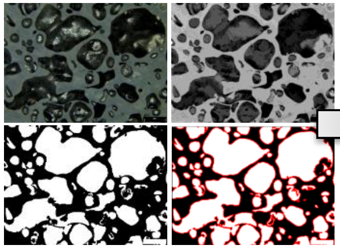
Accomplishments

Task 3.1: Characterization and Processing of Coal Char/ Coke



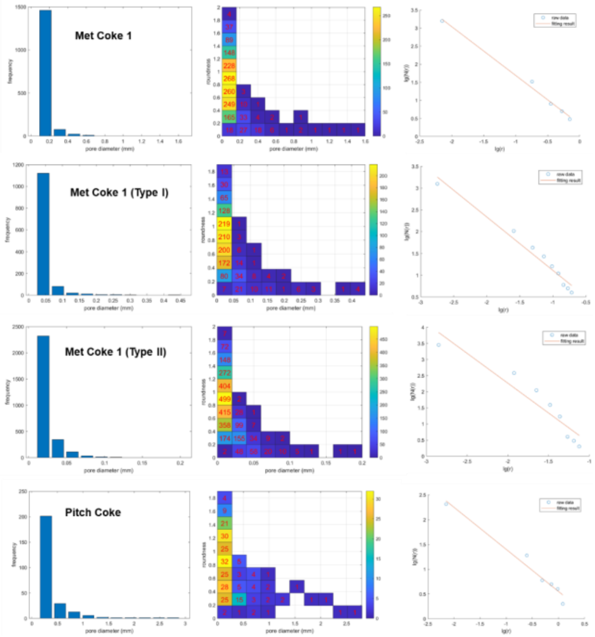
Optical Stereomicroscopy

Four (4) different coal char types:
- Metallurgical coke from two sources (3 types)
- Pitch coke



In-house imaging process algorithm (code) for microstructural analysis

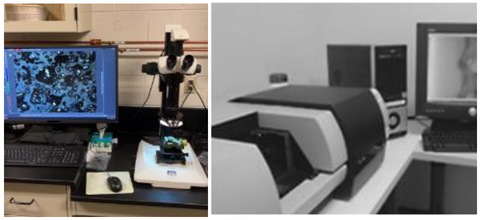
Geometric feature extraction



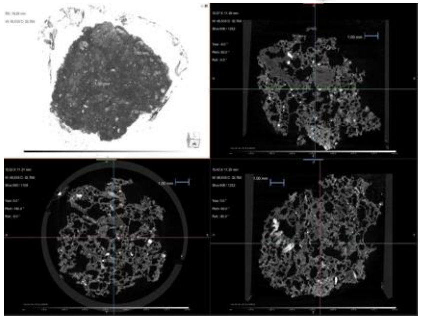
Parameter	Description
Porosity	The ratio of the pixel count of the total area occupied by pores and the total field area of the image
Perimeter	The total length of the boundary around the detected image within the measure frame
Equivalent diameter	Diameter of a circle with the same area A as the region, defined as $\sqrt{\frac{4A}{\pi}}$
Length/ Breadth	Length: Length of the major axis of the ellipse that has the same normalized second central moments as the region Breadth: Length of the minor axis of the ellipse that has the same normalized second central moments as the region
Roundness	A parameter quantifies the shape of the pore using area A and perimeter P, i.e. $\frac{4\pi A}{P^2}$

Accomplishments

Task 3.1: Characterization and Processing of Coal Char/ Coke



Micro-CT



Processing of 3D XRM data (DragonFly Pro)

Met Coke-1: Porosity: 45%, Pore volume: 54.91mm^3 , Pore Surface Area: 1138mm^2

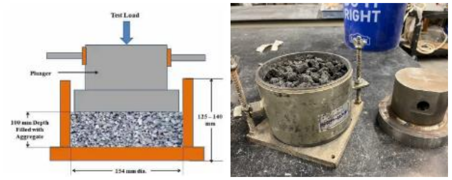
Met Coke-1 (Type I): Porosity: 38%, Pore volume: 38.57mm^3 , Pore Surface Area: 1348mm^2

Pitch Coke: Porosity: 59%, Pore volume: 210.09mm^3 , Pore Surface Area: 1525mm^2

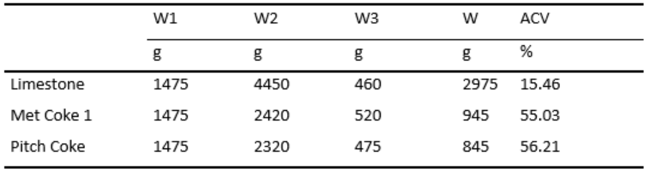
Met Coke-1 (Type II): Porosity: 17.26%, Pore volume: 90.24mm^3 , Pore Surface Area: 548mm^2

Accomplishments

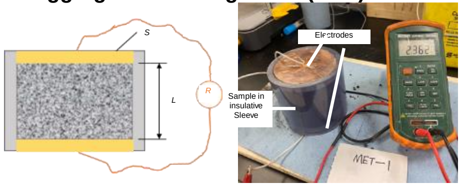
Task 3.1: Characterization and Processing of Coal Char/ Coke



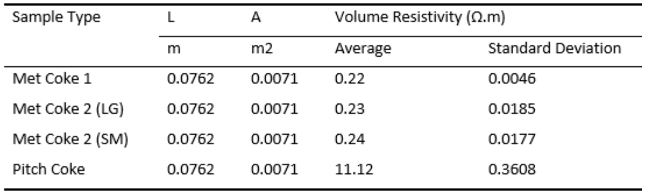
Aggregate Crushing Value (ACV) Test



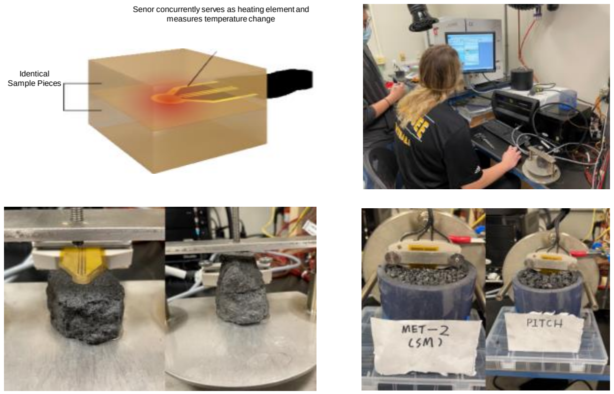
	W1	W2	W3	W	ACV
	g	g	g	g	%
Limestone	1475	4450	460	2975	15.46
Met Coke 1	1475	2420	520	945	55.03
Pitch Coke	1475	2320	475	845	56.21



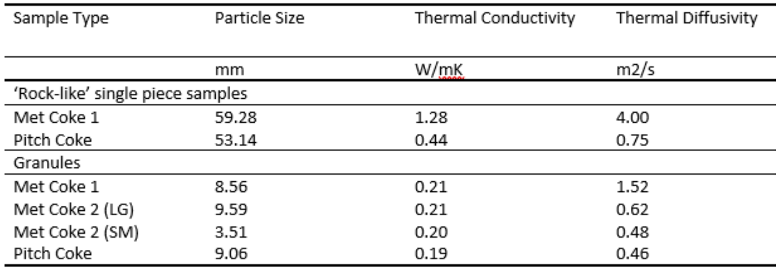
(Electric) Volumetric Resistivity Test



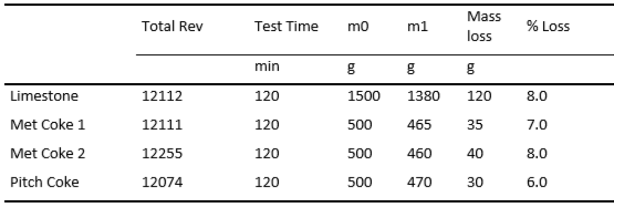
Sample Type	L	A	Volume Resistivity (Ω.m)	
	m	m2	Average	Standard Deviation
Met Coke 1	0.0762	0.0071	0.22	0.0046
Met Coke 2 (LG)	0.0762	0.0071	0.23	0.0185
Met Coke 2 (SM)	0.0762	0.0071	0.24	0.0177
Pitch Coke	0.0762	0.0071	11.12	0.3608



Thermal Conductivity Test (TPS)



Sample Type	Particle Size	Thermal Conductivity	Thermal Diffusivity
	mm	W/mK	m2/s
‘Rock-like’ single piece samples			
Met Coke 1	59.28	1.28	4.00
Pitch Coke	53.14	0.44	0.75
Granules			
Met Coke 1	8.56	0.21	1.52
Met Coke 2 (LG)	9.59	0.21	0.62
Met Coke 2 (SM)	3.51	0.20	0.48
Pitch Coke	9.06	0.19	0.46



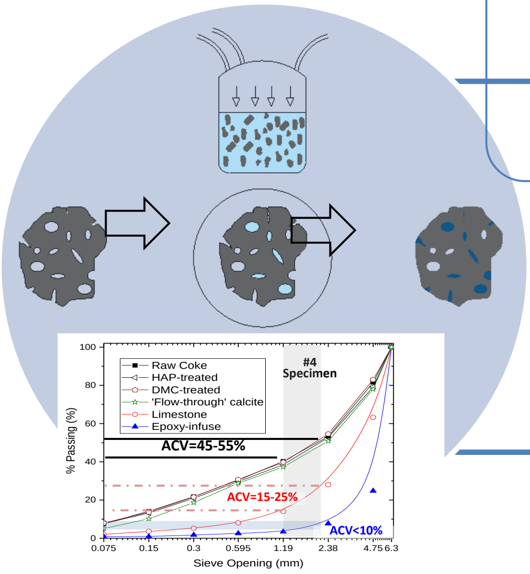
	Total Rev	Test Time	m0	m1	Mass loss	% Loss
		min	g	g	g	
Limestone	12112	120	1500	1380	120	8.0
Met Coke 1	12111	120	500	465	35	7.0
Met Coke 2	12255	120	500	460	40	8.0
Pitch Coke	12074	120	500	470	30	6.0

Key Takeaways (Subtask 3.1):

- **Metallurgical coke** has Low electric resistivity (<0.2 Ω.m measured in granules), reasonable mechanical strength to be used in pavements. However, it has high connected porosity (therefore low compressive strength (high ACV) and low abrasion resistance (high % loss as tested by Micro-Deval)). Intermediate thermal conductivity.
- Material properties are not sensitive to source. (Different pore-sizes are seen from difference sources)
- Met coke is suitable for conductive pavement development. Strengthening mechanical properties will be beneficial.
- **Pitch coke** is **NOT** suitable for conductive pavement development due to its **LOW electric conductivity** and has large volume of **isolated pore structure** (therefore difficult to improve).

Accomplishments

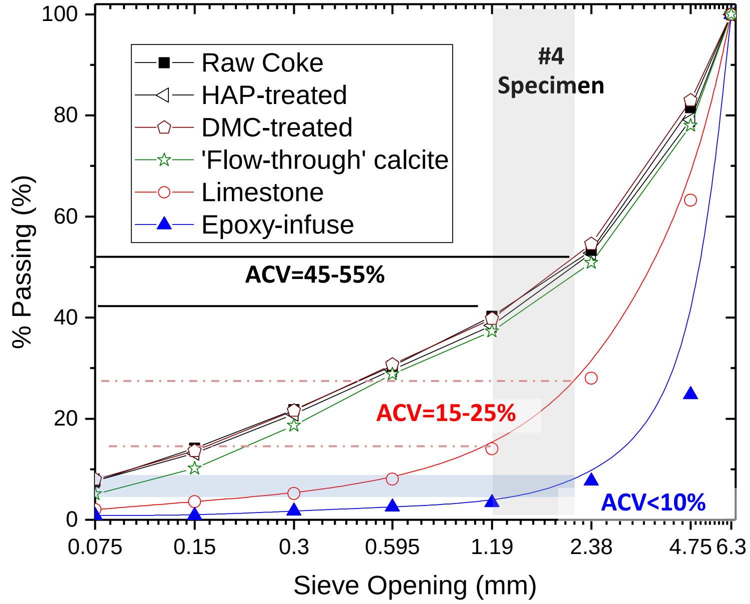
Task 3.2: Strategies to Enhance Coal Char Mech

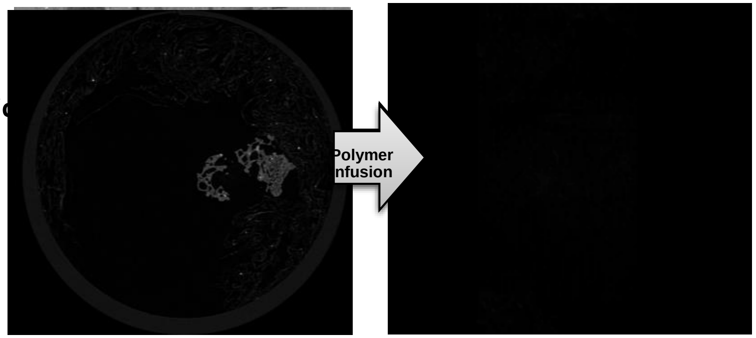


Polymer Infusion

Mineral Precipitation

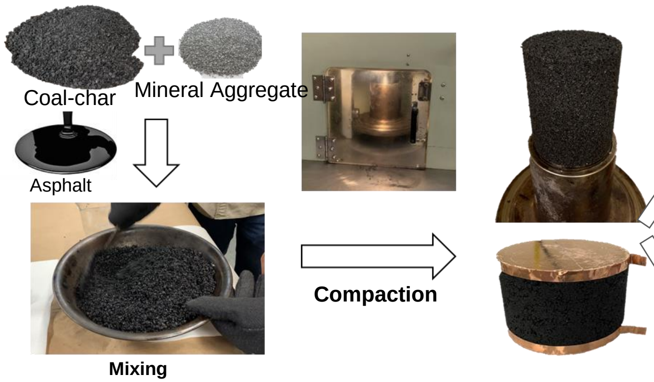
'Flow-through' Precipitati

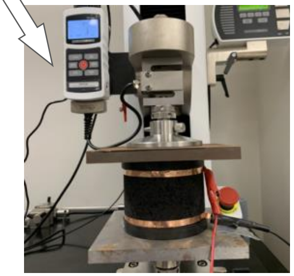




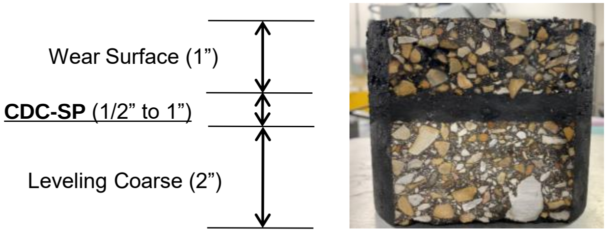
Accomplishments

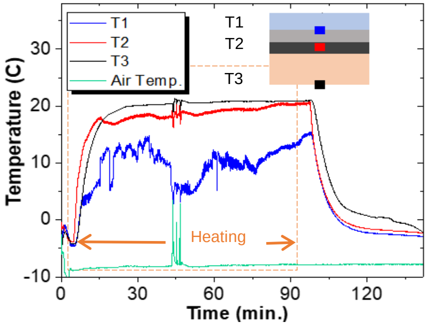
Task 4: Developing Multifunctional Coal-char Bearing Asphalt Concrete

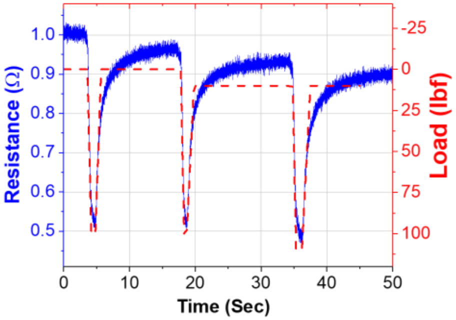


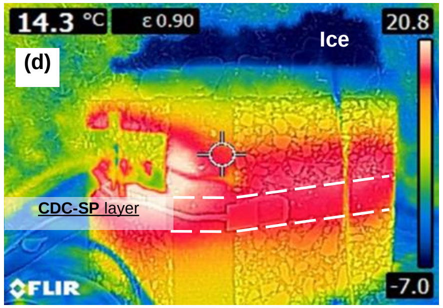


Strain Sensing



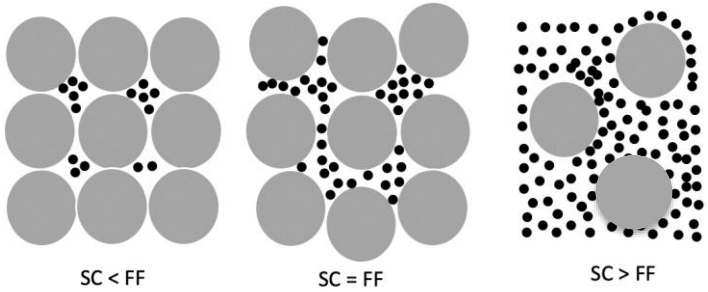






Accomplishments

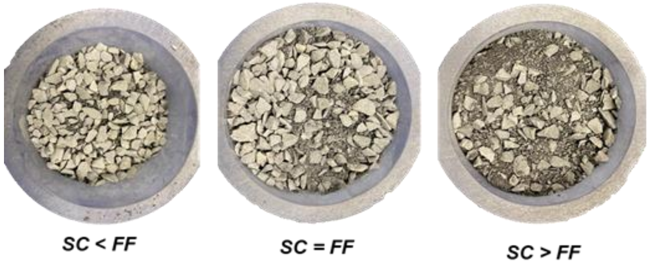
Task 4.1: Mixture design and engineering properties (complete)

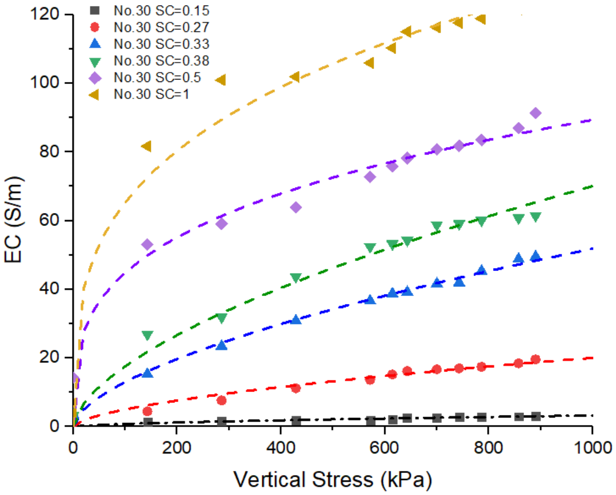


$$FF = \frac{G_s.e_L}{G_L(1+e_s)+G_s.e_L}$$

$$EC_{mix} = EC_p.\frac{(1-n)}{[1+(\frac{1}{SC}-1).\frac{G_{cp}}{G_{ncp}}]}.(\frac{L}{L_p})^2 + EC_w.\frac{n}{T^2} + EC_s.\frac{(1-n)}{T^2}.S_a.G_s.\rho_w$$

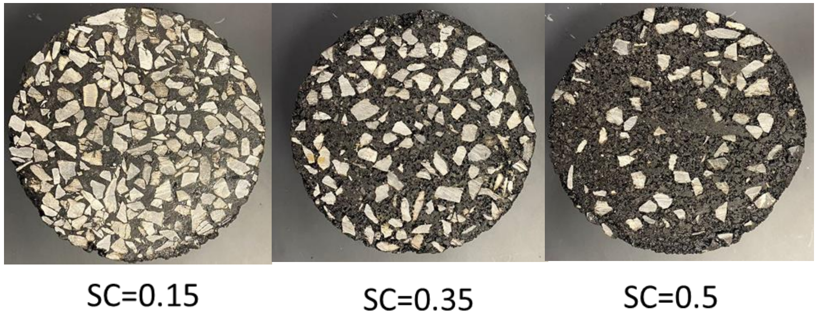
$$EC_{mix} = \alpha.\frac{(1-n)}{[1+(\frac{1}{SC}-1).\frac{G_{cp}}{G_{ncp}}]}.(\frac{L}{L_p})^2.(\frac{\sigma_v}{1kPa})^\beta = A.(\frac{\sigma_v}{1kPa})^\beta$$



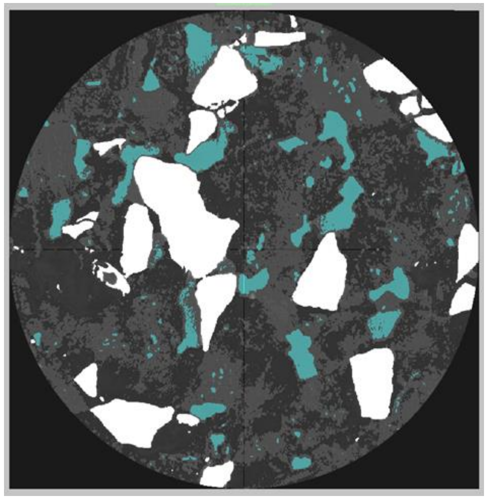


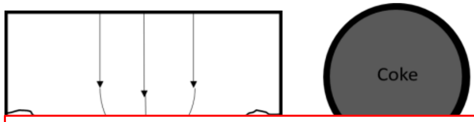
Accomplishments

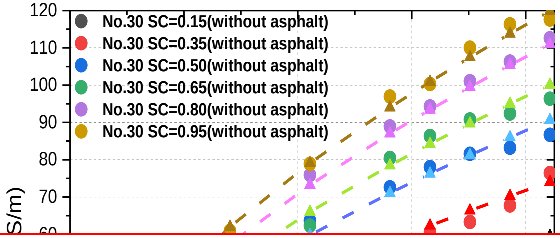
Task 4.1: Mixture design and engineering properties

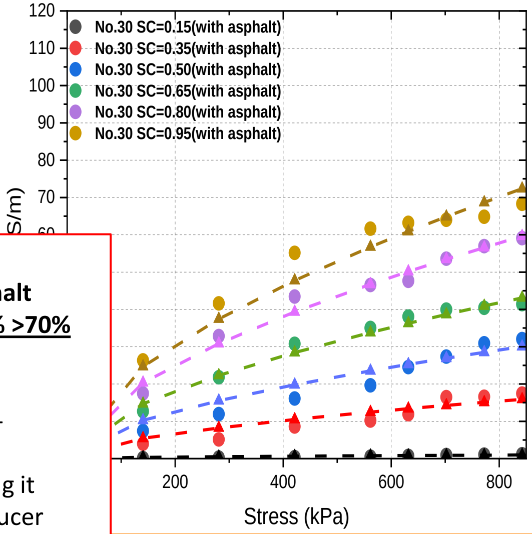


SC=0.15 SC=0.35 SC=0.5









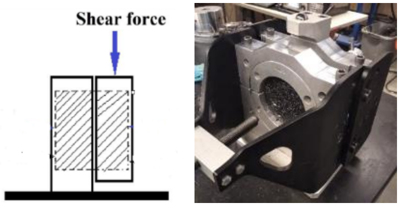
Key Takeaways:

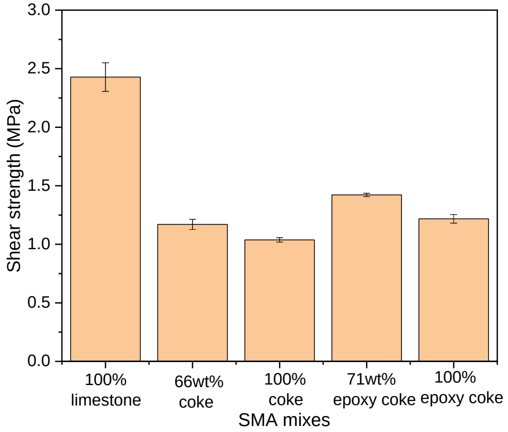
- Both ‘Superpave’ and ‘Marshall’ mixture design methods were used to design **Coal-char bearing Stone Mastic Asphalt (SMA)** mixtures. The carbon content calculation satisfies the <u>coal derived carbon wt% > 50% and total carbon wt% >70%</u> requirement by FOA.
- The **volumetric resistivity (main functionality) of the coal-char bearing asphalt is 1-2 magnitudes lower (better in performance!) than any existing technology in the market or under development**, while showing remarkable cost-performance metrics.
- This technology also **do NOT require any modification to the production and paving equipment or practice**. Making it easier to adopt by the road building industry. Future research may be conducted in collaboration with asphalt producer and contractor to further quantify its <u>**constructability**</u>.

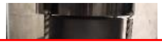
Accomplishments

Task 4.2: Mixture design and engineering properties

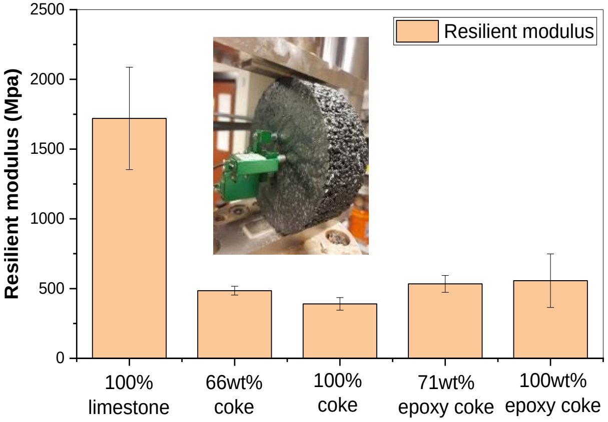
Direct Shear (AASHTO TP114-18)



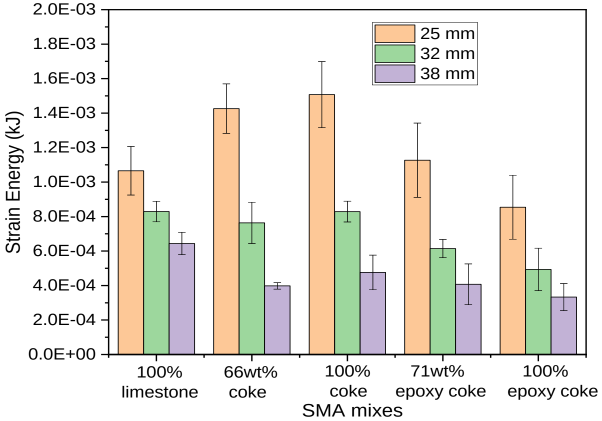




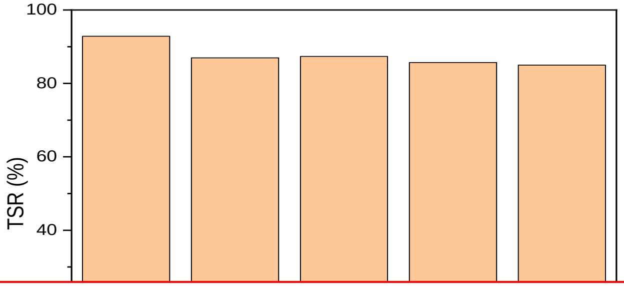
Resilient Modulus (ASTM D7369-20)



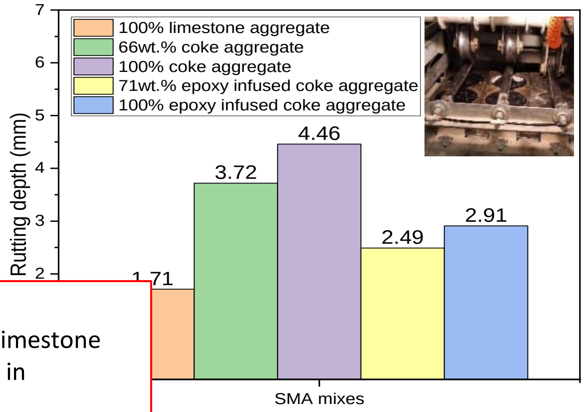
Simi-circular Bending (ASTM D8044-16)



Moisture Susceptibility (AASHTO T283-21)



Rutting resistance – APA Test (AASHTO T340-19)

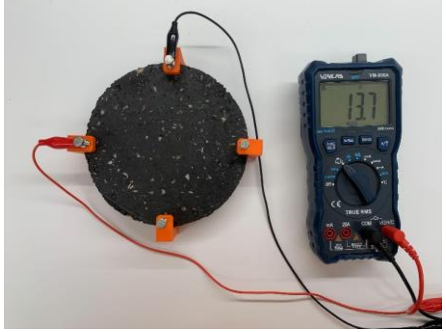


Key Takeaways:

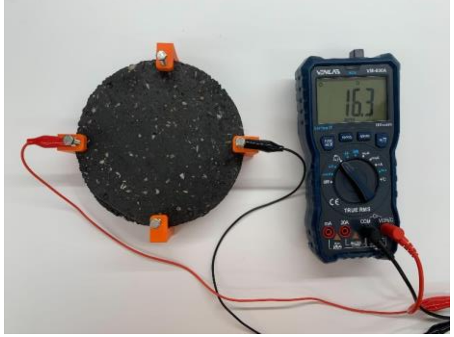
- Coal-char bearing HMA mixtures have lower shear strength and resilient modulus than the baseline with 100% limestone aggregate; however, the material performance has good potential to meet AASHTO/ ASTM standard to be used in pavement structure.
- Coal-char bearing HMA has acceptable durability against moisture damage, good fracture toughness, and acceptable resistance to rutting damage as tested by APA
- Overall coal-char bearing HMA has good potential to meet industrial standards for pavement applications.

Accomplishments

Task 3.3, 4.4: Functionalizing pavement for sensing (pilot)



Adjacent probe resistance



Opposite probe resistance

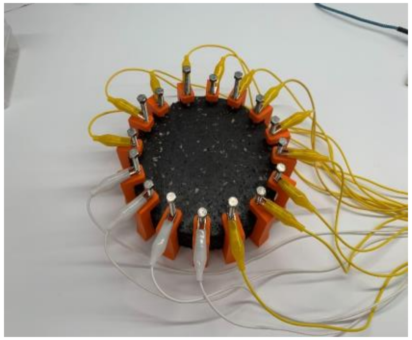


Figure 1

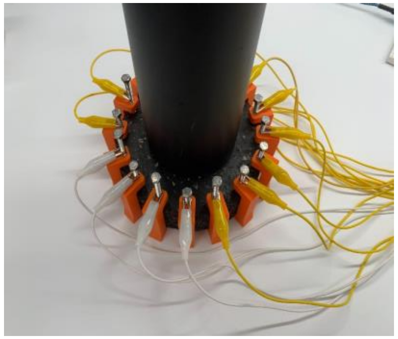
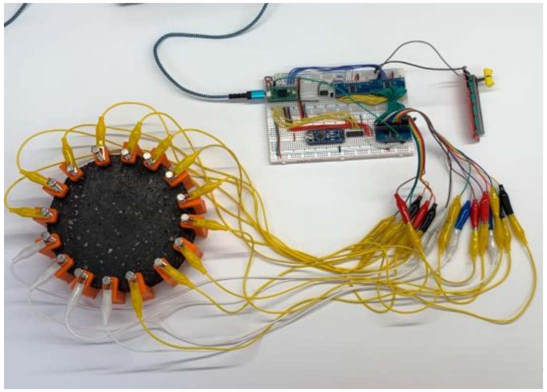


Figure 3



Electric Impedance Topography (EIT)

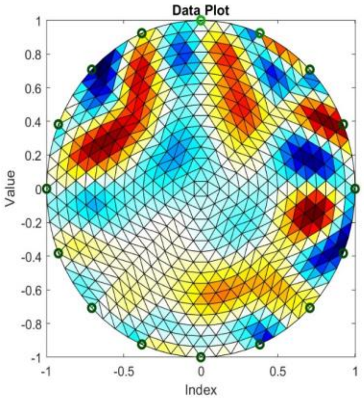


Figure 2

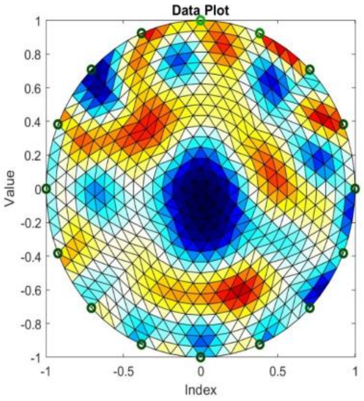
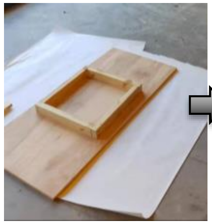


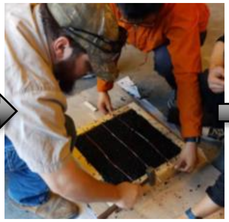
Figure 4

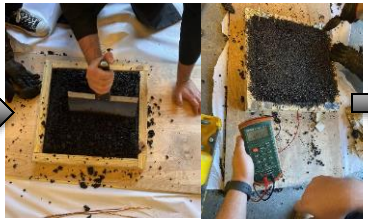
Accomplishments

Task 4.3: Benchtop/Laboratory-Scale Prototype Development and Testing (completed)

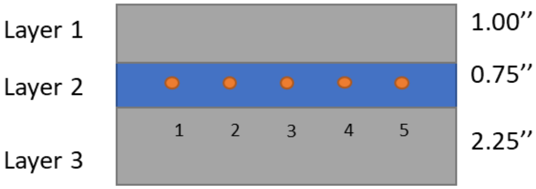

1. Mold


2. Compacting base layer


3. Embedding Electrodes


4. Compacting conductive asphalt layer and testing


5. Compacting surface overlay and testing



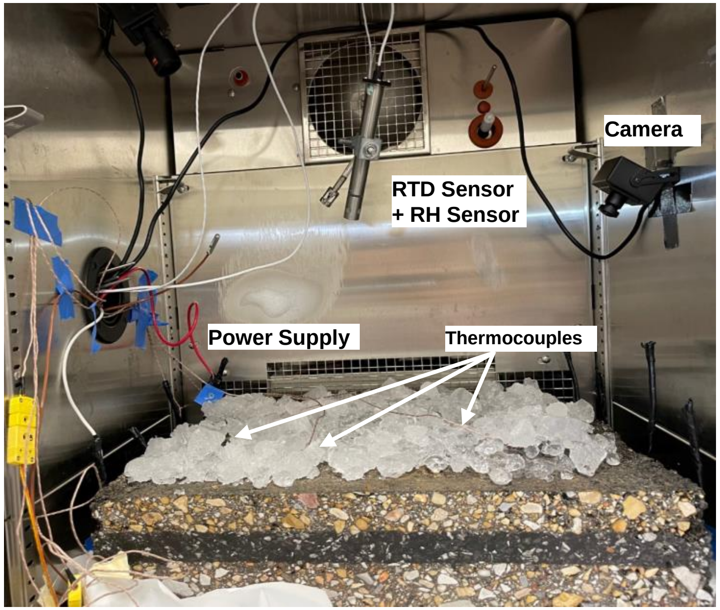
Surface overlay (SMA)

Functional layer (Cal char containing conductive asphalt)

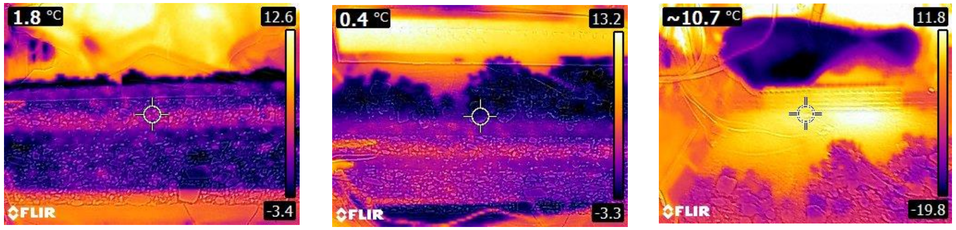
Base layer (Asphalt concrete)

Accomplishments

Task 4.3: Benchtop Prototype Development and Testing

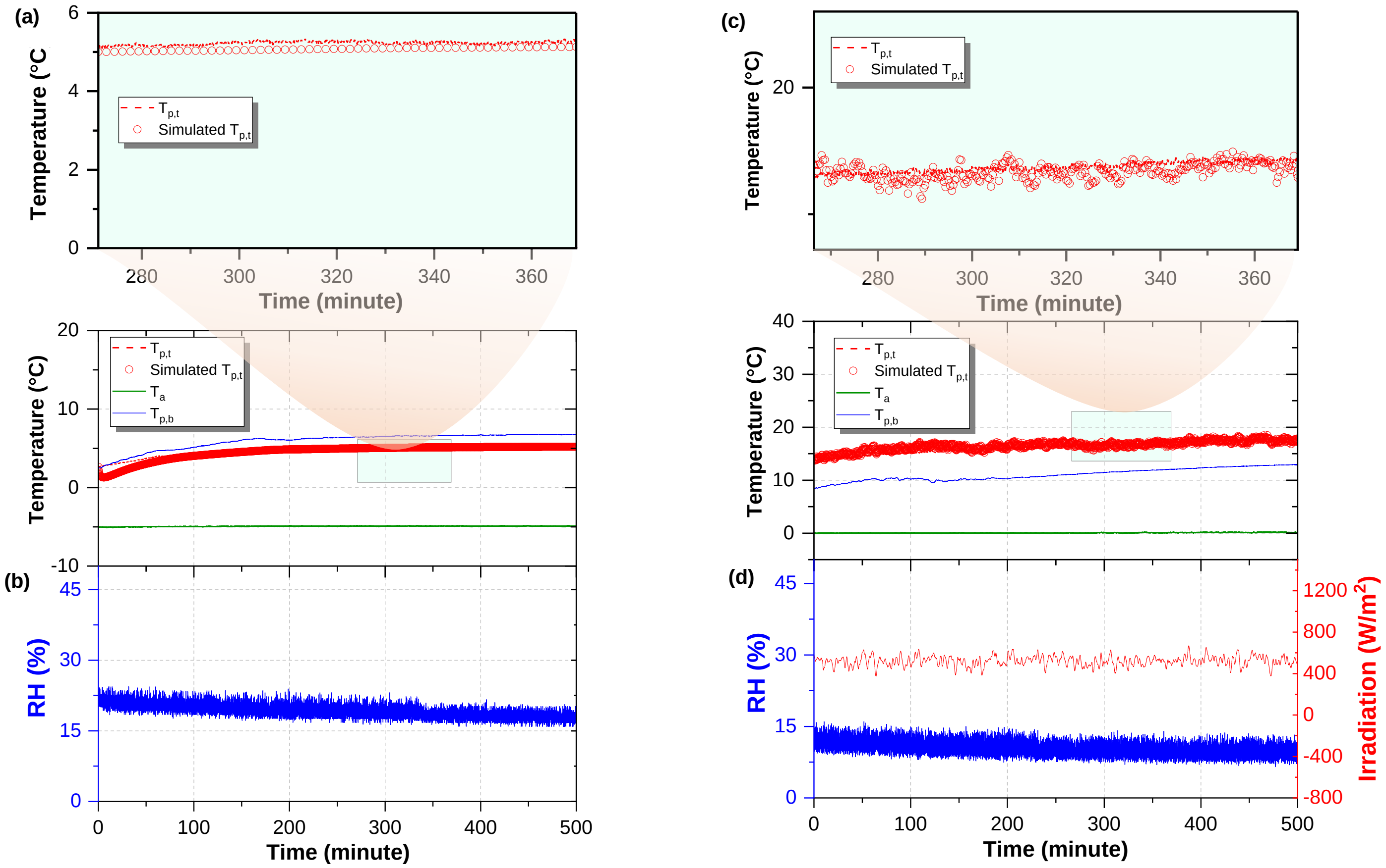


Environmental Temperature: -10 ℃; power supply: 12V, ~50-60W



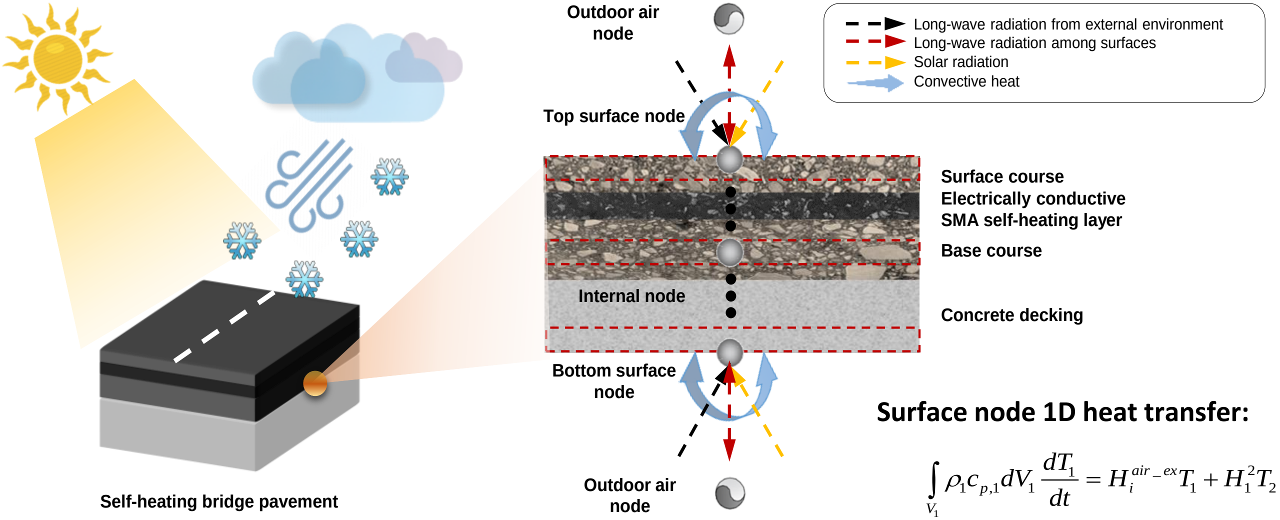
Accomplishments

Task 4.3: Benchtop Prototype Development and Testing



Accomplishments

Task 4.3: Development of Thermal Network Models and Control



Surface node 1D heat transfer:

$$\int_{V_1} \rho_1 c_{p,1} dV_1 \frac{dT_1}{dt} = H_i^{air\_ex} T_1 + H_1^2 T_2 - \left(H_1^{air\_ex} + H_1^2 \right) T_1 + Q_{1,sw} + Q_{1,lw}$$

$$Q_{1,sw} = \bar{\alpha}_1 I_s^{\downarrow} A_1$$

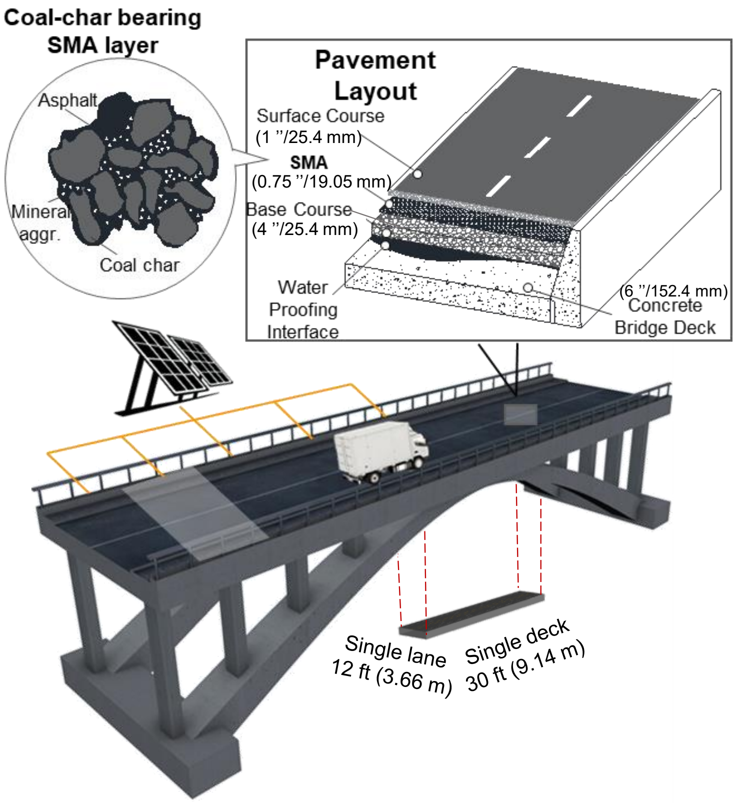
$$Q_{1,lw} = \left[F_1^{sky} \left(T_{sky,abs}^4 - T_{1,abs}^4 \right) + F_1^{grd} \left(T_{grd,abs}^4 - T_{1,abs}^4 \right) + F_1^{air\_ex} \left(T_{air\_ex,abs}^4 - T_{1,abs}^4 \right) \right] \cdot \sigma \varepsilon_1 A_1 + \sum_k \sigma \varepsilon_1 F_1^k \left(T_{k,abs}^4 - T_{1,abs}^4 \right) A_k$$

Internal nodes:

$$\int_{V_i} \rho_{i,} c_{p,i} dV_i \frac{dT_{i,}}{dt} = H_i^{i-1} T_{i-1} + H_i^{i+1} T_{i+1} - \left(H_i^{i-1} + H_i^{i+1} \right) T_i$$

Accomplishments

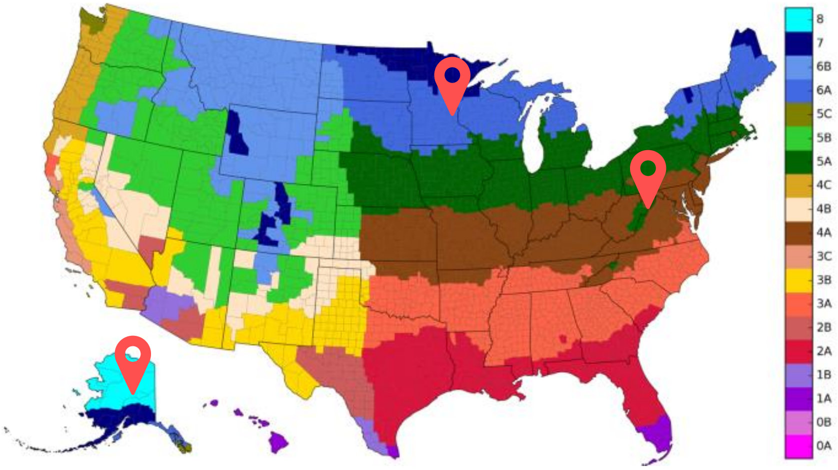
Task 4.3: Development of Thermal Network Models and Control



Whole-year heat transfer simulations

❖ Typical meteorological year 3 (TMY3) weather data

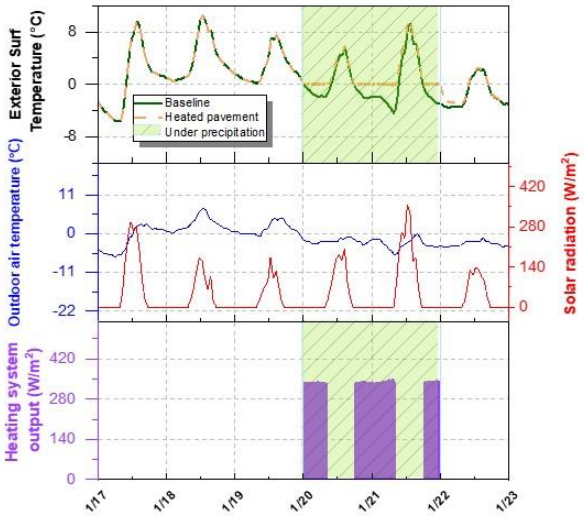
- Pittsburgh, Pennsylvania (ASHRAE climate zone 5A, cool humid)
- Minneapolis, Minnesota (ASHRAE climate zone 6A cold humid)
- Fairbanks, Alaska (ASHRAE climate zone 8, subarctic/arctic)



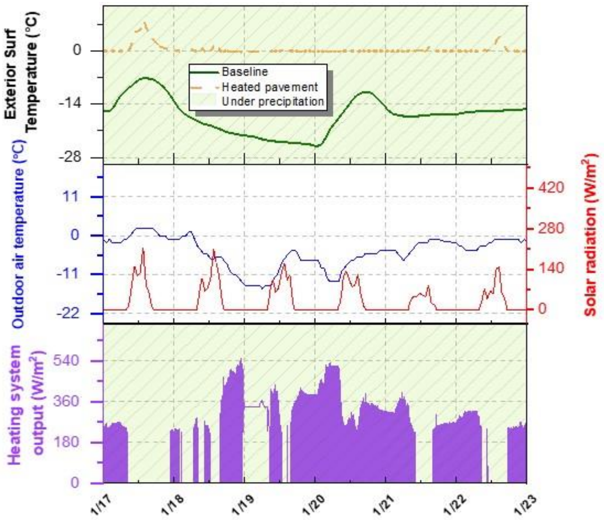
Accomplishments

Task 4.3: Performance Simulation

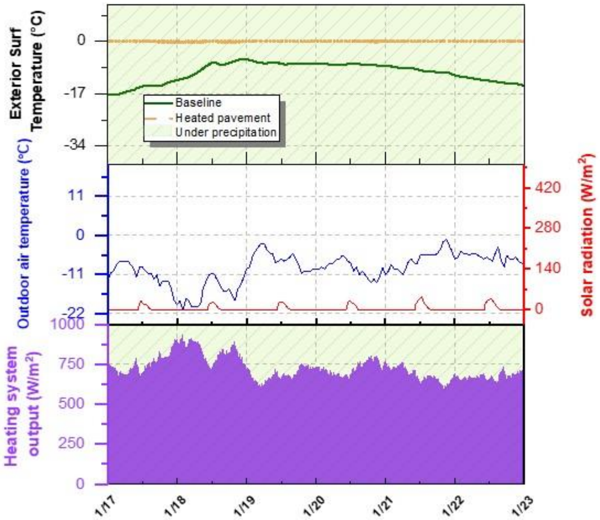
Pittsburg, PA



Minneapolis, MN

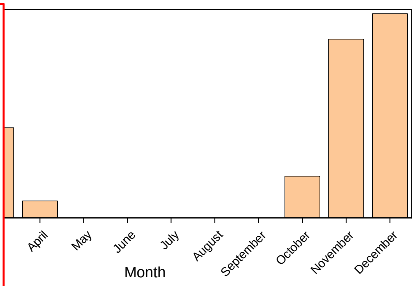


Fairbanks, AK



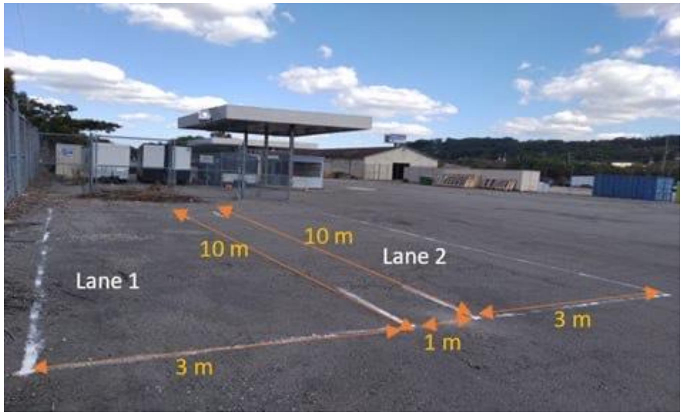
Takeaways:

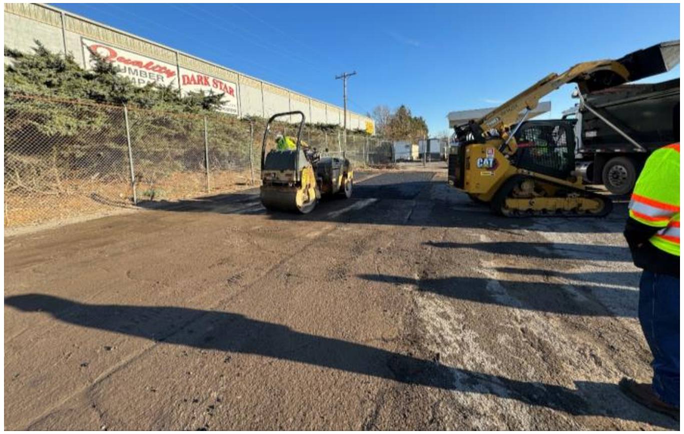
- A **thermal network model** was developed for the heating pavement based on the finite difference approach. The model is able to accurately model the thermal behavior of the heating pavement (i.e., temperature profile, heating power (and control), and energy consumption etc.).
- The model is able to consider various environmental variables including air temperature, wind speed, solar irradiation etc. **The model can be used to predict the power requirement and energy consumption of the heating pavement based on its design location**.
- Current energy use prediction does not consider precipitation prediction – i.e., heating is not required when no precipitation is forecasted even pavement temp. is below 0 ℃. Therefore actual energy use should be much lower. This feature will be added to the model development this quarter.



Progress and Current Status of Project

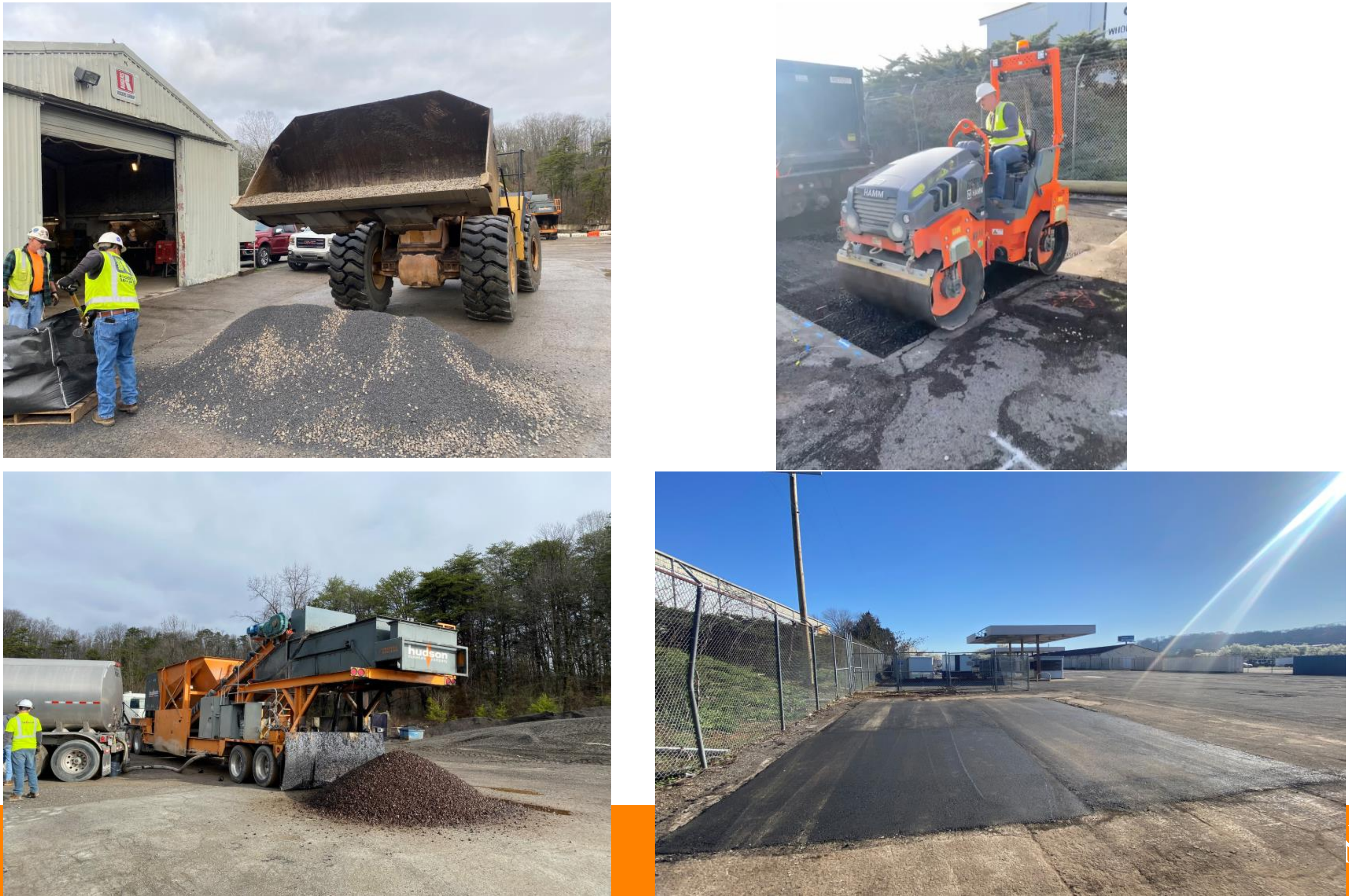
Task 5.1: Field Demonstration





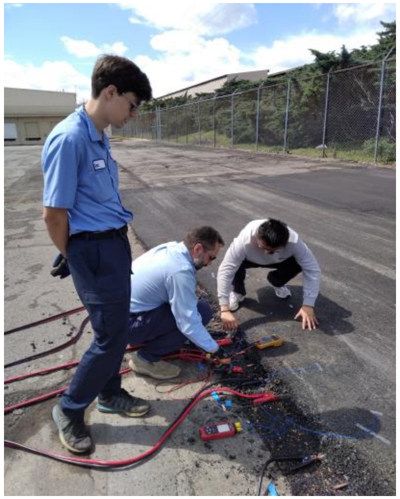
Progress and Current Status of Project

Task VI: Field Demonstration

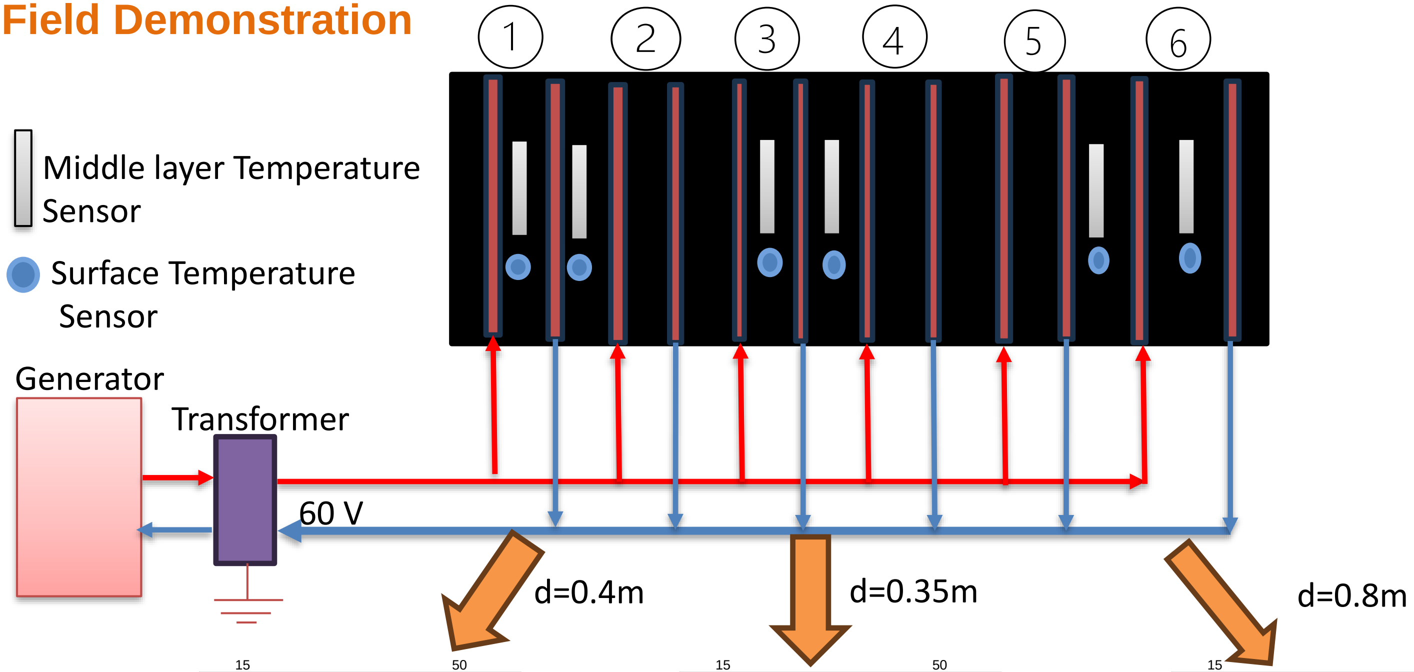


Progress and Current Status of Project

Task 5.1: Field Demonstration



Task 5.1: Field Demonstration



Middle layer Temperature Sensor

Surface Temperature Sensor

Generator

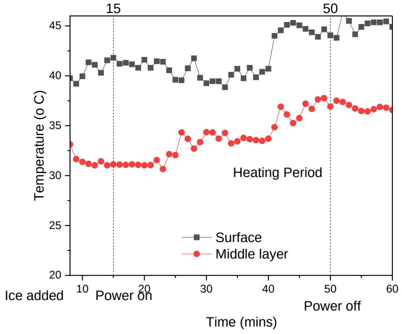
Transformer

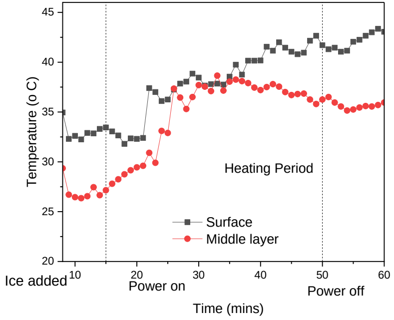
60 V

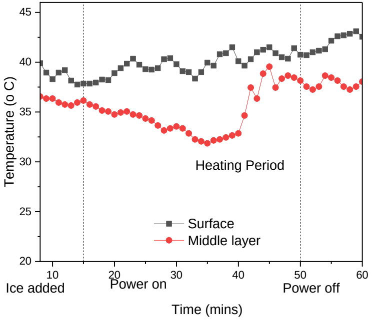
d=0.4m

d=0.35m

d=0.8m

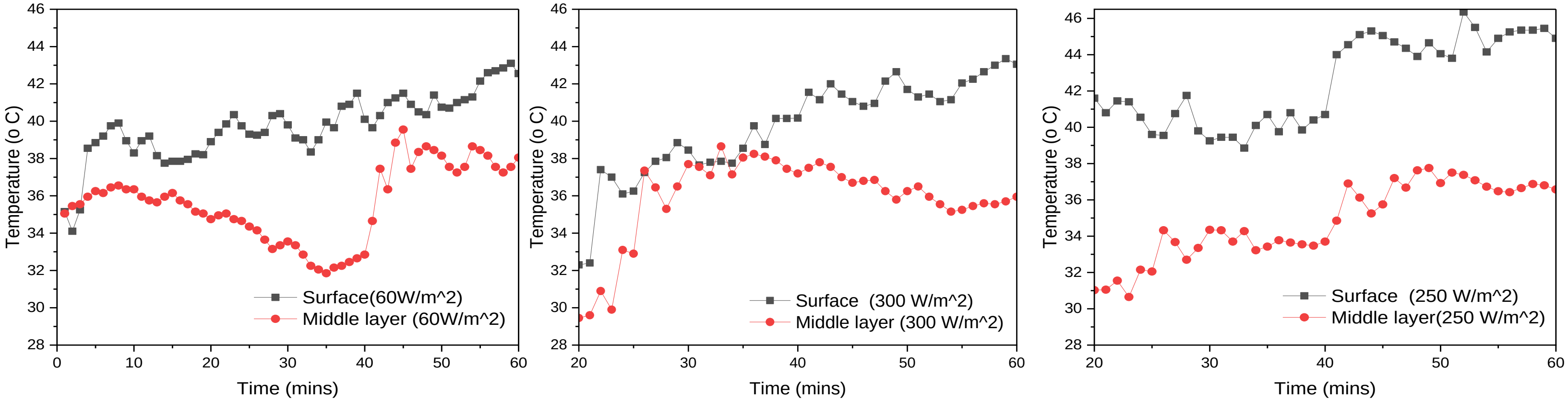


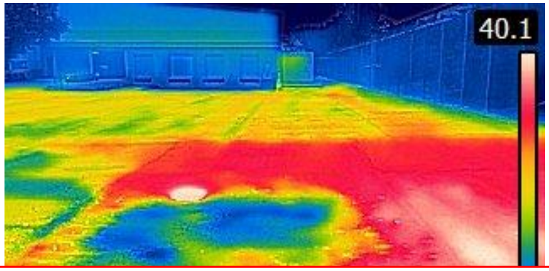




Progress and Current Status of Project

Task 5.1: Field Demonstration





Takeaways:

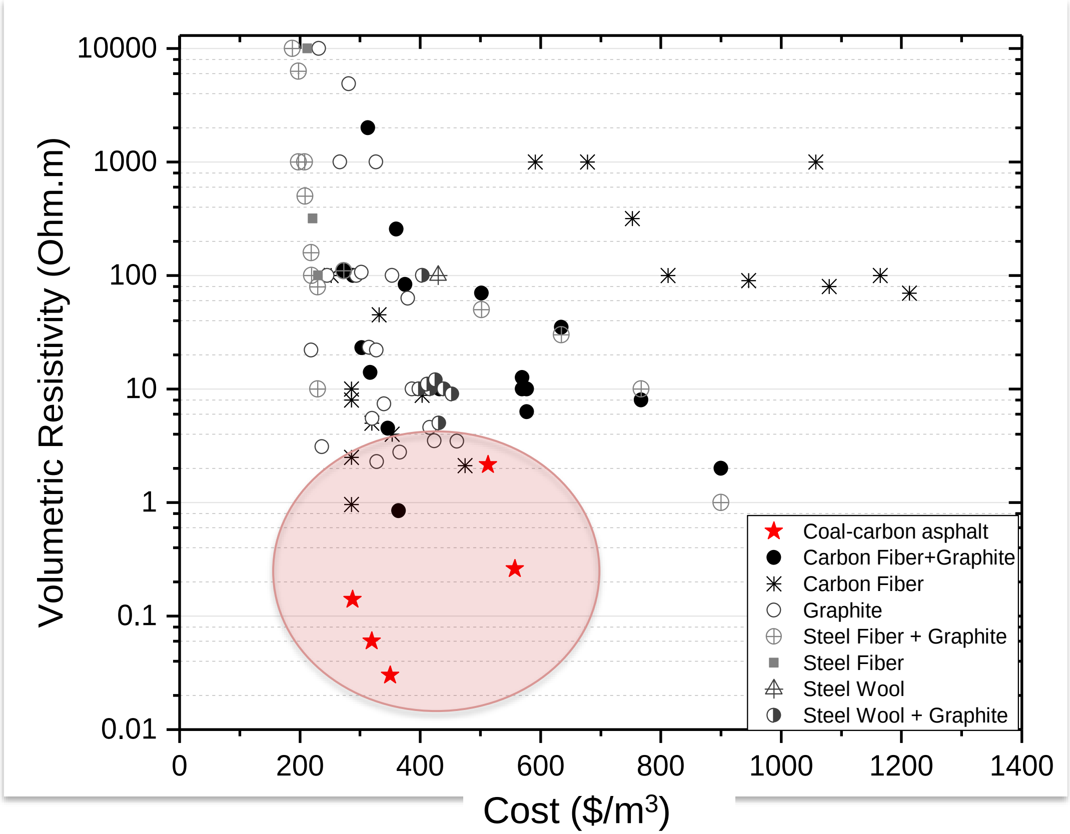
- The coal-carbon based pavement asphalt is field constructible.
- Scaled-up heating experiment was conducted.
- Due to the warm ambient temperature, demonstration of deicing behavior is challenging.

Accomplishments

Task 5.2 TEA Analysis

Material Cost

Unit price of coal char or coke is less than **$200/ton** in comparison with the cost of carbon fiber at **$32,000/ ton**, and **$1,960/ ton** for carbon black



Accomplishments

Task 5.2 TEA Analysis (in progress)

Bridge Parameters

Bridge type: Concrete cast-in-place
Lane number: 2
Length: 390 ft (118.9 m)
Width: 24 ft (7.31 m)
Average Daily Traffic (ADT): 24000 Veh
Discount rate: 4.0%
Life cycle: 50 years
Year 0: 2024

Alternative de-icing systems

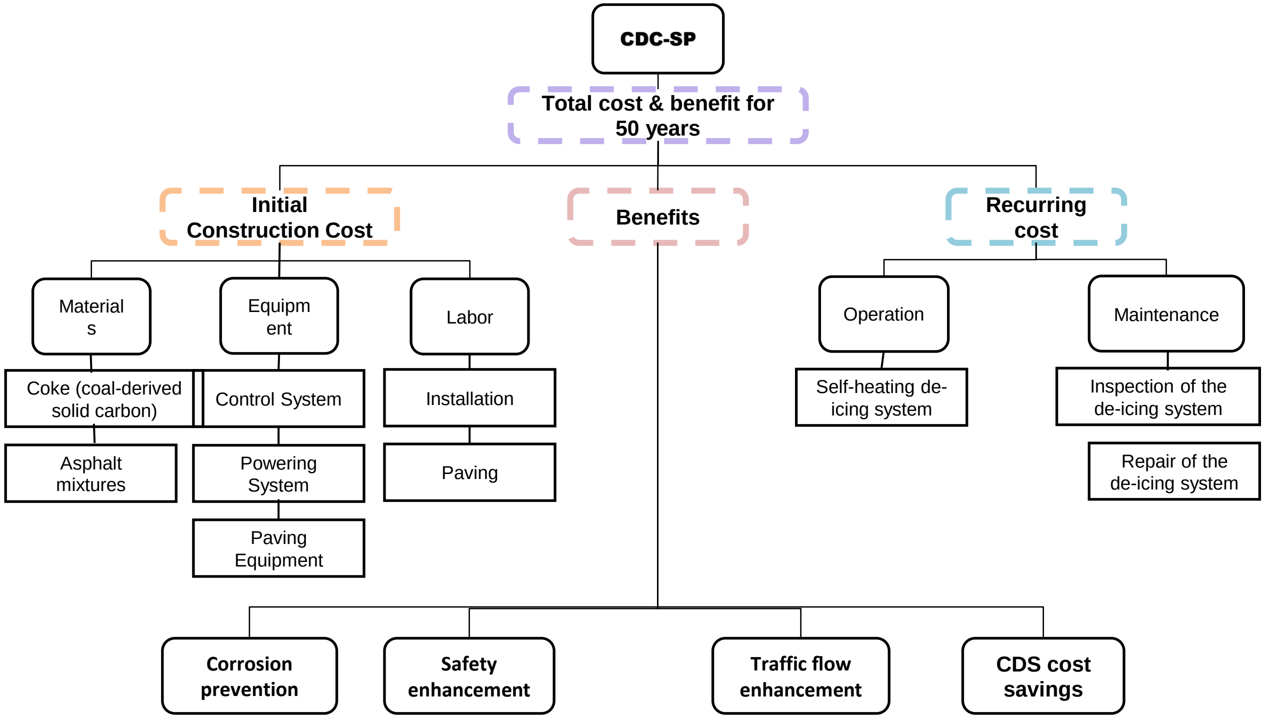
Conventional de-icing system (CDS)

- Mechanical and chemical methods

Coal-derived carbon enabled smart pavement (CDC-SP)

- Self-heating de-icing system

Cost & Benefit inventory of CDC-SP



- **CDC-SP**
  - **Total cost & benefit for 50 years**
    - **Initial Construction Cost**
      - Materials
        - Coke (coal-derived solid carbon)
        - Asphalt mixtures
      - Equipment
        - Control System
        - Powering System
        - Paving Equipment
      - Labor
        - Installation
        - Paving
    - **Benefits**
      - **Corrosion prevention**
      - **Safety enhancement**
      - **Traffic flow enhancement**
      - **CDS cost savings**
    - **Recurring cost**
      - Operation
        - Self-heating de-icing system
      - Maintenance
        - Inspection of the de-icing system
        - Repair of the de-icing system

Accomplishments

Task 5.2 TEA Analysis (in progress)

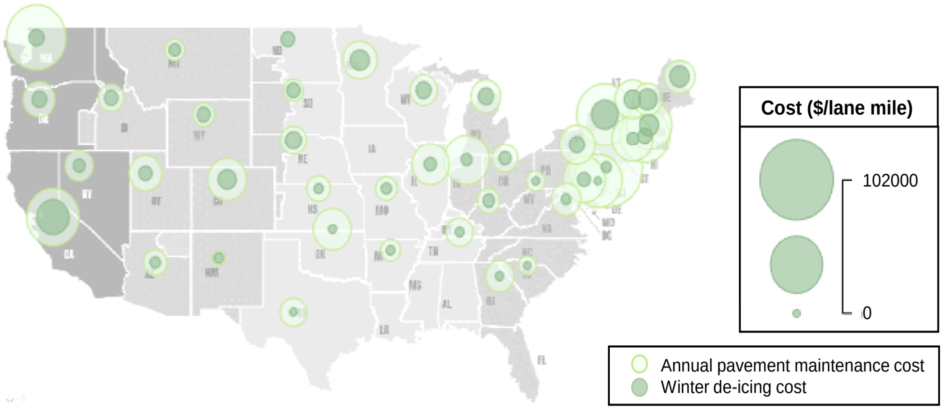
Initial Construction Cost of CDC-SP

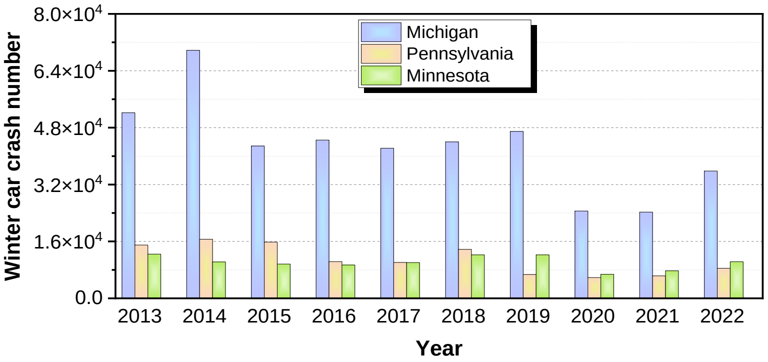
- Cost of non-conductive asphalt pavement
- Cost of electrically conductive coal-char charged asphalt mixture

Operation and Maintenance (O&M) Cost of CDC-SP

- The electric power cost of the self-heating pavement was quantified by a thermal network mode with experimental calibration.

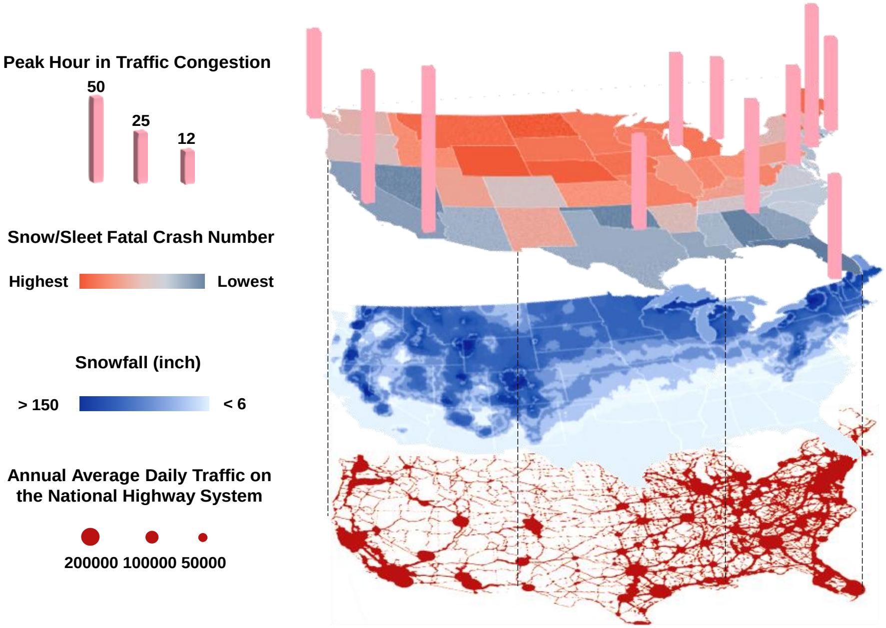
Cost-benefit estimation of CDC-SP

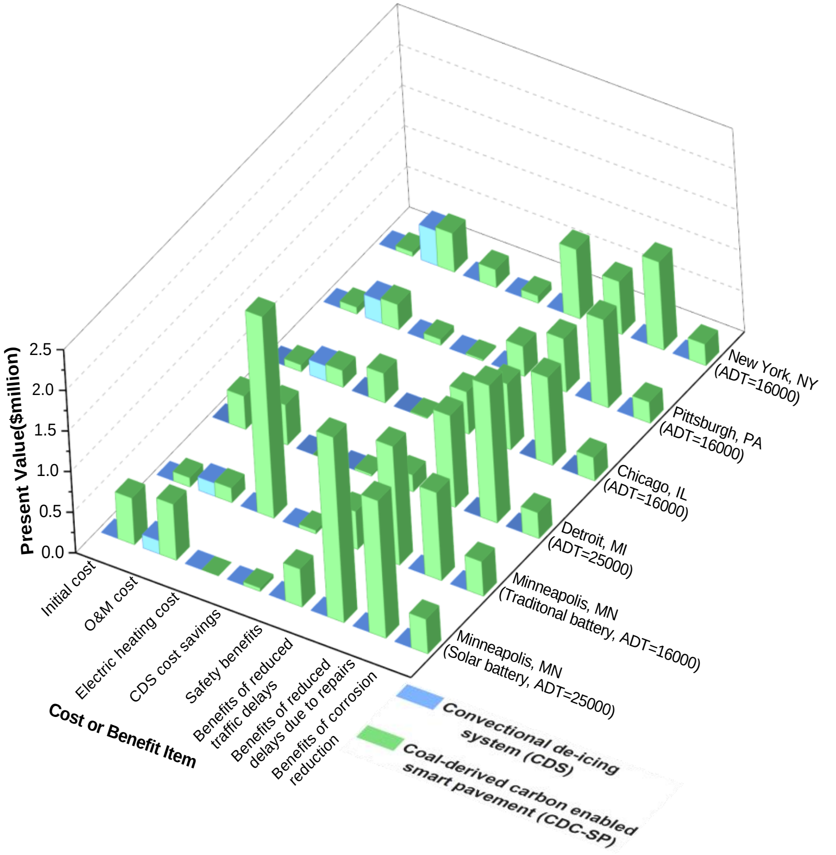




Accomplishments

Task 5.2 TEA Analysis

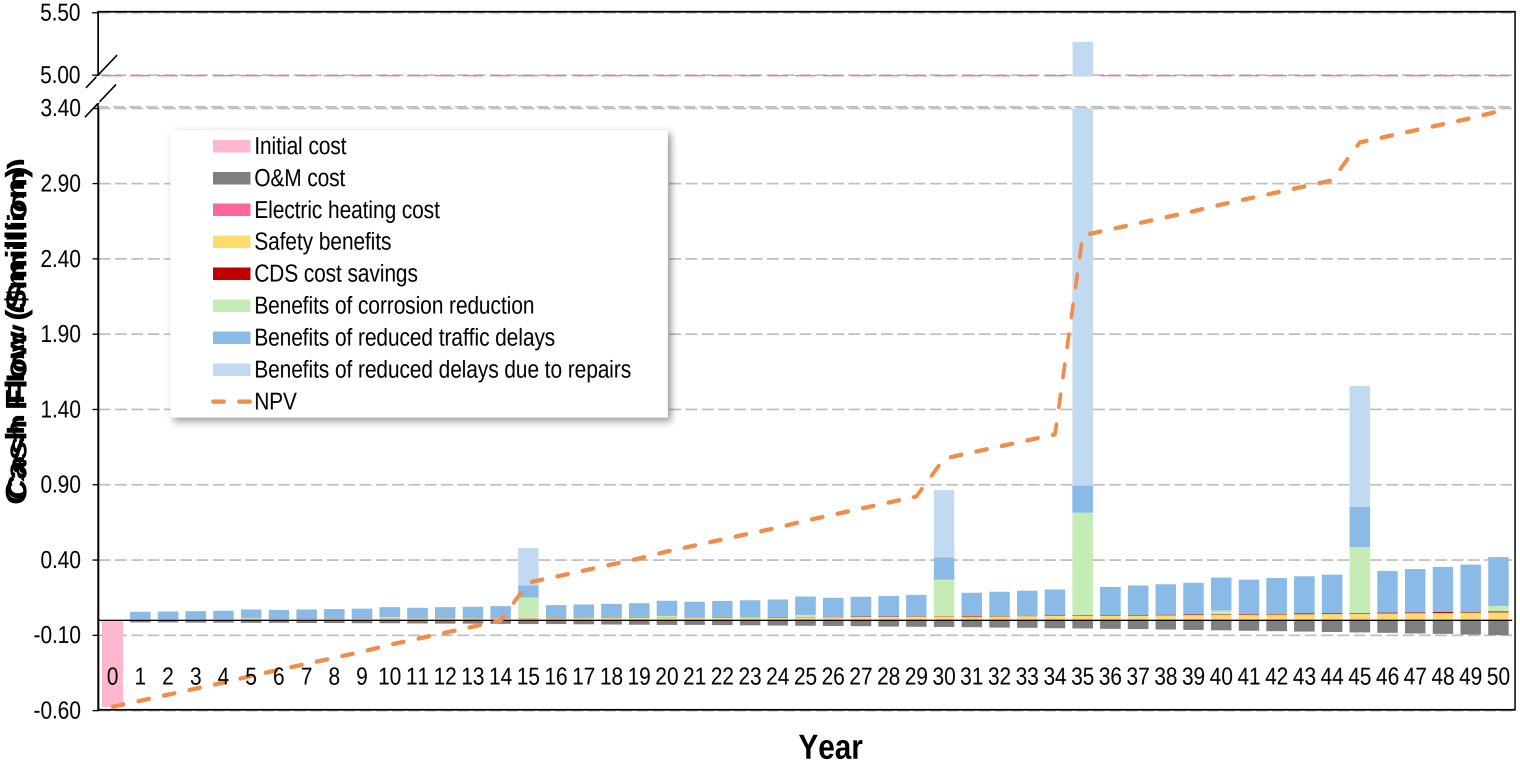




Accomplishments

Task 5.2 TEA Analysis

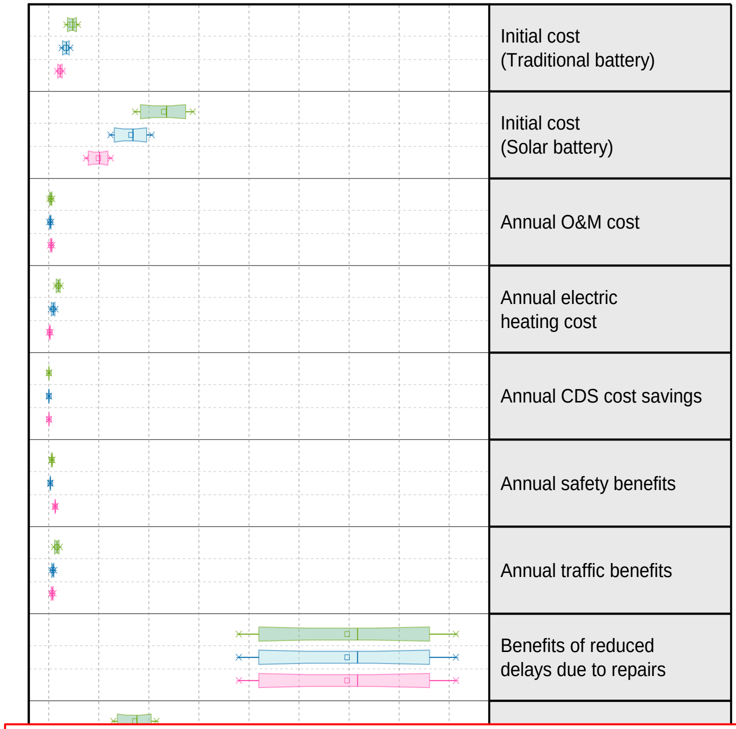
Life-cycle Cost Analysis

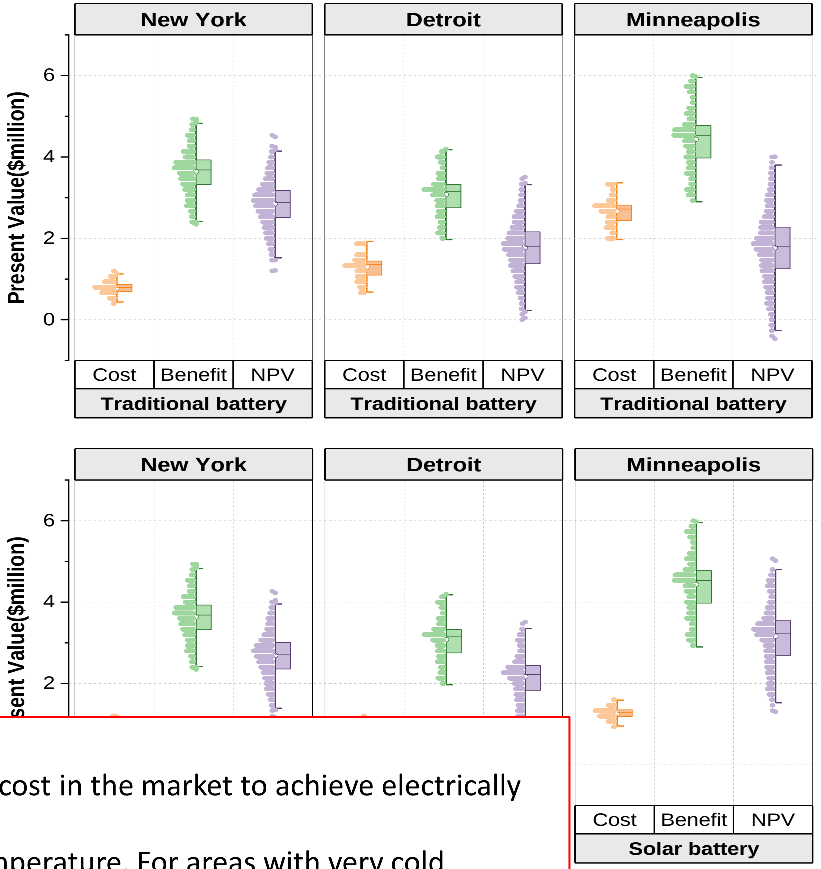


Progress and Current Status of Project

Task 5.2 TEA Analysis

Sensitivity Analysis





Takeaways:

- The coal-carbon based asphalt material is among the lowest cost in the market to achieve electrically conductive pavement.
- LCCA shows acceptable payback in areas with mildly cold temperature. For areas with very cold temperature, solar charging is needed to payback.
- The payback period is much shorter in urban areas where ADT is high.

Training and Workforce Development

Graduate Students Supported

Yucen Li
(PhD student)

Yanhai Wang
(PhD Student)

Yawen He
(former PhD Student, current post-doc at UTK)

Adam Brooks
(former PhD student, currently R&D staff at ORNL)

Undergraduate Researchers Supported

Resee Sorgenfrei (now PhD student at UTK)

Shayan Seyfimakrani (Currently working at GDOT)

Emily Stanton

Hsun Jui 'Ray' Chang

Griffin Bedell

Summary

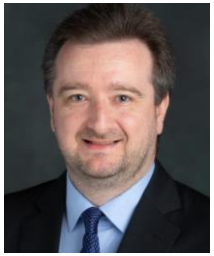
Accomplishments

- A new type of multifunctional conductive asphalt material was developed using coal derived solid carbon (coal char/coke). The material has far better electrical conductivity than existing conductive asphalt materials. Experimental tests conducted so far indicate strong potential to pass AASHTO specifications.
- A polymer-infusion technique was developed for processing coal-char to enhance its mechanical properties. Test results indicate that the process is effective and the polymer-infused coal char is strong, electrically conductive.
- Benchtop scale prototype was produced and deicing performance demonstrated under lab conditions.
- Simulation models were developed to assist the design and performance prediction of this new multifunctional pavement system. A control algorithm is developed for pavement heating control.
- Full-scale prototype constructed and tested.
- LCCA is completed to provide quantitative information for cost-benefit analysis.

Publication: Several publications are under review/preparation. Journal papers were submitted to Journal of Applied Thermal Engineering, Fuels, and Journal of Cleaner Production. Research findings and results are to be disseminated at conferences including ASCE Cold Region Engineering conference, Transportation Research Board (TRB) annual meeting, and ASCE Construction Research Congress.

Hongyu 'Nick' Zhou
PI @ UTK

Baoshan Huang
Co-PI @ UTK



Pawel Polaczyk
Former Senior Personnel @ UTK Currently at Texas Tech University

Wei Hu
Former Co-PI @ UTK (currently at Youngstown State)

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THANK YOU!