Quarterly Progress and Performance Indicators Report:
Project Number and Title: 2.16 – Enhancing the Durability of Bridge Decks by Incorporating Microencapsulated Phase Change Materials (PCMs) in Concrete
Research Area: Thrust 2: New materials for longevity and constructability
PI: *PI and home institution Sumanta Das, University of Rhode Island*
Co-PI(s): *Mayrai Gindy, University of Rhode Island*
Reporting Period: 07/01/2022 – 09/30/2022 ***(Project duration:** 1/1/2022-12/31/2023)*
Submission Date: *09/30/2022*

Overview:

- Developing numerical models to predict the freeze-thaw performance of PCM-incorporated concrete
- Upscaling the concrete model to the bridge deck model to evaluate the freeze-thaw performance
- Currently generating a large dataset to enable efficient performance prediction.
- Obtained the required microencapsulated PCMs and the Freeze-thaw cabinet equipment
- Planning to start the experiments in October 2022.

Meeting the Overarching Goals of the Project:

- Evaluation of freeze-thaw/chloride ingress-induced damage characteristics in Rhode Island helps us understand the primary problem and will help us determine the PCM-concrete performance tuning requirements in Rhode Island.
- Completing Numerical models and obtaining simulated data upfront will help us design the experiments
- Freeze-Thaw experiments will help us design the PCMs for optimized performance

Accomplishments:

- Development of simulation models: Micromechanics-based models are developed successfully; upscaling is successfully implemented, and the macro-scale bridge deck models are now available to generate a large dataset for efficient large-scale performance tuning using a machine learning approach.
- Due to the delay in Freeze-thaw equipment acquisition, we focused on getting the numerical models done before starting with the experiments. We now obtained the freeze-thaw equipment as well as PCMs and currently, the experimental plan is being finalized. We hope to start making samples for our experiments next October 2022.

Task, Milestone, and Budget Progress:

Complete the following tables to document the work toward each task and budget (add rows/remove rows as needed, make sure you complete the Overall Project progress row, and include all tasks even if they have ended or have not been started)…

Table 1: Task Progress			
Task Number: Title	**Start Date**	**End Date**	**% Complete**
Task 1.1: Evaluate freeze-thaw/chloride ingress-induced damage in Rhode Island	01/01/22	04/30/22	100%
Task 1.2: Thermo-mechanical Freeze-Thaw experiments	10/01/22	03/31/23	0%
Task 1.3: Evaluate the Combined effects of freeze-thaw and chloride ingress	04/01/23	07/31/23	0%
Task 2.1: Material Structure at Different Scales: Probing the Structure	06/01/23	09/30/23	0%
Task 2.2: Develop Modeling /Prediction Tools	05/01/22	10/31/22	90%
Task 2.3: Optimized PCM-concrete overlay Design for Rhode Island weather Conditions	10/01/23	12/31/23	0%
Phase 1 Overall	01/01/22	07/31/23	25%
Phase 2 Overall	05/01/22	12/31/23	60%

Table 2: Milestone Progress			
Milestone #: Description	**Corresponding Deliverable**	**Start Date**	**End Date**
Milestone 1.1: Freeze-thaw damage in Rhode Island	A comprehensive and broader understanding of the existing problems.	01/01/22	04/30/22
Milestone 1.2: Freeze-thaw experiments and performance assessment	Comprehensive experimental data on the mechanical performance of control and PCM-incorporated concrete under a freeze-thaw environment	10/01/22	03/31/23
Milestone 1.3: Combined freeze-thaw and chloride ingress results	Successful completion of this task will yield comparative experimental data on the performance of the PCM-incorporated concrete under combined freeze-thaw and chloride ingress environments.	04/01/23	07/31/23
Milestone 2.1: Multiscale Characterization	Micromechanical behavior of PCM-incorporated binder; 2D/3D microscopic visualizations for distribution of PCMs in the binder	06/01/23	09/30/23
Milestone 2.2: Multiscale Material model	The thermo-mechanical predictive model to assess freeze-thaw/chloride ingress-induced damage in PCM-concrete overlayed bridge decks	05/01/22	10/31/22
Milestone 2.3: Materials design optimization	Optimized PCM-concrete overlay design (dosage, size distribution, transition temperature) for RI Weather Conditions	10/01/23	12/31/23

Table 3: Budget Progress		
Project Budget	**Spend – Project to Date**	**% Project to Date (include the date)**
Phase 1 Full Budget: $166,280	$116,480 (Federal + Cost Share)	70.5% (09/30/2022)
Phase 2 Full Budget: $184,147	$0 (Federal + Cost Share)	0%

Is your Research Project Applied or Advanced?

☒ **Applied** (*The systematic study to gain knowledge or understanding necessary for determining the means by which a recognized and specific need may be met.)*

☐ **Advanced** *(An intermediate research effort between basic research and applied research. This study bridges basic (study to understand fundamental aspects of phenomena without specific applications in mind) and applied research and includes transformative change rather than incremental advances. The investigation into the use of basic research results to an area of application without a specific problem to resolve.)*

Education and Workforce Development:

Answer the following questions (N/A if there is nothing to report):

1. Did you provide any workforce development or training opportunities to transportation professionals (already in the field)? If so, what was the training? When was it offered? How many people attended? (i.e. The research team provided an in the field training for the SAR technology for 3 maintenance crew members of the MassDOT on 3/31/2021. The members learned how to use the technology and interrupt the data.) N/A

2. Did you hold meetings with any transportation industry organizations or DOTs? If so, what was the meeting's purpose? When was it offered? How many people attended?

   The research team met with Our Technical Champion John W. Preiss, Deputy Chief Engineer/ State Bridge Engineer, RIDOT to discuss the project plans and to update them on the progress of the research findings. The next meeting will be held during quarter 4.

3. Did you host/participant in any K-12 education outreach activities? If so, what was the activity? What was the target age/grade level of the participants? How many students/teachers attended? When was the activity held? N/A We hope to involve K-12 students next year once some of the basic research tasks are performed.

Technology Transfer:

Complete all of the tables below and provide additional information where requested. Please provide ALL requested information as this is one of the most important sections for reporting to the USDOT. ***ONLY provide information relevant to this reporting period.***

Use the table below to complete information about conference sessions, workshops, webinars, seminars, or other events you led/attended where you shared findings as a result of the work you conducted on this project:

Table 4: Presentations at Conferences, Workshops, Seminars, and Other Events					
Type	**Title**	**Citation**	**Event & Intended Audience**	**Location**	**Date(s)**
i.e. Conference, Symposium, DOT/AOT presentation, Seminar, etc.	Presentation Title	Full Citation	Name of event (i.e. TIDC 1st Annual Conference) or who was the presentation given to?		
N/A	N/A	N/A	N/A	N/A	N/A

Use the table below to report any publications, technical reports, peer-reviewed articles, newspaper articles referencing your work, graduate papers, dissertations, etc. written as a result of the work you conducted on this project. Please list only completed items and exclude work in progress.

Table 5: Submitted/Accepted Publications, Technical Reports, Theses, Dissertations, Papers, and Reports				
Type	**Title**	**Citation**	**Date**	**Status**
i.e. Peer-reviewed journal, conference paper, book, policy paper, magazine/newspaper article	Publication title	Full citation		i.e. Submitted, accepted, under review (by org. submitted to)
N/A	N/A	N/A	N/A	N/A

Answer the following questions (N/A if there is nothing to report):

1. Did you deploy any technology during the reporting period through pilot or demonstration studies as a result of this work? If so, what was the technology? When was it deployed? N/A

2. Was any technology adopted by industry or transportation agencies as a result of this work? If so, what was the technology? When was is adopted? Who adopted the technology? N/A

3. Did findings from this research project result in changing industry or transportation agency practices, decision making, or policies? If so, what was the change? When was the change implemented? Who adopted the change? N/A

4. Were any licenses granted to industry as a result of findings from this work? If so, when? To whom was the license granted? N/A

5. Were any patent applications submitted as a result of findings from this research? If so, please provide a copy of the patent application with your report. N/A

6. Did industry organizations or DOTs provide cost-share (cash or in-kind) to your research during the reporting period? Who was the organization? Please provide an in-kind support invoice from the organization with your report (this is kept confidential and used for record keeping purposes only). N/A

Please add figures/images that can be included on the website and/or in marketing/social media materials to further clarify your research.

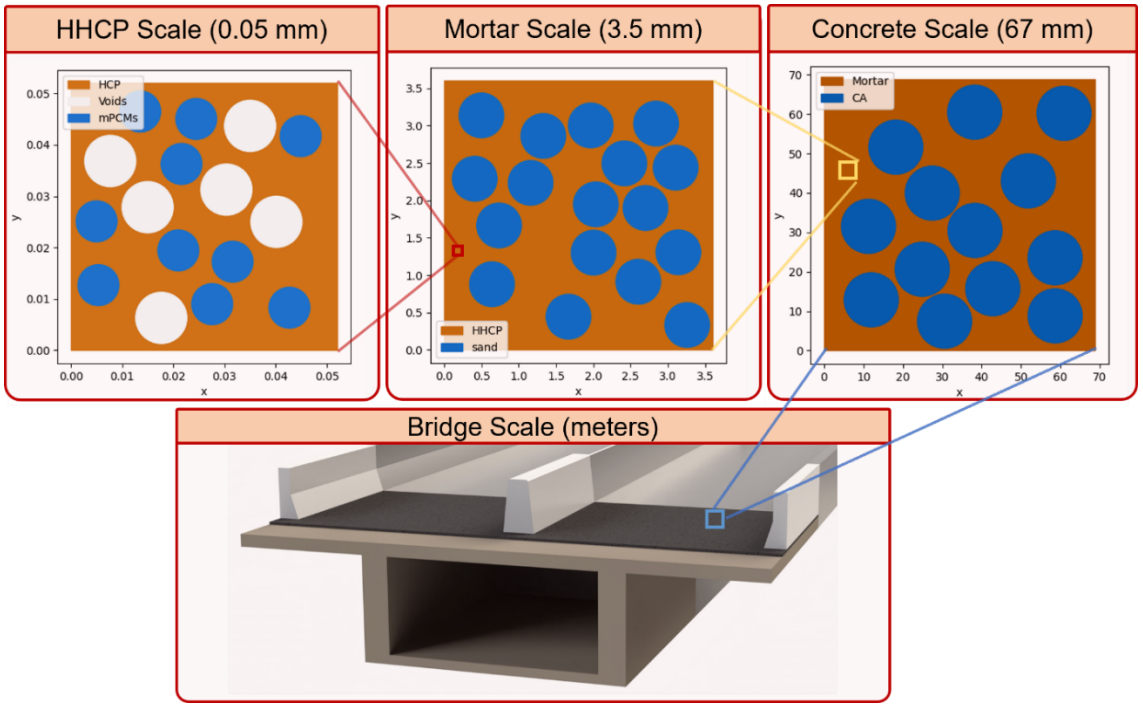

Fig. 1 The length scales of each upscaling step and the corresponding microstructure distribution.

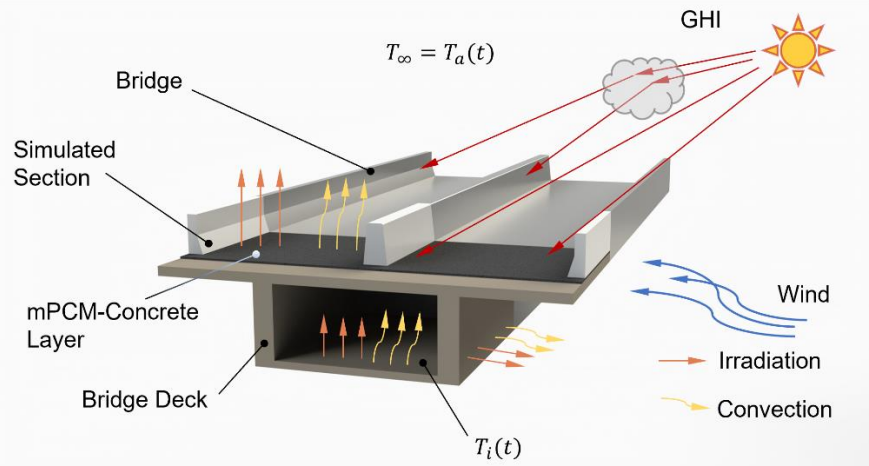

Fig. 2 The thermal interaction between the bridge and the environment.

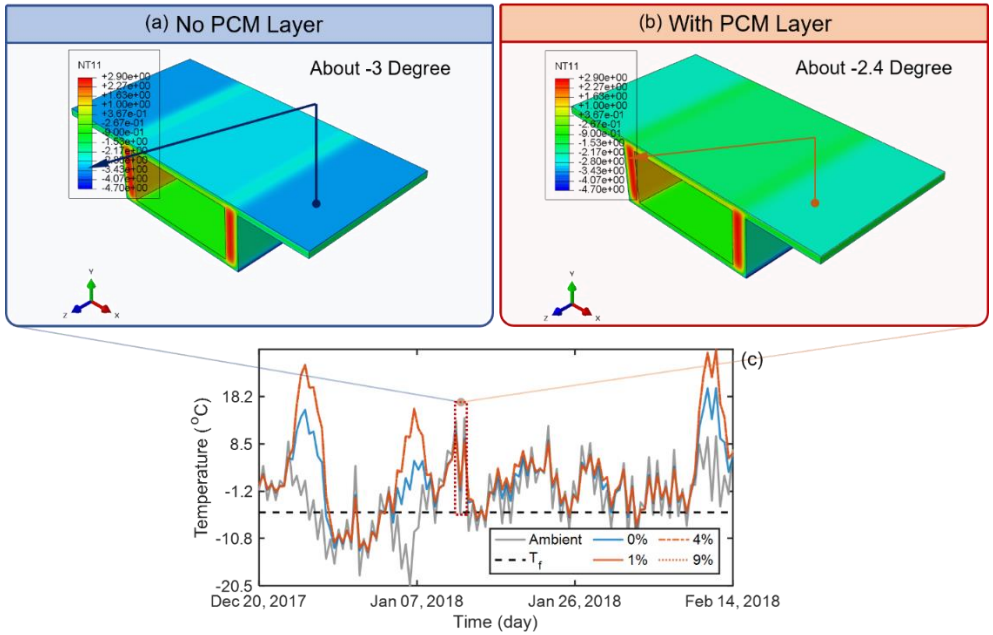

Fig. 3 A comparison of the temperature field of the bridge when (a) no PCM layer is applied and (b) a 14mm thick PCM layer is in action on the 25th night of the considered diurnal histories.

Describe any additional activities involving the dissemination of research results not listed above under the following headings:

Outputs:
Definition: Any new or improved process, practice, technology, software, training aid, or other tangible product resulting from research and development activities. They are used to improve the efficiency, effectiveness, and safety of transportation systems. List any outputs accomplished during this reporting period: N/A

- Developed the multiscale numerical framework to evaluate the influence of PCMs on the freeze-thaw response of concrete bridge decks.

Outcomes:
Definition: The application of outputs; any changes made to the transportation system, or its regulatory, legislative, or policy framework resulting from research and development activities. List any outcomes accomplished during this reporting period:

- Nothing to report this quarter

Impacts:
Definition: The effects of the outcomes on the transportation system such as reduced fatalities, decreased capital or operating costs, community impacts, or environmental benefits. The reported impacts from UTCs are used for the assessment of each UTC and to make a case for Federal funding of research and education by demonstrating the impacts that UTC funding has had on technology and education. NOTE: The U.S. DOT uses this information to assess how the research and education programs (a) improve the operation and safety of the transportation system; (b) increase the body of knowledge and technologies; (c) enlarge the pool of people trained to develop knowledge and utilize technologies; and (d) improves the physical, institutional, and information resources that enable people to have access to training and new technologies. List any outcomes accomplished during this reporting period:

Nothing to report this quarter

Participants and Collaborators:

Use the table below to list individuals (compensated or not) who have worked on the project other than students.

Table 6: Active Principal Investigators, faculty, administrators, and Management Team Members				
Individual Name & Title	**Dates involved**	**Email Address**	**Department**	**Role in Research**
Sumanta Das, Assistant Professor	01/01/22 - present	Sumanta_das@uri.edu	Civil Engineering, URI	PI
Mayrai Gindy, Professor	01/01/22 - present	mayraig@uri.edu	Civil Engineering, URI	Co-PI

*Use the table below to list **all** students who have participated in the project during the reporting period. (This includes all paid, unpaid, intern, independent study, or any other student that participated in this project.) **ALL FIELDS ARE REQUIRED.***

Table 7: Student Participants during the reporting period								
Student Name	**Start Date**	**End Date**	**Advisor**	**Email Address**	**Level**	**Major**	**Funding Source**	**Role in research**
Bolaji Oladipo	07/01/22	---	Sumanta Das		PhD	Civil Eng.	TIDC	Developing numerical models
Hewenxuan Li	07/01/22	---	Sumanta Das		PhD	Civil Eng.	TIDC	Numerical models
Rakesh Paswan	08/29/22	---	Sumanta Das		PhD	Civil Eng.	Fellowship	Freeze-thaw experiments and planning

Use the table below to list any students who worked on this project and graduated or received a certificate during this reporting period. Include information about the student's accepted employment during the reporting period

Table 8: Students who Graduated During the Reporting Period			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
Anir Gubbala	BS	2022	Currently MS student at URI
Rebecca Meyers	MS	2022	Water Resources Engineer at Fuss & O'Neill

Use the table below to list any students that participated in Industrial Internships during the reporting period:

Table 9: Industrial Internships			
Student Name	**Degree/Certificate Earned**	**Graduation/Certification Date**	**Did the student enter the transportation field or continue another degree at your university?**
N/A			

*Use the table below to list **organizations** that have been involved as partners on this project and their contribution to the project during the reporting period.*

Table 10: Research Project Collaborators during the reporting period						
Organization	**Location**	**Contribution to the Project**				
		Financial Support	**In-Kind Support**	**Facilities**	**Collaborative Research**	**Personnel Exchanges**
		List the amount	List the amount	Mark with an "x" where appropriate		
N/A						

*Use the table below to list **individuals** that have been involved as partners on this project and their contribution to the project during the reporting period. (**List your technical champion(s) in this table.** This also includes collaborations within the lead or partner universities who are not already listed as PIs; especially interdepartmental or interdisciplinary collaborations.)*

Table 11: Other Collaborators				
Collaborator Name and Title	**Contact Information**	**Organization and Department**	**Date(s) Involved**	**Contribution to Research**
John W. Preiss, RIDOT Bridge engineer		RIDOT Bridge Engineering Division	07/01/22 - present	technical champion

Use the following table to list any transportation related course that were taught or led by researchers associated with this research project during the reporting period:

Table 12: Course List						
Course Code	**Course Title**	**Level**	**University**	**Professor**	**Semester**	**# of Students**
CVE 465	Analysis and Design of Reinforced Concrete Structures	Undergrad	URI	Das	Fall 2022	28

Changes:

No changes in the schedule since the previous quarter.

Planned Activities:

List the activities planned during the next quarter.

- Generate a large dataset from the developed multiscale simulation model and start developing an efficient neural network-based performance prediction
- Starting with sample prep and freeze-thaw experiments
- Interdisciplinary experimental training for doctoral student Rakesh Paswan
- Numerical simulation and machine learning training for Bolaji Oladipo and Hewenxuan Li