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**Transportation Infrastructure Precast Innovation Center**

**(TRANS-IPIC)**

**University Transportation Center (UTC)**

***Thermally Conductive Pre-cast Concrete Pavement for Urban Heat Island mitigation***

***- phase II: Implementation***

**[*UT-23-RP-01*]**

Quarterly Progress Report

For the performance period ending *[****April 1st, 2025****]*

**Submitted by:**

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University of Texas at San Antonio

**Collaborators / Partners:**

Microtek laboratories Company

City of San Antonio

Tindall Corporation

**Submitted to:**

TRANS-IPIC UTC

University of Illinois Urbana-Champaign

Urbana, IL

**TRANS-IPIC Quarterly Progress Report (Section 1 – 7, 5 pages max.):**

**Project Description:**

1. Research Plan - Statement of Problem

Urban areas are increasingly challenged by the Urban Heat Island (UHI) effect, where conventional concrete pavements absorb and retain excessive heat, resulting in higher surface temperatures, increased energy usage, and diminished pedestrian comfort. With paved surfaces covering a substantial portion of urban environments, they significantly contribute to UHI formation. Traditional cooling methods, such as reflective coatings and permeable pavements, face challenges related to durability, cost, and long-term efficiency, and are sometimes restricted by local municipal guidelines. This research tackles this issue by developing an innovative thermally adaptive concrete sidewalk pavement that incorporates phase change materials (PCMs) to regulate surface temperatures passively. By integrating organic microencapsulated PCMs within the concrete mix, the pavement can dynamically store and release heat, effectively lowering peak temperatures and improving thermal efficiency without relying on external energy sources. This novel approach establishes a sustainable cooling pavement system that offers a cost-effective, durable, and scalable solution for urban infrastructure. Through enhanced thermal performance, material sustainability, and improved cost-efficiency over time, this research redefines the functional role of concrete in mitigating urban heat challenges and enhancing urban resilience.

1. Research Plan - Summary of Project Activities (Tasks)

**Task 1:** **Mechanical Property Testing**

Objective**:** To ensure PCM integration does not compromise the mechanical integrity of concrete.

**Task 2:** **Finite Element Model (FEM) Simulation**

Objective**:** Simulate the thermal behavior of PCM-enhanced pavements under various conditions presenting different geographical zones for broader applications.

**Task 3:** **Optimization of PCM-Concrete Mix Design**

Objective**:** To refine the mix design for maximum thermal performance and mechanical strength.

**Task 4: Pilot Real-World Application**

Objective**:** Evaluate the performance of PCM-enhanced concrete in a real-world environment.

**Task 5: Development of Industry Guidelines**

Objective**:** Provide practical guidelines for the adoption of PCM-enhanced concrete in the industry.

**Task 6: Dissemination of Results**

Objective**:** To share research findings with the academic and professional community.

**Project Progress:**

1. Progress for each research task

* *Task 1: Mechanical Property Testing* ***[50% Completed]***
* *Task 2: Finite Element Model (FEM) Simulation* ***[25% Completed]***
* *Task 3: Optimization of PCM-Concrete Mix Design* ***[50% Completed]***
* *Task 4: Pilot Real-World Application* ***[0% Completed]***
* *Task 5: Development of Industry Guidelines* ***[0% Completed]***
* *Task 6: Dissemination of Results* ***[0% Completed]***

1. Percent of research project completed

*The average completion percentage would be:*

*(50% + 25% + 50% + 0% + 0% + 0%) / 6 tasks = % 125/ 6 tasks ≈* ***20.83%***

***Description:***

* *Task 1: Mechanical Property Testing* ***[50% Completed]***

Comprehensive mechanical testing, including compressive strength tests, slump tests, and workability assessment, was conducted to evaluate the impact of PCM integration using the addition method. The tests were performed at 7, 14, and 28 days of curing, following ASTM curing procedures to ensure consistency and reliability of the results. The mechanical performance evaluation aimed to determine how varying PCM content influences the structural integrity of the concrete, while the workability assessment focused on how PCM integration affects the concrete’s mixing, handling, and placement characteristics. Identifying the optimal PCM dosage is essential to balance improved thermal efficiency with acceptable mechanical strength and workable concrete properties for practical implementation.



Mechanical Analysis.

* *Task 2: Finite Element Model (FEM) Simulation* ***[25% Completed]***

A 3D Finite Element Model (FEM) was developed to simulate the thermal behavior of PCM-integrated concrete for the addition method during 4-hours heating and cooling cycle and assess its effectiveness in reducing surface temperatures. The numerical modeling aimed to evaluate how PCM integration influences temperature regulation, moderates thermal fluctuations, and maintains cooling benefits over extended periods. This simulation provided valuable insights into optimizing PCM dosage and integration methods to achieve effective thermal management, reduce maintenance needs, and enhance energy efficiency. The FEM results will be compared with experimental findings to validate the model’s accuracy and reliability.

A concrete block with wires and a measuring tape

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Examples of Different current Finite Element Models

* *Task 3: Optimization of PCM-Concrete Mix Design* ***[50% Completed]***

Following the comprehensive mechanical study and concurrent thermal analysis for the addition method, a significant step toward optimization has been initiated. The process focuses on refining the mix design to achieve maximum thermal performance while maintaining acceptable mechanical strength. This iterative approach involves assessing different PCM concentrations, conducting further thermal tests as necessary, and fine-tuning the mix proportions to strike a balance between structural integrity and thermal efficiency for practical implementation.

1. Expected progress for next quarter

The upcoming quarter will focus on refining the mix design to address the mechanical trade-offs associated with PCM integration. This effort will involve conducting a comprehensive mechanical study using an alternative approach—the sand replacement method—to enhance structural performance compared to the addition method. Additionally, the finite element modeling will be advanced to simulate longer time periods, specifically 8-hour cycles, for the addition method to assess its effectiveness and validate its thermal performance over extended durations. To build the sidewalk, coordination and communication efforts are ongoing with the relevant parties. For this report, the schematic of the proposed real pilot test for different cool sidewalk mechanisms is presented.

A diagram of a cross section

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Proposed Real Pilot Test for Different Cool Sidewalk Mechanisms for each segment

1. Educational outreach and workforce development

* A tour to UTSA prospective high school students, emphasizing urban heat challenges, *March 2025*

A group of people standing outside

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Educational Outreach Events at UTSA

1. Technology Transfer

* **Microtek Laboratories, Inc.:** Shared our experimental results, highlighting the temperature reduction achieved in precast concrete integrated with PCM. These results provide insight into the thermal performance improvements enabled by PCM.
* **Tindall Corporation:** Collaborated in several meetings to share our design mixed details for scaling up the project. Leveraged Tindall's expertise in precast concrete to refine and adapt the design for large-scale implementation.

**Research Contribution:**

1. Papers that include TRANS-IPIC UTC in the acknowledgments section:

* Accepted manuscript for presentation at the TRB Annual Meeting, *Jan 2025.*
* Submitted manuscript to Int. J. of Pavement Engineering, *Dec 2024 (under review).*
* Prepared manuscript for submission to J. of Construction and Building Materials, *April 2025.*

1. Presentations and Posters of TRANS-IPIC funded research:

* *Presented in the Transportation Research Board, January 2025.*

*Radwan, I. and Dessouky, S. “Cool Pavements for Mitigating Urban Heat Island Effect using PCM in Precast Concrete.” 2025 Transportation Research Board Annual Meeting, January 6, 2025, Washington, DC.*

A group of men in a room

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Research poster and presentation at AMS20 committee in TRB 2025

1. Please list any other events or activities that highlights the work of TRANS-IPIC occurring at your university (please include any pictures or figures you may have). Similarly, please list any references to TRANS-IPIC in the news or interviews from your research.

Dr. Dessouky co-supervised a group of graduate students from Civil Engineering, Mechanical and school of Architecture at UTSA in their 2025 DOE Solar Decathlon competition. In this 10-week competition, the students submitted a report/presentation towards retrofitting the School of Art Campus building into net-zero.

A group of people standing in front of a large screen

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UTSA Solar Decathlon team’s kickoff meeting held inside a retrofit project, featuring various attendees including industry professionals and academics.

**Appendix 1**: Research Activities, leadership, and awards (cumulative, since the start of the project)

1. Number of presentations at academic and industry conferences and workshops of UTC findings

* No. = 6

1. Number of peer-reviewed publications submitted based on outcomes of UTC funded projects

* No. = 1

1. Number of peer-reviewed journal articles published by faculty.

* No. =

1. Number of peer-reviewed conference papers published by faculty.

* No. =

1. Number of TRANS-IPIC sponsored thesis or dissertations at the MS and PhD levels.

* No. MS thesis =
* No. PhD dissertations = 1
* No. citations of each of the above =

1. Number of research tools (lab equipment, models, software, test processes, etc.) developed as part of TRANS-IPIC sponsored research

* Research Tool #1 (Name, description, and link to tool) =

The pavement-based indoor experiments assess how PCM affects surface temperature under controlled conditions for four- and eight-hour cycles heating and cooling.

A collage of several lights

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Reflective Thermal – Insulated Box for Indoor Heating Experiment set-up; Heating phase; Cooling phase.

* Research Tool #2 (Name, description, and link to tool) =

Perform compressive strength tests to ensure PCM integration does not compromise structural integrity.

A collage of different images of a machine

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Compressive stress testing

* Research Tool #3 (Name, description, and link to tool) =

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Finite Element Models Using ABAQUS Software to analyze heat capacity fo flow for precast concrete

1. Number of transportation-related professional and service organization committees that TRANS-IPIC faculty researchers participate in or lead.

* Professional societies
  + No. participated in = **1 (Bituminous Committee, ASCE)**
  + No. lead =
* Advisory committees (No. participated in & No. led)
  + No. participated in =
  + No. lead = **1 (planning commission at City of San Antonio)**
* Conference Organizing Committees (No. participated in & No. led)
  + No. participated in = 1 (North American Society for Trenchless Technology Meeting)
  + No. lead =
* Editorial board of journals (No. participated in & No. led)
  + No. participated in =
  + No. lead = **2 (ASCE, and J. of Infr. Solution.)**
* TRB committees (No. participated in & No. led)
  + No. participated in = **2**
  + No. lead = **1**

1. Number of relevant awards received during the grant year

* No. awards received = **1 (City of San Antonio)**

1. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.

* No. Undergraduate =
* No. Graduate =

1. Number of internships and full-time positions secured in the industry and government during the grant year.

* No. of internships = **1 (Texas Department of Transportation)**
* No. of full-time positions = None

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