Cool Concrete Sidewalk Pavements: Mitigating Urban Heat Island Effect with Integrating Phase Change Materials

Islam Radwan[1] | Samer Dessouky[2]

[1]PhD Graduate Researcher, [2]Professor of Civil and Environmental Engineering- University of Texas at San Antonio, [3]Professor of Department of Earth and Planetary Sciences University of Texas at San Antonio

ASCE TEXAS CECON2025 CIVIL ENGINEERING CONFERENCE

UTSA

TRANS-IPIC TRANSPORTATION INFRASTRUCTURE PRECAST INNOVATION CENTER

INTRODUCTION

Urban Heat Island Effect:

- Urban heat islands are areas in cities that are significantly warmer than surrounding rural areas due to the urban developments.

Phase change material (PCM):

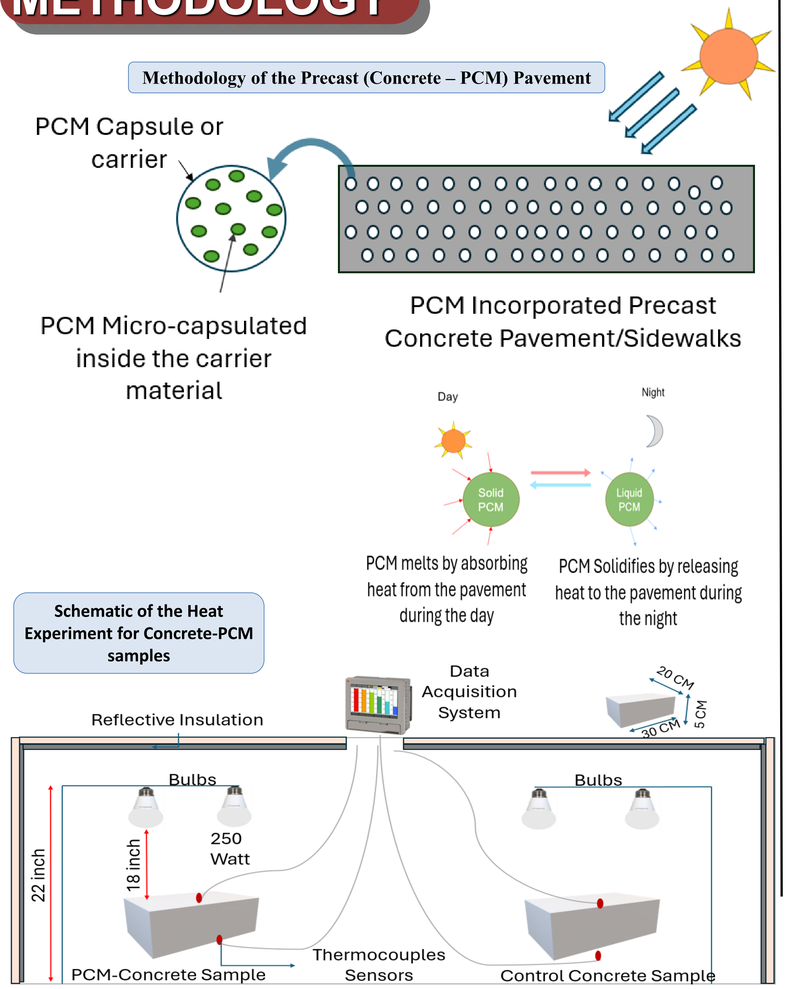
- PCM is a heat-fusion substance that melts and solidifies at a certain temperature.

OBJECTIVES

- Cooling and Reducing the sensible heat of the Sidewalk pavement.
- Improving urban environmental conditions, contributing to lower CO2 emissions.
- Reducing the need for cooling systems through improved thermal management.

METHODOLOGY

Methodology of the Precast (Concrete – PCM) Pavement



Schematic of the Heat Experiment for Concrete-PCM samples

EXPERIMENTATION

- Organic PCM is better for the concrete as it is chemically stable and has non-toxic properties.
- Micro-capsulated PCM to prevent the leakage while phase change happens.
- The melting temperature and Latent heat of fusion are key factor for PCM Selection.
- Thermocouples sensors on Top and Bottom Surfaces of concrete samples with 0%, 5%, and 10%.

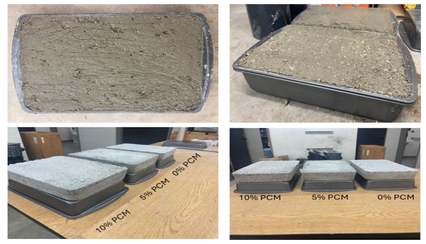
Pavement Temperature Observation Test:

Two-Hour and Four-Hour Cycle:

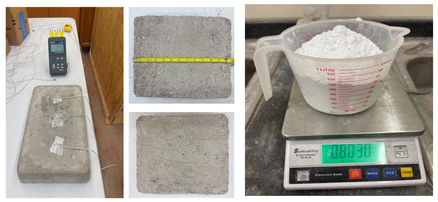
- Heating and Cooling for 2 hours; temperatures recorded.

Material thermal characteristics:

- Specific Heat Capacity, Thermal Conductivity, Thermal Diffusivity.



Concrete- PCM samples with 0%, 5% and 10%



Thermocouples sensors **Organic Micro-capsulated PCM**

Samples Preparation

Differential Scanning Calorimeter (DSC) | Laser Flash Analysis (LFA) | Gas Pycnometer

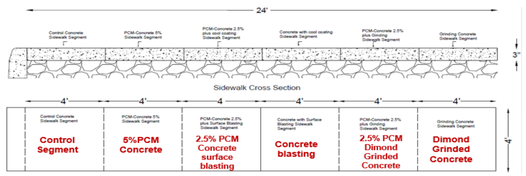
Heating Experiment set-up

Material Properties

Mechanical Study

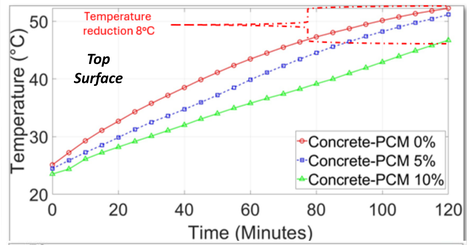
Real Case Study

- Real Cool Sidewalk as a large-scale pilot test for 24 feet long.
- The Cool sidewalk contains different 5 cool mechanisms.
- PCM with different percentages, Reflective cool coating, and reflective grinding.

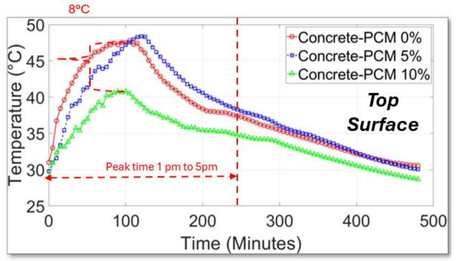


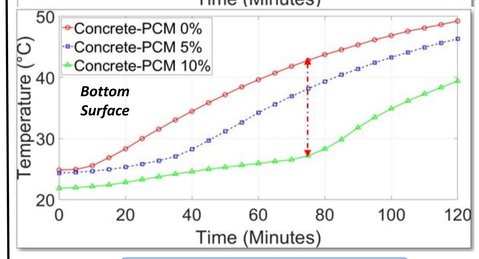
Cool Sidewalk Cross-Section

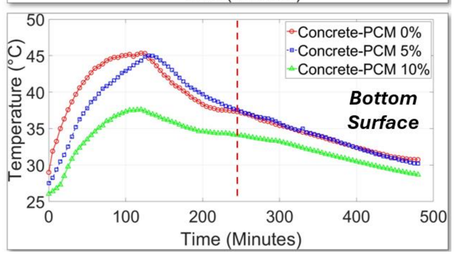
RESULTS



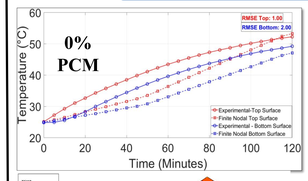
Temperature reduction 8°C

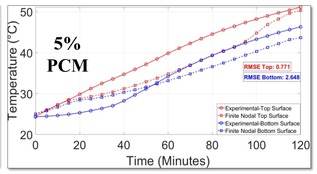




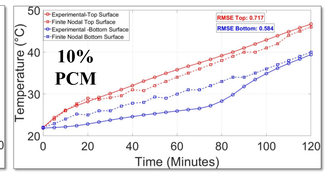


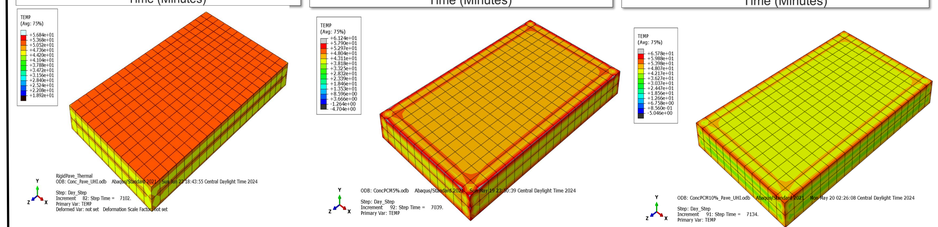
Indoor Four-Hour cycles





Outdoor Exposure (1 pm – 9pm)





Finite Element Analysis (Four-Hour Simulation)

Conclusion

- PCM Effectiveness: PCM reduces concrete temperatures during 2-hour heating cycles.
- Finite Element Simulations match experimental results, confirming model reliability.
- Urban Heat Mitigation: PCM can aid in heat mitigation but requires optimized use.

Acknowledgment

We express our gratitude to Dr. Arturo Montoya and Dr. Alan Whittington for their guidance . The City of San Antonio for supplying the materials. The Department of Transportation (DOT) and the Transportation Infrastructure Precast Innovation Center (TRANS-IPIC) are recognized for funding of this project. Microtek for providing the PCM and technical assistance.