Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

University Transportation Center (UTC)

Computer Vision-Based Sorptivity Test for Automated Durability Assessment and Service Life Prediction of Precast Concrete

UI-25-RP-05

Quarterly Progress Report
For the performance period ending [June 30th]

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Collaborators / Partners:
NONE

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

Project Description:

1. Research Plan - Statement of Problem

    Durability and service life of concrete transportation infrastructure are strongly governed by the transport of water, chlorides, sulfates, and other aggressive agents through the pore network. Conventional test methods used to assess these transport properties, including ASTM C1585 sorptivity and AASHTO T 358 surface resistivity, are labor-intensive, time-consuming, and susceptible to operator variability. In addition, estimating long-term aging behavior and service-life-related durability parameters typically requires months of testing, which limits rapid decision-making for precast concrete production and quality assurance.

    This project addresses the need for a rapid, automated, and reliable method to evaluate permeability-related durability in precast concrete. The proposed computer vision-based sorptivity method is intended to increase testing throughput, reduce human error, and provide early feedback on curing quality, permeability, and long-term aging behavior. Such a tool is especially important as the precast industry adopts newer cement systems and supplementary cementitious materials, for which traditional durability databases may be insufficient. By enabling fast and low-cost assessment of porosity, permeability, and curing performance, the project aims to support more durable precast elements, improved service life prediction, and reduced maintenance costs for transportation infrastructure.

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

    Task 1: Prediction of resistivity based on results of CV-based sorptivity test

    It is critical to link the sorptivity measured by our CV-based method to the durability of concrete. The first subtask 1.1 of this research task will use resistivity as a measure of permeability. An extensive dataset comprising approximately 20 concrete mix compositions will be developed, including different w/c ratios, cement type, SCM replacement ratios, and aggregate type and volume. The AASHTO T 358-15 surface resistivity measurement will be conducted to obtain the target of prediction. The second subtask 1.2 is to perform the CV-based sorptivity test on the same samples to obtain initial and secondary sorptivity. The relationship between these results and the resistivity will be explored. A preliminary test has been conducted using 4 different concretes specimens, and a strong correlation has been observed, which demonstrates the potential of this proposed approach. This proposed task, combining a more extensive dataset, will further validate the feasibility and reveal any potential barriers.

    Task 2: Estimation of ageing coefficient based on sorptivity

    Task 2.1 will extend the curing duration from 28d to 56 and 90d. Longer time samples will also be prepared and tested in Phase II of this project to further improve the accuracy. The ageing coefficients determined based on sorptivity will be compared to those based on surface resistivity. This task will justify the application of the CV-based sorptivity test on the durability assessment of concrete specimens after long- term curing and also establish the sorptivity test as a new approach for service life prediction. Task 2.2 will utilize the advantage of this automated rapid test to improve the estimation of ageing coefficients. For a selected subset of samples, the sorptivity will be measured more frequently to generate full curves of permeability evolution over time. These results are expected to improve the accuracy and precision of ageing coefficients and allow prediction based on early-stage results.

Task 3: Evaluation of curing using sorptivity

Task 3 will further explore the application of the CV-based sorptivity test as a method to evaluate the extent and quality of curing. Curing conditions more relevant to the production of precast concrete will be used and prepared for the scale-up of the proposed technology. Task 3.1 will verify the CV-based sorptivity test as an automated, rapid alternative method to the standard methods for concrete cured under different conditions. Submerged in water curing, different moisture conditions, and dry curing in air will be tested. The sorptivity obtained will be compared to ASTM C1585 to reveal the impact of curing conditions. Task 3.2 will explore the feasibility of using sorptivity to optimize the demolding time. Samples demolded after different initial curing durations and subjected to various post-curing conditions and durations will be tested. Resistivity and strength will be used to evaluate the sufficiency of curing, and to verify if the sorptivity obtained using our proposed method can be used as a measure of curing quality.

Project Progress:

3. Progress for each research task

Task 1 100% completed
Task 2 20% completed
Task 3 0% completed to date

Task 1 focused on developing and validating the computer vision-based sorptivity framework and establishing its capability for automated permeability assessment. During this reporting period, a complete image acquisition and analysis pipeline was developed for continuous monitoring of water absorption in concrete specimens. The experimental setup consisted of a fixed digital camera that continuously captured images of multiple specimens during the ASTM C1585 sorptivity test. A region-of-interest (ROI) refinement procedure was implemented to isolate the exposed concrete surfaces and eliminate background features, ensuring consistent image quality for subsequent analysis (Fig. 1).

A Vision Transformer (ViT)-based semantic segmentation model was trained to identify the wetted region in each image automatically. The segmented wetting front was subsequently converted into penetration depth as a function of time, enabling automated determination of the initial and secondary sorptivity coefficients without manual measurements (Fig. 2). The developed framework successfully tracked the progression of capillary absorption over the entire duration of the test, demonstrating robust performance under varying wetting conditions.

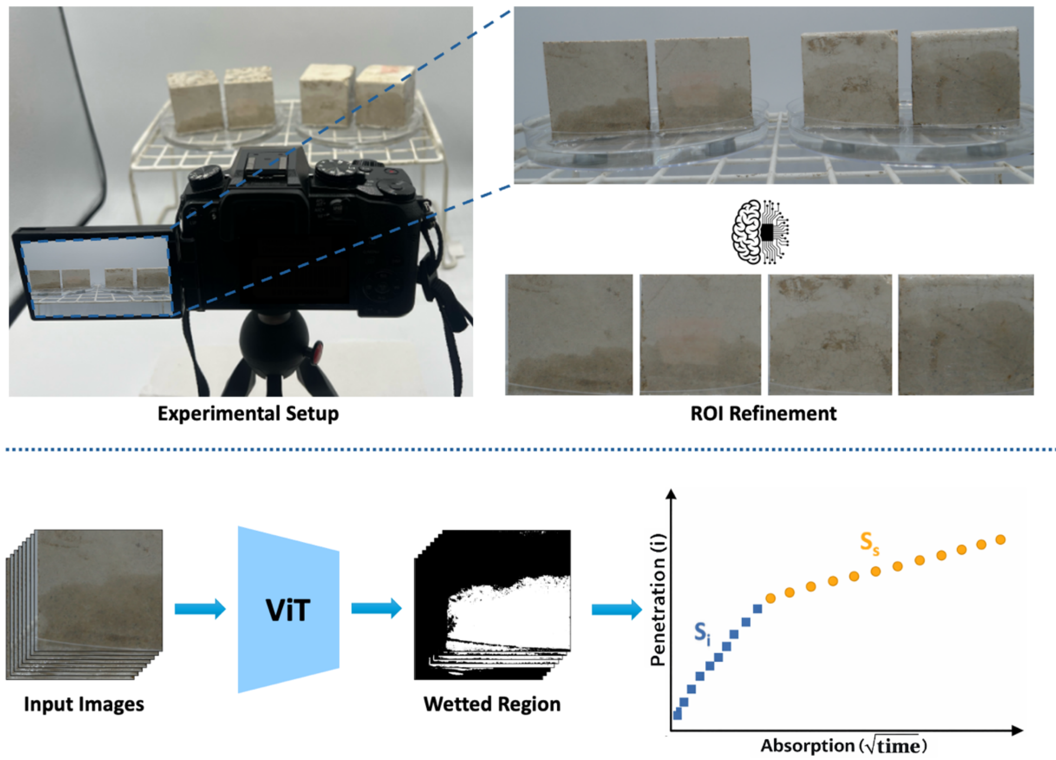

Figure 1. *Experimental workflow for the computer vision-based sorptivity test. A fixed digital camera continuously records concrete specimens during water absorption testing. Images are automatically cropped through region-of-interest (ROI) refinement before being processed by a Vision Transformer (ViT)-based segmentation model to identify the wetted region. The extracted wetting front is converted into penetration depth as a function of the square root of time, enabling automated determination of initial (S_i) and secondary (S_s) sorptivity.*

The computer vision-derived sorptivity measurements were compared with the standard ASTM C1585 results obtained during the previous quarter. The automated approach accurately reproduced the measured penetration behavior while significantly reducing manual intervention and enabling continuous monitoring throughout the experiment. Combined with the previously established relationship between sorptivity and surface resistivity, these results complete Task 1 and demonstrate the feasibility of using computer vision for rapid, automated durability assessment of precast concrete.

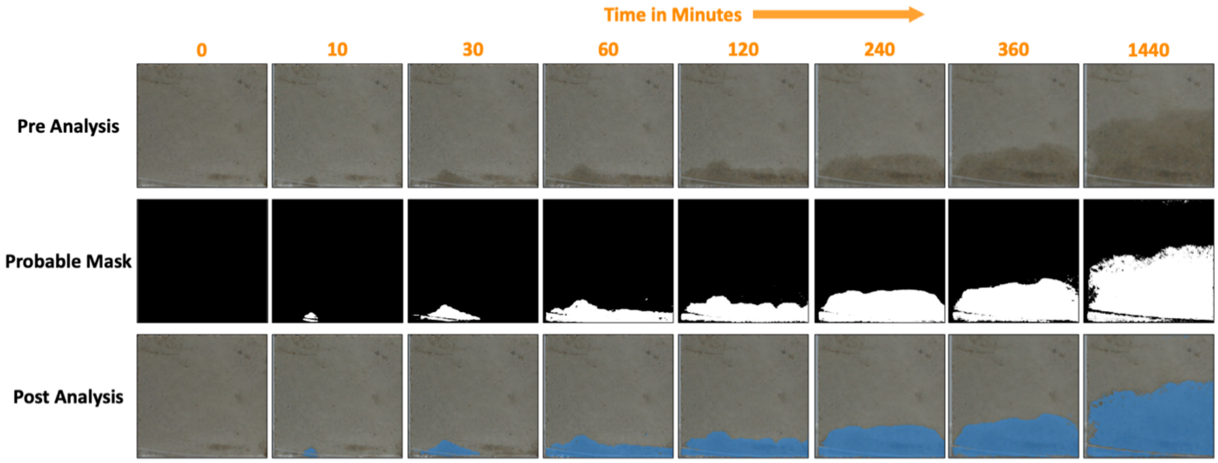

Figure 2. *Representative results from the computer vision-based sorptivity analysis showing the progression of capillary absorption over time. The top row presents the original specimen images acquired during testing, the middle row shows the predicted segmentation masks identifying the wetted region, and the bottom row illustrates the detected wetting front overlaid on the original images. The automated framework accurately tracks the advancement of water penetration from 0 to 1440 minutes without manual intervention.*

Initial activities for Task 2 were initiated during this reporting period. Concrete specimens required for long-term monitoring were prepared and are currently undergoing extended curing to enable measurements at 56 and 90 days. The experimental protocol for frequent computer vision-based sorptivity measurements was finalized to generate high-resolution permeability evolution curves over time. These data will be used to determine ageing coefficients and compare the results with those obtained from conventional surface resistivity measurements. Preliminary data collection is currently underway.

4. Percent of research project completed

40% of the project is completed till the 2nd quarter.

5. Expected progress for next quarter

Task 1. *Prediction of resistivity based on results of CV-based sorptivity test [100% completed]*

Task 2. *Estimation of ageing coefficient based on sorptivity* [90% completed]

Task 3. *Evaluation of curing using sorptivity [10% completed]*

6. Educational outreach and workforce development

Name of educational opportunity: The World of Coal Ash 2026
Title of Presentation: Automated Durability Testing of Concrete with Supplementary Cementitious Materials via Computer Vision
Location of event: Lexington, Kentucky.
Date of event: May 6th, 2026.

7. Technology Transfer

   NA

Research Contribution:

8. Papers that include TRANS-IPIC UTC in the acknowledgments section:
   None

9. Presentations and Posters of TRANS-IPIC funded research:
   None

10. 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.
    None

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

A. Number of presentations at academic and industry conferences and workshops of UTC findings
   - No. = 01

B. Number of peer-reviewed publications submitted based on outcomes of UTC funded projects
   - No. = 00

C. Number of peer-reviewed journal articles published by faculty.
   - No. =00

D. Number of peer-reviewed conference papers published by faculty.
   - No. =00

E. Number of TRANS-IPIC sponsored thesis or dissertations at the MS and PhD levels.
   - No. MS thesis =
   - No. PhD dissertations =
   - No. citations of each of the above =

F. 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) =
   - Research Tool #2 (Name, description, and link to tool) =
   - Research Tool #3 (Name, description, and link to tool) =

G. Number of transportation-related professional and service organization committees that TRANS-IPIC faculty researchers participate in or lead.
   - Professional societies
     - No. participated in = 2
     - No. lead = 1
   - Advisory committees (No. participated in & No. led)
     - No. participated in = 0
     - No. lead = 0
   - Conference Organizing Committees (No. participated in & No. led)
     - No. participated in = 0
     - No. lead = 0
   - Editorial board of journals (No. participated in & No. led)
     - No. participated in = 4
     - No. lead = 2
   - TRB committees (No. participated in & No. led)
     - No. participated in = 2
     - No. lead = 0

H. Number of relevant awards received during the grant year
   - No. awards received = 1

I. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.
   - No. Undergraduate = 0
   - No. Graduate = 0

J. Number of internships and full-time positions secured in the industry and government during the grant year.
   - No. of internships = 0

- No. of full-time positions = 0

References:

1. AASHTO (2021). Standard method of test for surface resistivity indication of concrete's ability to resist chloride ion penetration, AASHTO T 358-21. Washington, DC: American Association of State Highway and Transportation Officials.
2. Alderete N.M., Villagran Zaccardi Y.A., De Belie N. (2020). 'Mechanism of long-term capillary water uptake in cementitious materials', Cement and Concrete Composites, 106, p. 103448.
3. ASTM International (2020). Standard test method for measurement of rate of absorption of water by hydraulic-cement concretes, ASTM C1585-20. West Conshohocken, PA: ASTM International.
4. Kabir H., Garg N. (2023). 'Rapid prediction of cementitious initial sorptivity via surface wettability', npj Materials Degradation, 7, p. 52.
5. Kabir H., Wu J., Dahal S., Joo T., Garg N. (2024). 'Automated estimation of cementitious sorptivity via computer vision', Nature Communications, 15, p. 9935.
6. Shankaramurthy B.M., Hasiuk F., Wang K., Sargam Y., Li W. (2025). 'Influence of coarse aggregate pore structure on the pore structure and water absorption of concrete', Construction and Building Materials, 491, p. 142751.