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 [October 1st]

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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 60% completed
Task 3 80% completed to date

During this reporting period, the computer vision-based sorptivity framework was applied to the full set of precast concrete mixtures and refined for the frequent, long-duration monitoring required in Tasks 2 and 3. Specimens are imaged continuously by a fixed digital camera during ASTM C1585 testing, and the wetted region on the exposed face of each specimen is segmented automatically at every time step (Fig. 1a). Instead of relying on a limited number of discrete mass measurements, the segmentation masks are converted into a wetted-area ratio, defined as the fraction of the specimen face reached by the waterfront, which is tracked continuously over the full 24-hour test without manual intervention.

Figure 1b presents the evolution of the wetted-area ratio with the square root of time for seven precast mixtures (C1–C6 and C8). All mixtures show an approximately linear increase in wetted area with $\sqrt{t}$ during the initial absorption period, consistent with capillary-driven uptake, followed by a slower rate of advance at later times. The method clearly differentiates the mixtures: C1 shows the fastest waterfront advance, wetting nearly 90% of the specimen face within the first 6 hours, whereas the least absorptive mixtures reach only about 55–65% after 24 hours. The slope of the initial linear portion of each curve (waterfront slope) was then compared with the initial sorptivity (Si) measured gravimetrically according to ASTM C1585 (Fig. 1c). A strong linear relationship was obtained ($R^2 = 0.98$, RMSE = 14×10^{-4} mm/s$^{0.5}$), confirming that the image-derived waterfront slope is a reliable surrogate for the standard sorptivity measurement across a wide range of absorption rates.

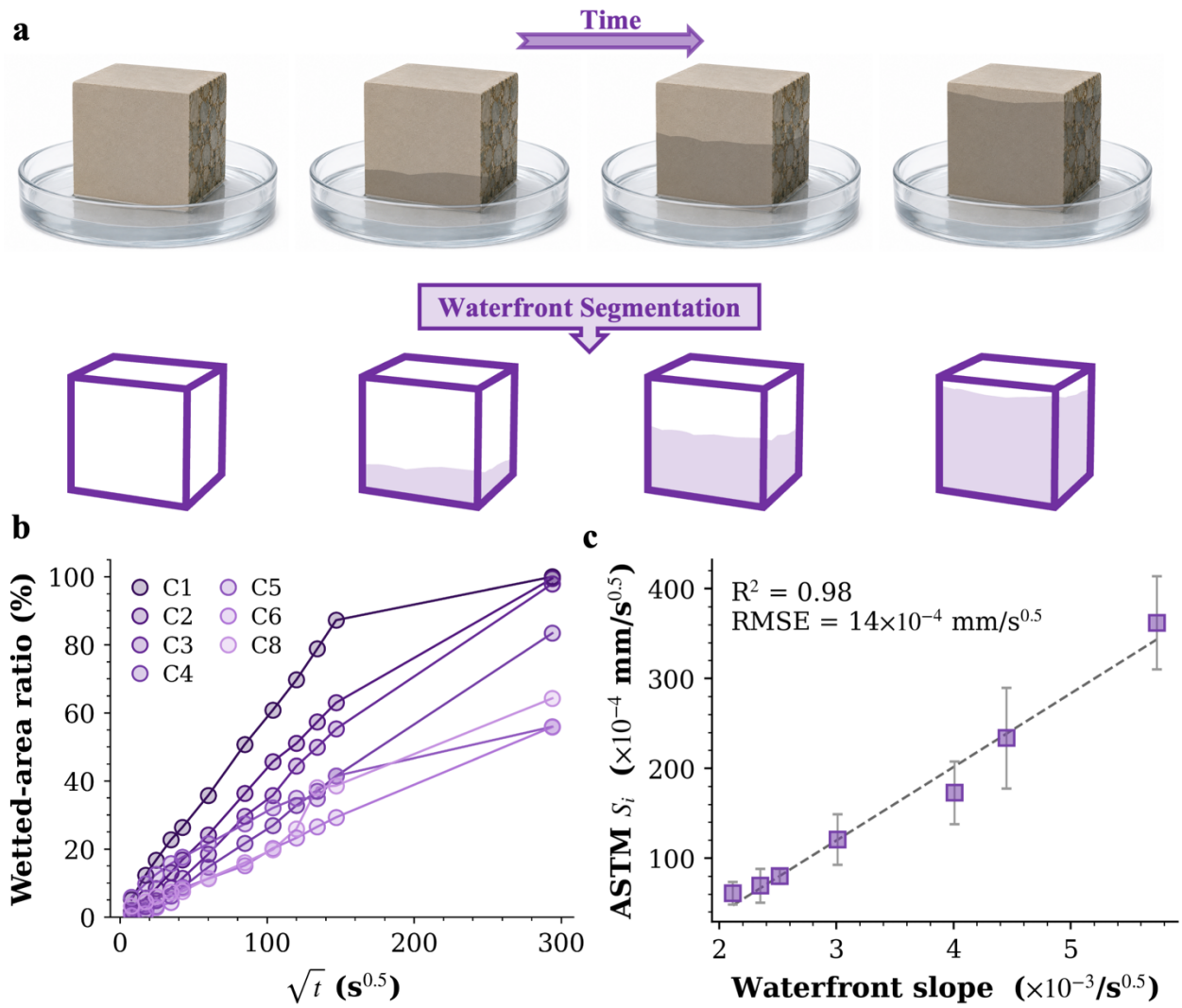


Figure 1. *Computer vision-based tracking of capillary absorption in precast concrete. (a) Schematic of the waterfront segmentation workflow, in which the wetted region on the specimen face is segmented automatically from continuously acquired images as water absorption progresses. (b) Wetted-area ratio as a function of the square root of time for seven precast concrete mixtures (C1–C6, C8). (c) Correlation between the image-derived waterfront slope and the initial sorptivity (Si) measured according to ASTM C1585; error bars indicate variability across replicate specimens and the dashed line shows the linear fit.*

These results further strengthen the conclusions of Task 1 and, combined with the previously established relationship between sorptivity and surface resistivity, demonstrate the feasibility of computer vision for rapid, automated durability assessment of precast concrete. Under Task 2, specimens prepared for long-term monitoring have reached extended curing ages, and computer vision-based sorptivity measurements at 56 and 90 days are being performed alongside surface resistivity measurements. Because the waterfront slope is extracted automatically from each test, sorptivity can be measured far more frequently than is practical with the gravimetric procedure, providing continuous curves of permeability evolution from which ageing coefficients will be determined and compared with resistivity-based values. For Task 3, concrete specimens were recently cast for three curing regimes representative of precast production and field conditions: moist curing, air (dry) curing, and full submersion in water (Fig. 2).

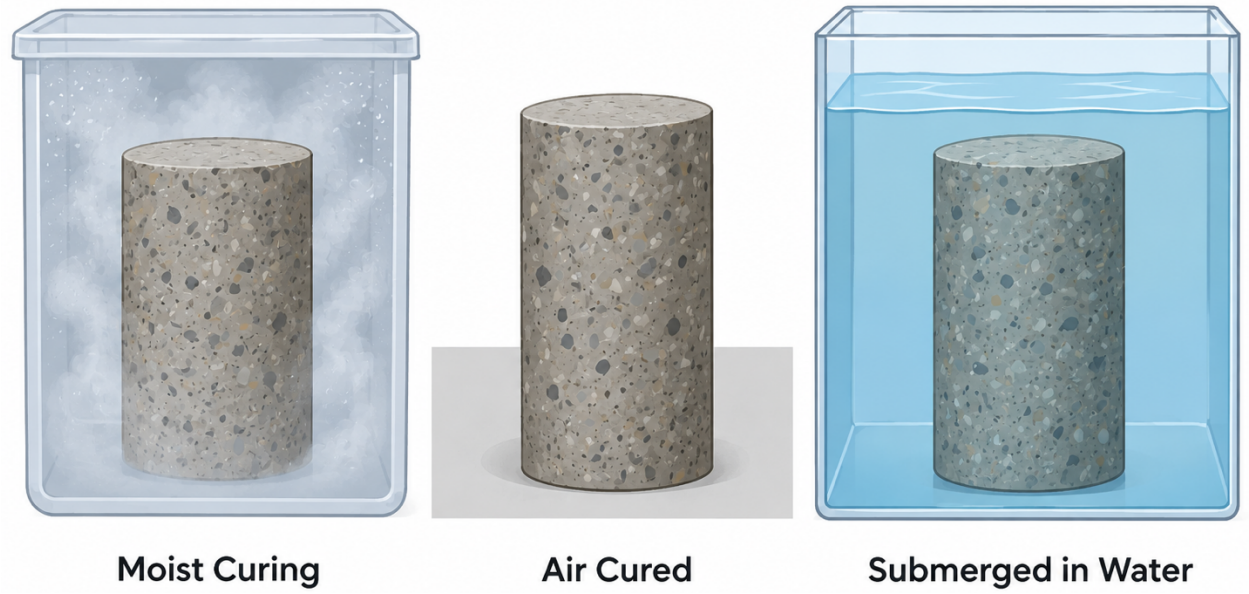


Figure 2. *Curing regimes planned for Task 3 to evaluate the sensitivity of the computer vision-based sorptivity test to curing quality: moist curing in a sealed high-humidity container (left), air curing under ambient laboratory conditions (middle), and submersion in water (right).*

The specimens are currently undergoing curing under these regimes and will be tested in the coming weeks. Computer vision-based sorptivity tests will be conducted on specimens from each curing regime and compared with ASTM C1585 measurements to quantify the effect of curing conditions on capillary absorption (Task 3.1). Inadequately cured (air-cured) specimens are expected to exhibit higher sorptivity owing to a coarser and more connected near-surface pore structure, which will directly test whether the automated method can distinguish sub-optimal curing from proper curing. Task 3.2, in which specimens demolded after different initial curing durations will be evaluated using sorptivity, surface resistivity, and compressive strength, will follow in the next quarter.

4. Percent of research project completed

80% 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.