



## **Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)**

### **University Transportation Center (UTC)**

New Simplified and Adaptive Method for Quality Control of Precast Elements through  
Advanced NDT Evaluation  
PU-25-RP-02

Quarterly Progress Report  
For the performance period ending 4/1/2026

**Submitted by:**

Mirian Velay-Lizancos (PI), [mvelayli@purdue.edu](mailto:mvelayli@purdue.edu)  
Lyles School of Civil and Construction Engineering  
Purdue University

Jan Olek (Co-PI), [olek@purdue.edu](mailto:olek@purdue.edu)  
Lyles School of Civil and Construction Engineering  
Purdue University

Husam H. Elgaali, [helgaal@purdue.edu](mailto:helgaal@purdue.edu)  
Lyles School of Civil and Construction Engineering  
Purdue University

**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**

Premature removal of precast elements from the formwork, or transferring loads to pre-stressed elements before the concrete develops adequate strength, can result in damage to the precast element, as well as lead to significant accidents in extreme cases. Even in the cases where the damage is not visible, these premature operations cause microcracks and minor flaws that, while not initially affecting the serviceability of the element, will lead to reduced durability. These production-induced cracks are especially relevant for the durability of precast elements used in transportation infrastructure, as these elements are frequently exposed to moisture and deicing salts. When present, even small early cracks can accelerate deterioration from water ingress, freeze-thaw cycles, and chlorides, more so than in precast elements used in more sheltered applications (e.g, building components). On the other hand, performing these operations later than needed will result in a reduction of the productivity of the precast factories. Therefore, accurately determining the optimal timing for these operations is crucial for producing more durable concrete precast elements by preventing damage from premature handling while maintaining or even increasing production volume. As discussed in Section 2 (Background), some methods, such as the maturity method [1,2], which relies on internal temperature measurements at single points [3], can estimate the evolution of compressive strength from limited data [4]. However, these approaches have significant drawbacks because they do not capture strength development across the entire element and therefore cannot detect heterogeneity between different regions of the elements.

Furthermore, methods that rely on internal sensors are impractical for implementation in every precast element produced because installing sensors in each unit requires significant labor and costly consumables (the internal sensors themselves). As a result, sensors are typically placed in only one or two elements, leaving the uniformity of strength development across the entire production unverified. Continuous, automated monitoring of early-age compressive strength in all precast elements would support more accurate decisions on form removal and load transfer, enabling producers to optimize production schedules and ensure durability. Therefore, a simplified, scalable, and cost-effective approach, that can be implemented in precast plants of any size, would significantly improve the timing of production operations and enhance the overall durability of transportation precast concrete elements.

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

**Task 1: Materials acquisition, characterization, and mixture design selections.** The first task involves acquiring the raw materials necessary to produce several concrete mixtures, characterizing each compound, and completing the mixture design of the cementitious composites, which will be used in subsequent tasks. Furthermore, trial batches will be conducted to adjust the mixtures and obtain reasonable parameters for a typical concrete used in the precast production of transportation elements. Relevance: This task is required to complete the following tasks.

**Task 2: Empirical determination of the correlation between the evolution of the internal temperature(with a single sensor) and the external temperature measured with a thermal camera when the ambient temperature is 70°F.** To be able to implement thermal cameras as part of an extended maturity method that tests every point of the precast element, a correlation between the internal temperature of the same and the surface temperature over time needs to be established.

To achieve this, Task 2 is divided into three subtasks:

**Task 2.1. Cast of different sizes and shapes.** Cubic specimens in at least three different sizes and cylindrical specimens in two different sizes will be cast to provide a range of sample volumes. In addition, to better represent the geometry of precast concrete elements such as girders or beams, custom molds, simulating common bridge-girder profiles (for instance bulb-tee or T-section geometries), will also be fabricated and used to cast scaled-down version of these elements in an attempt to capture the influence of aspect ratio, surface-to-volume effects, as well as potential temperature and moisture gradients encountered in full-scale precast members. Each specimen, regardless of shape, will be equipped with an internal sensor positioned at its geometric center to monitor temperature, moisture, and other relevant parameters during curing and testing.

**Task 2.2. Temperature monitoring.** The internal and external temperatures will be monitored and recorded using the internal sensor with a datalogger and an infrared thermal camera.

**Task 2.3. Analyzing the data and determining the correlation between the external temperature and the internal temperature based on the volume of the sample and the distance between the internal sensor and the surface.** Relevance: Task 2 will lay the foundation for simplifying the maturity method by utilizing external temperature monitoring instead of internal temperature, while accounting for internal temperature evolution through the use of these correlations. Further tasks are needed for that; this task is just providing the input data for the model to be developed in future tasks.

**Task 3: Assess the effect of the ambient temperature on the correlation between the evolution of the internal temperature (with a single sensor) and the external temperature measured with a thermal camera.** As many precast production facilities are not temperature-controlled, understanding the role of the ambient temperature on the correlations between surface temperature and internal temperature is required to develop a simplified method that can serve many different types of precast plants. To achieve this, we will need to repeat tasks 2.1 to 2.3, keeping the samples in a temperature-controlled chamber at both lower and higher temperatures than the reference temperature specified in Task 2.

**Task 4. Train a model to estimate the internal temperature of concrete using the surface temperature history,** the distance from the element's mass center to surface points, ambient temperature, volume of concrete, and the expected heat of hydration based on mixture design and binder type. The model will be trained with the data collected in Tasks 2 and 3.

**Task 5. Test and validate the temperature model.** A new batch of concrete will be prepared, and samples of sizes different from those used previously will be used to evaluate model accuracy. Additional samples will be cast if needed to refine, retest, and validate the model.

**Task 6. Adapt the maturity method to estimate the compressive strength at internal and external points of the precast element** using the estimated internal temperature values predicted by the model in Task 5, rather than assuming a uniform internal temperature. Validate these strength estimates by cutting the precast elements and performing compressive strength tests on both interior and exterior sections. The maturity of each cut piece of the element will be calculated using a spatially varying temperature history prediction from Task 5 rather than a single point internal temperature history that is commonly used in the maturity method. Then, the cut samples will be tested, and the measured strengths will be compared to the strengths predicted by the modified maturity method to assess the accuracy of the estimation.

**Task 7. Develop guidelines for implementing the proposed simplified method to estimate early-age compressive strength at representative points of a precast element.** Based on the results of previous tasks, develop guidelines for using thermal cameras instead of internal temperature sensors to apply the modified maturity method to the entire element. The model developed in Task 4 and tested and validated in Tasks 5 and 6, will be used to build a proof-of-concept tool that will automatically translate the data from a thermal camera and ambient temperature histories, along with mixture design information, into estimated compressive strength at any point of the element.

**Task 8. Develop workforce training materials and make them publicly available on platforms such as YouTube and the TRANS-IPIC website.** In addition to the written guidelines from Task 7, we will record and distribute videos covering: (i) the importance of timely removal of precast elements from forms, including the risks of premature or excessively delayed operations, (ii) the fundamentals of established methods for estimating early-age concrete strength in precast elements, and (iii) tutorials explaining the new simplified method developed in this project, including its advantages, limitations, and guidance for adapting it when mixture designs differ significantly from those used during model calibration.

**Task 9. PI Submits Final DRAFT report to TRANS-IPIC for editing and publication**

**Task 10. Report Posted to TRANS-IPIC website**

**Project Progress:**

3. Progress for each research task  
**Task 1 [100 % completed to date]**

The raw materials necessary to produce the three concrete mixtures, characterized by all binders and aggregates, were completed, and the three mixture designs of the cementitious composites, which will be used in subsequent tasks. Furthermore, trial batches were completed, and reasonable parameters for a typical concrete used in the precast production of transportation elements were obtained.

Characterization of the Aggregates:

*Table 1. Gradation size [5], specific gravity, and absorption of coarse [6] and fine [7] aggregates.*

Property	ASTM Test	Coarse Aggregate	Fine Aggregate
Gradation Classification	C33	#67	Table 1
Specific Gravity SSD	C127/C128	2.75	2.65
Absorption	C127/C128	1.39	1.54

*Table 2. Gradation analysis [8] for the coarse and fine aggregates.*

Coarse Aggregate		Fine Aggregate	
Sieve Size	Percent Passing	Sieve Size	Percent Passing
1"	100%	#4	100%
3/4"	90%	#8	85%
1/2"	44%	#16	57%
3/8"	25%	#30	28%
#4	6%	#50	8%
#8	1%	#100	2%
Pan	0%	#200	0%

Characterization of the Binders:

*Table 3. X-ray fluorescence analysis (XRF) using the Lab X500 XRF analyzer.*

Chemical Component [%]	Type IL OPC (PLC)	Class C Fly Ash (FAC)	Silica Fume (SF)
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	27.4	53.5	97.5
SiO <sub>2</sub>	20.1	32.0	97.3
Al <sub>2</sub> O <sub>3</sub>	4.6	15.5	0.0
Fe <sub>2</sub> O <sub>3</sub>	2.7	5.9	0.2
CaO	64.3	35.1	0.4
SO <sub>3</sub>	3.3	2.2	0.2

*Table 4. Specific gravity measured by gas-comparison [9], using the Accupyc II 1340 pycnometer.*

*Particle size analysis (PSA) was measured using the Anton Paar 1090 Series.*

Binder	Specific Gravity	D <sub>10</sub> Volume (µm)	D <sub>50</sub> Volume (µm)	D <sub>90</sub> Volume (µm)	Avg. Volume (µm)
Type IL OPC (PLC)	3.112	1.90	11.22	30.37	14.51
Class C Fly Ash (FAC)	2.796	1.06	4.87	15.73	7.13
Densified Silica Fume (SF)	2.283	-	-	-	-

Trial Batch Mixture Design:

*Table 5. Trial Batch Mixture Design for reference mixture (A).*

<b>Reference (A) Mixture</b>	<b>Component</b>	<b>Measurement</b>	<b>Units</b>
<b>Mixture Design</b>	Type IL Cement (PLC)	11.55	lb/0.5 ft <sup>3</sup>
	Water	5.08	
	Coarse Aggregate, SSD	31.17	
	Fine Aggregate, SSD	25.32	
	High Water Reducing Agent (HWRA)	7.00	mL/0.5 ft <sup>3</sup>
	Air Entraining Agent (AEA)	1.20	
<b>Results</b>	w/cm	0.440	
	Slump	4.5"	
	Air Content	7%	
	Compressive Strength (28-day)	5363 ± 169 psi	

Final Concrete Mixture Design:

*Table 6. Final concrete mixture design for all three mixtures.*






<b>Component</b> <i>*Constant Paste Volume = 28.2%</i>	<b>Measurement (per yd<sup>3</sup> of concrete)</b>			<b>Units</b>
	<b>A (Reference)</b>	<b>B</b>	<b>C</b>	
Type IL Cement (PLC)	624	468	561	lb/yd <sup>3</sup>
Class C Fly Ash (FAC)	0	140	0	
Densified Silica Fume (SF)	0	0	46	
Water	275	275	275	
Coarse Aggregate, SSD	1683	1683	1683	
Fine Aggregate, SSD	1361	1361	1361	
High Water Reducing Agent (HWRA)	378	378	378	mL/yd <sup>3</sup>
Air Entraining Agent (AEA)	65	65	65	
Water-to-Cementitious Ratio (w/cm)	0.440	0.451	0.452	-

**Task 2 [20 % completed to date]** This task started in February, as scheduled, and it will be completed by May 2026. Progress details for sub-tasks 2.1-2.3 are described below.

**Task 2.1.** Cast of different sizes and shapes.

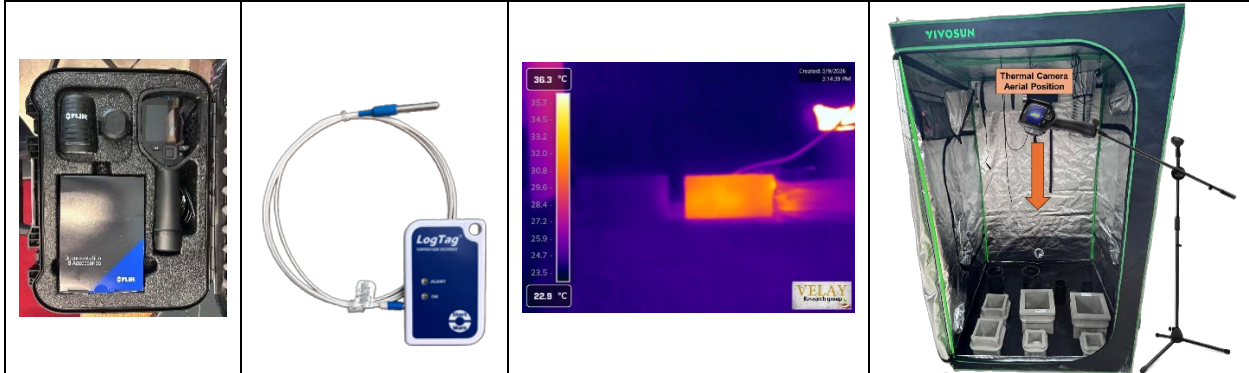
Progress: Cubic specimens of three sizes (100 mm, 150 mm, 200 mm) and cylindrical specimens of two sizes (4"x8" & 6"x12") were obtained. The order of the models of the corresponding sizes was placed on February 6<sup>th</sup>. The molds arrived on March 25<sup>th</sup>.

*Figure 1. Images of the six mold geometries.*

<b>Cube A</b>	<b>Cube B</b>	<b>Cube C</b>	<b>Cylinder A</b>	<b>Cylinder B</b>
100 mm or 3.9"	150 mm or 5.9"	200 mm or 7.9"	4" (d) x 8" (l)	6" (d) x 12" (l)
				

**Task 2.2.** A new thermal camera was received during the first week of February, and the appropriate software was obtained. An operating procedure and experimental setup for the thermal camera and the software were finalized. The temperature sensors and data loggers were ordered in February; they arrived on March 20<sup>th</sup>. The testing setup is currently being prepared, and the first batch will be conducted on April 6<sup>th</sup>.

Figure 2. FLIR E8 Pro thermal camera, temperature sensor, software analysis, and schematic of setup.



**Task 2.3.** To be completed after tasks 2.1 and 2.2.

- Task 3 [0 % completed to date]** The proposed schedule has this task to begin in April 2026.
- Task 4 [0 % completed to date]** The proposed schedule has this task to begin in June 2026.
- Task 5 [0 % completed to date]** The proposed schedule has this task to begin in July 2026.
- Task 6 [15 % completed to date]** The proposed schedule has this task to begin in July 2026. However, we have begun this task by performing the experiment to obtain energy activation (ASTM C1074). The materials and equipment for the energy activation experiment were acquired. We also finalized the experimental design and logistics for the activation energy experiment. The samples will be prepared from March 30<sup>th</sup> to April 3<sup>rd</sup> for the first (reference) mixture design.
- Task 7 [0 % completed to date]** The proposed schedule has this task to begin in June 2026.
- Task 8 [0 % completed to date]** The proposed schedule has this task to begin in July 2026.
- Task 9 [0 % completed to date]** The proposed schedule has this task to begin in November 2026.
- Task 10 [0 % completed to date]** The proposed schedule has this task to begin in December 2026.

4. Percent of research project completed  
A 25% of the project was completed in the first quarter.
5. Expected progress for next quarter  
During the next quarter we expect to continue and have 100% completion of task 2, as well as begin and have 50% completion of task 3, 20% completion of task 4, 20% completion of task 7. Furthermore, we will continue and expect to have 30% completion of task 6 (determine the activation energy of the three mixtures).
6. Educational outreach and workforce development  
N/A
7. Technology Transfer  
N/A

## **Research Contribution:**

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

Since January 1<sup>st</sup> 2026:

[1] Aniya Edwards, Rui Bai, Raikhan Tokpatayeva, Jan Olek, Mirian Velay-Lizancos, "Effect of relative humidity on the effectiveness of CO<sub>2</sub> in recovered carbon black nanomodified mortars", Trans-IPIC Workshop (Conference paper), 2026 [Submitted]

### 9. Presentations and Posters of TRANS-IPIC funded research:

Since January 1<sup>st</sup> 2026:

N/A yet, but expected for next quarter:

[1] Aniya Edwards, Raikhan Tokpatayeva, Jan Olek, Mirian Velay-Lizancos, "Advanced curing methods and nanomodification for accelerated production of durable precast elements: Opportunities and challenges." Presentation, Trans-IPIC Workshop, Rosemont 2026.

### 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.

N/A

**Appendix 1:** Research Activities, leadership, and awards (cumulative, since the start of the project) [The project started in January 2026].

- A. Number of presentations at academic and industry conferences and workshops of UTC findings
  - o No. = 0
- B. Number of peer-reviewed publications submitted based on outcomes of UTC funded projects
  - o No. = 1
- C. Number of peer-reviewed journal articles published by faculty.
  - o No. = 1
- D. Number of peer-reviewed conference papers published by faculty.
  - o No. = 0
- E. Number of TRANS-IPIC sponsored thesis or dissertations at the MS and PhD levels.
  - o No. MS thesis = 1
  - o No. PhD dissertations = 2 (in progress)
    - No. citations of each of the above = N/A (the dissertation is not public yet)
- F. Number of research tools (lab equipment, models, software, test processes, etc.) developed as part of TRANS-IPIC sponsored research
  - o N/A
- G. Number of transportation-related professional and service organization committees that TRANS-IPIC faculty researchers participate in or lead.
  - o Professional societies
    - No. participated in = 5
    - No. lead = 0
  - o Advisory committees (No. participated in & No. led)
    - No. participated in =3
    - No. lead = 0
  - o Conference Organizing Committees (No. participated in & No. led)
    - No. participated in =0
    - No. lead =0
  - o Editorial board of journals (No. participated in & No. led)
    - No. participated in =3
    - No. lead =0
  - o TRB committees (No. participated in & No. led)
    - No. participated in =1
    - No. lead =0
- H. Number of relevant awards received during the grant year
  - o No. awards received = 1
- I. Number of transportation related classes developed or modified as a result of TRANS-IPIC funding.
  - o No. Undergraduate = 0
  - o No. Graduate = 0
- J. Number of internships and full-time positions secured in the industry and government during the grant year.
  - o No. of internships = 0
  - o No. of full-time positions = 1

## **References:**

- [1] V.M. Malhotra, N.J. Carino, Handbook on nondestructive testing of concrete, CRC Press, 2004.
- [2] ASTM Committee C09.64, ASTM C1074-11 Standard Practice for Estimating Concrete Strength by the Maturity Method, in: Annual Book of ASTM Standards Volume 04.02, 2015: p. 10.  
<https://doi.org/10.1520/C1074-11>.
- [3] M. Velay-Lizancos, I. Martinez-Lage, P. Vazquez-Burgo, The effect of recycled aggregates on the accuracy of the maturity method on vibrated and self-compacting concretes, Archives of Civil and Mechanical Engineering 19 (2019) 311–321. <https://doi.org/10.1016/J.ACME.2018.11.004>.
- [4] A. Luke, W. Konon, S. Punurai. Maturity method in prestressed concrete applications, FHWA NJ 2004-022; New Jersey Department of Transportation Bureau of Research and Technology and U.S. Department of Transportation Federal Highway Administration, 2004.
- [5] ASTM C33 – 24: Standard Specification for Concrete Aggregates, ASTM International Journal (2024).
- [6] ASTM C127 - 25: Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate, ASTM International Journal (2025).
- [7] ASTM C136 - 25: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, ASTM International Journal (2025).
- [8] ASTM C33 – 24: Standard Specification for Concrete Aggregates, ASTM International Journal (2025).
- [9] ASTM C604 - 18: Standard Test Method for True Specific Gravity of Refractory Materials by Gas Comparison Pycnometer, ASTM International Journal (2023).