

Exhibit D

Research Project Submission Template

Recipient/Grant (Contract) Number: University of Illinois Urbana-Champaign / Purdue University / Grant No.: 69A 355 234 8333

New simplified and Adaptive Method for Quality Control of Precast elements through Advanced NDT Evaluation

Center Name: Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

Research Priority: Improving the Durability and Extending the Life of Transportation Infrastructure

Principal Investigator(s): Mirian Velay-Lizancos (PI), Jan Olek (Co-PI)

Project Partners: N/A

Research Project Funding: \$108,500 (\$70,000 Federal and \$38,500 Non-Federal)

Project Start and End Date: 01/16/2026 – 01/15/2027

Project Description:

Premature formwork removal or load transfer can cause damage to the precast elements and, therefore, reduce their durability, whereas delaying these operations reduces production volume. Thus, optimizing the timing for formwork removal and load transfer is critical to produce durable precast elements efficiently. This timing highly depends on the evolution of the compressive strength. Current maturity methods estimate strength using temperature data from single points; however, the homogeneity of concrete properties throughout the elements is not tested, and this approach requires internal sensors that are not recovered after production. This project aims to develop new tools for timing early production operations (such as removal from formwork and load transferring) for every single produced element in an inexpensive and scalable manner. Timing the optimal age for these operations is crucial for producing more durable precast transportation infrastructure elements, as it avoids damage from premature operations while maintaining maximum production volume.

US DOT Priorities:

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, which relies on **internal temperature measurements at single points**, can estimate the evolution of compressive strength from limited data. 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.**

Outputs:

For year 1 of this project, the anticipated results are:

- A model capable of estimating the temperature history (and therefore the maturity and early-age compressive strength) at representative points throughout any precast concrete element based on thermal images, mix design, and ambient temperature as inputs, without the need for internal sensors.
- A new method and associated user-friendly tool to determine the optimal timing of early-age production operations (such as formwork removal and load transfer) for each precast element. This approach is inexpensive, scalable, and helps prevent premature operations that could compromise durability (see Section 7 for related details).

Outcomes/Impacts:

For year 1 (scope of this proposal): (i) A new, simplified, and adaptive method for quality control of precast elements through non-destructive testing (NDT) evaluation will be proposed based on the temperature history at each point of the element, (ii) An user-friendly tool to precisely determine the optimal timing of early-age production operations (such as formwork removal and load transfer) for each precast element in an inexpensive, scalable way, without relying on internal sensors, (iii) A step-by-step manual or protocol enabling precasters to calibrate the method for their own mixtures if their mix design differs from the design of mixes the initially calibrated model.

Final Research Report: URL link to the project's final report will be provided upon the completion of the project.