Exhibit D

Research Project Submission Template

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

3D Printed Smart Permanent Concrete Formwork for Precast Structural Component-Structural Performance – Phase 2: Large Scale Testing

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

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

Principal Investigator(s): Yen-Fang Su (PI), Ayman Okeil (Co-PI)

Project Partners: N/A

Research Project Funding: $105,001 ($70,000 Federal and $35,001 Non-Federal)

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

Project Description:

In Phase 1, the research team demonstrated promising results using additive manufacturing techniques combined with novel self-sensing materials to develop smart precast concrete permanent formwork at the small scale. Comprehensive work has been conducted, ranging from materials characterization, evaluation of 3D printed samples, to development of preliminary Multiphysics models. While this technology shows potential to transform U.S. transportation infrastructure, its small-scale demonstration requires large-scale validation for real-world application. Thus, **this research proposal aims to expand Phase 1 outcomes to large-scale precast structural columns**. The large-scale self-sensing formwork for column specimens will be 3D printed using a robotic arm-based system, and steel reinforcement will be added. These specimens will be tested under axial compression, with deformation fields monitored using digital image correlation. The results will evaluate the structural and self-sensing behavior of the columns. The project's outcome will lay the foundation for a new generation of intelligent, resilient infrastructure.

US DOT Priorities:

The United States faces a critical challenge with aging and deteriorating transportation infrastructure, as 43% of roads and highways and tens of thousands of bridges are in poor or mediocre condition1. Structural Health Monitoring (SHM) has become a crucial aspect of maintaining and ensuring the integrity of concrete infrastructure, yet current technologies face limitations in durability, material compatibility, power requirements, and cost. Overcoming these barriers and incorporating essential functionalities will be key to improving the longevity and resilience of future precast concrete (PC) transportation systems. Self-sensing cementitious composites (SSCC)2 offer a promising alternative, and their integration with additive manufacturing (AM) enables smart formwork systems that both shape concrete and embed sensing capabilities. Our previous research demonstrated this concept at a small scale with promising results. Building on these promising results, the **next step is to evaluate the structural performance of large-scale 3D printed smart formwork to validate its feasibility and bridge the gap toward real-world applications**. These large-scale tests are pivotal in validating and accelerating the deployment of groundbreaking AM techniques combined with SSCCs, laying the foundation for a new generation of intelligent, high-performance precast concrete systems in transportation infrastructure. This project will directly support the mission of TRANS-IPIC to lead innovation in precast concrete technology and USDOT's strategic goals of Transformation and Safety, paving the way for a smarter, more resilient, and longer-lasting transportation infrastructure system.

Outputs:

Aligned with the goals of TRANS-IPIC, this project is expected to deliver impactful advancements in both construction technology and smart infrastructure materials. The anticipated outcomes include: **(a) Innovative Large-Scale Additive Manufacturing Techniques:** This research will demonstrate the feasibility and advantages of using AM for fabricating large-scale smart precast concrete columns. The project will contribute to the development of scalable, automated construction methods that reduce labor, improve precision, and enable complex geometries not achievable through conventional formwork. **(b) Validated Self-Sensing Concrete Systems for Structural Health Monitoring:** Through experimental testing, the project aims to validate the performance of self-sensing cementitious composites in 3D printed columns. These materials will enable real-time monitoring of structural behavior, including strain, cracking, and damage progression, offering a transformative approach to long-term infrastructure maintenance and safety. **(c) Enhanced Understanding of Local and Global Structural Behavior in 3D Printed Elements:** The project will generate valuable insights into the unique local behaviors of 3D printed concrete and how these influence global structural performance under cyclic loading. **(d) Design Guidelines and Performance Data for Transportation Infrastructure Applications:** The results will inform the development of design recommendations for integrating 3D printed SSCC columns into transportation infrastructure. This includes performance benchmarks under various loading conditions, reinforcement strategies, and formwork configurations.

Outcomes/Impacts:

(i) Low-Cost Real-time Infrastructure Health Monitoring: Integrating SSCC into large-scale 3D-printed concrete columns will provide a cost-effective and scalable solution for continuous monitoring of strain, cracking, and degradation, enabling proactive maintenance and improved safety for bridges, piers, and other critical assets. **(ii) Guidelines for Additive Manufacturing in Structural Applications:** The project will generate validated data to inform design and construction guidelines for 3D-printed concrete, including reinforcement strategies, formwork design, and performance thresholds under cyclic loading, supporting the transition from lab-scale to field deployment. **(iii) Policy & Regulation Recommendations:** Findings will support new policies and standards that advance the use of intelligent materials and AM in transportation infrastructure, aligning with durability, sustainability, and lifecycle goals. **(iv) Public & Private Sector Collaboration:** Demonstrating the feasibility of 3D-printed smart columns will foster collaboration among public agencies (DOTs, FHWA) and private-sector stakeholders, accelerating commercialization and field adoption of advanced construction technologies.

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