Exhibit D

Research Project Submission Template

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

Digital Twins for Evaluation of Precast Concrete Bridge Girders

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

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

Principal Investigator(s): Pinar Okumus (PI), Negar Elhami Khorasani (Co-PI)

Project Partners: N/A

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

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

Project Description:

Bridge owners need smart tools to manage their aging inventories within budget and safety constraints. This project will develop a digital twin framework tailored for prestressed concrete bridges, enabling continuous condition assessment through integrated inspection, evaluation, and analysis. A digital twin is a dynamic virtual representation of a bridge that evolves with time by incorporating data from design, construction, inspection, monitoring, evaluation, and structural analysis. The proposed digital twin will incorporate a bridge evaluation tool that estimates stiffness changes in girders during service life and finite element models that can determine the impact of stiffness change on load distribution. This will capture beneficial load re-distribution effects stemming from stiffness changes to eliminate unduly conservative load ratings and bridge girder health assessments. This work will lay the foundation for data-informed infrastructure management, demonstrating how digital twins enhanced with machine learning can transform bridge health monitoring from reactive to proactive.

US DOT Priorities:

Departments of Transportation (DOT) are required to periodically evaluate and load rate bridges in their inventories to ensure public safety. For majority of bridges, load ratings are updated after every inspection (typically 2 years) if the condition of the bridge changes and are performed using less detailed computer-generated evaluations for resource efficiency. Load ratings that utilize more detailed analyses are performed at even longer intervals when bridges undergo significant changes in terms of loading or capacity. Since neither the simplified nor detailed load ratings provide continuous information on bridge health, these evaluations can miss safety issues between inspections. In addition, lack of detail in simplified analyses may trade assessment efficiency for added conservatism that may lead to unnecessary bridge closures or load restrictions affecting the economy. Digital twins (DT) can address these issues by providing continuously updated and detailed information on bridge health for timely and accurate decision making on intervening actions.

The goal of this project is to create a DT framework, tailored for prestressed concrete bridges, that integrates bridge inspection, evaluation, and analysis, focusing on the effects of cracking on stiffness, capacity, and load redistribution. This goal will be accomplished by incorporating data from crack measurements, machine learning algorithms that translate crack measurements to stiffness, and finite element analyses (FEA) that map stiffness changes to changes in demand and capacity into a DT workflow. The finite element model components updated with output from machine learning algorithms will allow capturing of beneficial load re-distribution between prestressed girders due to changing girder stiffness in service. Being able to realistically predict demand will prevent unnecessary bridge closures.

While DTs are currently being incorporated into load rating programs (Dahlberg et al. 2024), existing DTs serve general purposes and do not focus on stiffness-based evaluation for prestressed concrete bridges. This information is critical for prestressed concrete bridges that may exhibit signs of distress due to environmental stressors, overloading, or aging. By providing a modern and smart tool to bridge owners for bridge evaluation, this project will contribute to effective bridge maintenance and extended service life as prioritized by TRANS-IPIC and US DOT.

Outputs: This project will deliver a DT framework for prestressed concrete bridges that integrates crack-based stiffness evaluation, machine learning algorithms, system- and member-level analyses, and visualization through a bridge information model. The research will generate workflows for translating inspection and monitoring data into girder stiffness, quantifying load redistribution effects, and realistically assessing girder capacity under distress or deterioration. These results will provide DOTs with new methods to evaluate stiffness degradation over time, capture beneficial load redistribution effects, and avoid conservative assumptions that shorten service life. In doing so, the project directly supports TRAN-SIPIC's strategic goal of improving durability and extending the life of transportation infrastructure by enabling proactive bridge management.

Outcomes/Impacts:

The expected implementable outcome is a DT framework for bridge evaluation that state DOTs can adopt to improve prestressed concrete bridge assessments and load rating processes. This tool can provide continuously or regularly updated demand-capacity comparisons that reduce unnecessary closures, extend service life, and enhance public safety. Technology transfer will be achieved through collaboration with NYSDOT in selecting a demonstration bridge, development of a Matlab-based workflow, preparation of a user documentation, and dissemination of results through reports, conferences, and outreach to practitioners. Together, these efforts will ensure that the research outcomes translate into a practical technology that can be adopted and deployed by bridge engineers and owners.

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