Exhibit D

Research Project Submission Template

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

Advanced concretes for girders with unbonded post-tensioning strands

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

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

Principal Investigator(s): [Ravi Ranade (PI), Pinar Okumus (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:

Compared to bonded post-tensioning (PT), unbonded PT offers distinct advantages, including replaceability and ease of maintenance of strands, and it enables the construction of spliced girders and segmental bridges. However, the absence of strand-concrete bond limits the structural capacity of girders with unbonded PT. This research proposes the use of Engineered Cementitious Composite (ECC), a ductile fiber-reinforced concrete, to improve the flexural performance of unbonded PT girders. The project aims to develop an ECC mix tailored for prestressed concrete applications, experimentally validate ECC's structural benefits for girders with unbonded PT, generate detailed numerical models of the girder to expand experimental investigation, and establish design methodologies that incorporate ECC's tensile properties in prestressed concrete girder design. Through a combination of material development, beam testing, finite element modeling, and parametric studies, the research seeks to advance the use of ECC in long-span bridge girders and contribute to more efficient and durable infrastructure systems.

US DOT Priorities:

Unbonded post-tensioning (PT) plays a critical role in segmental construction and spliced girders, making it particularly valuable for long-span bridges. Since the strands are external or housed in ducts and not bonded to the surrounding concrete with grout, they remain accessible throughout the bridge's service life, allowing for inspection, evaluation, and even replacement if necessary. However, the absence of bond between the strands and the concrete introduces structural inefficiency. An unbonded posttensioned girder's capacity is typically governed by concrete crushing or, when bonded reinforcement is present, by fracture of that reinforcement, rather than by yielding of the PT strands. As a result, the capacity of an unbonded post-tensioned girder is significantly smaller than its bonded counterpart. Thus, unbonded PT trades off capacity for serviceability, durability, and construction ease.

In this project, we propose the use of a ductile fiber-reinforced concrete (FRC), instead of conventional concrete (CC), to increase the girder's strength and displacement capacity, while retaining the benefits of unbonded PT. A ductile FRC, due to its distributed microcracking behavior, is more compatible with the strand's tensile deformation, and numerical analysis shows that it could substantially improve the structural behavior of an unbonded PT girder and bring it closer to that of a bonded PT girder. This research, therefore, broadens the use of unbonded PT in durable and longer-lasting bridges and directly addresses the USDOT's and TRANS-IPIC's research priority of improving the durability and extending the life of transportation infrastructure.

Outputs:

The proposed research will investigate an innovative application of an advanced concrete material (ECC)

in transportation infrastructure. Specifically, the proposed research will generate the following deliverables:

- A new ECC mixture composition with compressive strength between 8-12 ksi and tensile strain capacity of at least 1% suitable for precast concrete bridge applications. In addition to improving flexural strength, ECC is known to provide superior shear strength and durability. Therefore, the ECC developed in this project could be used more broadly in prestressed concrete members, wherever superior mechanical performance and durability are required compared to CC.
- Vital empirical data for the use of durable advanced materials in structural elements that are crucial for the longevity of our transportation infrastructure.
- A detailed numerical model for simulating the behavior of a girder with unbonded PT. This model can be used to investigate the girder behavior more deeply without costly experiments.
- Recommendations for incorporating the unique material properties of ECC in the design of precast concrete elements with unbonded strands. This could broaden the use of ECC and other novel materials in transportation infrastructure.

Outcomes/Impacts:

The proposed research addresses a high-priority need for various state DOTs, as girders with unbonded PT are necessary for longer span segmental and spliced construction. Unbonded PT aids DOTs in monitoring strand stresses or replacing strands over service life. However, girders with unbonded PT have much smaller moment capacities compared to girders with bonded strands. To compensate for lower strength, designers use additional strands, bonded reinforcement, or larger girders. These extra measures diminish the competitiveness of prestressed concrete for longer spans. This research aims to promote the use of unbonded PT by addressing challenges related to flexural strength. Designs with ECC will lead to higher strengths as well as material savings (i.e., fewer strands, smaller amount of bonded reinforcement, or shallower sections). The outcome will be test data, numerical models, and design recommendations that demonstrate the feasibility of using ECC for precast concrete members, which encourage the use of materials that can extend the service life of precast concrete bridges.

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