Exhibit D

Research Project Submission Template

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

Automated Construction of Concrete Bridge Components With Shape Memory Bars

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

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

Principal Investigator(s): Bassem Andrawes

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:

This project aims to address the challenge of incorporating prestressing in the automated construction of bridge components without using hydraulic jacking or concrete forms. The approach will utilize existing large 3D concrete printers currently employed in the construction of 3D-Printed Concrete (3DPC) buildings, ensuring that the transportation industry can easily adopt the methods demonstrated. As prestressed concrete elements are commonly used in bridges, this project will introduce an innovative technique for internally prestressing large 3DPC components with complex shapes using rebars made from a novel class of metallic material known as shape memory alloy (SMA). This new reinforcement can be activated (prestressed) through heating. The research will explore induction heating as a potential industrial method for prestressing the SMA bars without the need for direct contact. Overall, this research aims to provide the transportation industry with an efficient and practical method for prestressing structural 3DPC components used in transportation infrastructure.

US DOT Priorities:

The decline of transportation infrastructure in the U.S. is a persistent issue that impacts various precast concrete (PC) structures nationwide. Specifically, 6.8% of bridges are classified as being in poor condition, which poses a significant risk to public safety if not addressed. The loss of bridges could severely disrupt the transportation of goods and negatively affect local economies. Therefore, research into efficient construction methods for new concrete structures is essential to ensure the rapid and large-scale replacement of deteriorating bridge components. Traditional construction methods tend to be slow, largely due to their reliance on excessive labor and equipment. As a result, there is an increasing interest in automation as a way to expedite the construction process and improve overall efficiency.

Automated additive manufacturing, commonly known as 3D printing, is emerging as a transformative technology that could revolutionize the future of infrastructure in the U.S. The increasing interest in the use of 3D-printed concrete (3DPC) addresses both efficiency concerns at a large scale and sustainability issues in traditional concrete production. The automation involved in this construction method allows for the mass production of concrete more quickly and with fewer workers. Additionally, this approach enables more innovative designs, as 3D printers can create complex shapes with voids that conventional formwork would struggle to achieve. This capability is essential for producing geometrically optimized structures, thereby minimizing the amount of concrete needed for creating or repairing future transportation infrastructure. However, one of the main challenges faced by 3DPC is the application of internal prestressing using conventional methods, such as pretensioning or post-tensioning. The concept of constructing structures in layers, as done with 3DPC, complicates the application of these traditional prestressing techniques, as it eliminates the need for conventional concrete forms.

This project aims to tackle the issue of internal prestressing in large-scale 3DPC without relying on hydraulic mechanical jacking or concrete forms. The approach will leverage existing large 3DPC printers currently used for constructing 3DPC buildings, ensuring that the US transportation industry can readily adopt the demonstrated methods. Many bridges require prestressed concrete elements, and this project will experimentally validate the potential of prestressed 3DPC. There is currently a lack of research in this area, so we will introduce a novel approach by embedding shape memory alloy (SMA) reinforcement and thermally activating it for prestressing 3DPC. The data collected from these experimental tests will be used to develop efficient and safe designs utilizing finite element method (FEM) software.

Outputs:

The anticipated results of this project involve conducting experiments to validate the use of 3DPC in manufacturing geometrically optimized bridge girders, aimed at enhancing transportation infrastructure efficiency without compromising safety. The process will closely follow realistic construction procedures, addressing the feasibility of utilizing commercially available 3D printers. Additionally, it will explore and mitigate concerns related to shipping 3DPC elements. The project will experimentally explore, for the first time, the use of Shape Memory Alloys (SMA) to produce prestressed 3DPC on a large scale. By comparing specimens that include SMA with those that do not, this project aims to show that prestressed 3DPC enhances both structural performance and construction efficiency.

Outcomes/Impacts:

This research will provide the transportation industry with the first large-scale experimental data on the feasibility of using 3D concrete printing technology to create efficient PC transportation structural components with internal reinforcement and prestressing. Several 3DPC U.S. companies already possess the capabilities to print PC elements for bridges and can use the results of this project as inspiration. The research team will work with LX Construction, one of the leading 3D concrete printing companies in the U.S., which will help in facilitating the transfer of knowledge generated through this project to the industry.

The data collected from this project will help optimize girder designs with various span-to-depth ratios. Implementing these girder designs will facilitate greater automation in the construction of transportation infrastructure. Additionally, the project will showcase the use of a new class of "smart" reinforcement, namely, Shape Memory Alloys (SMAs), as an emerging technology for introducing internal prestressing of 3DPC structures with complex shapes. This method is not limited to the test specimens; it can be applied to any 3DPC structure, further reducing the consumption of concrete and steel. This, in turn, will enhance the efficiency of future transportation infrastructure projects. Moreover, the process of printing PC components and shipping them to construction sites complements the Accelerated Bridge Construction (ABC) approach, significantly shortening the on-site construction time.

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