# Exhibit D

**Research Project Requirement Template**

**Research project name: Desing, Manufacturing, and Characterization of Fiber Reinforced Shape Memory Polymer Rebars**

**Recipient/Grant (Contract) Number:** University of Illinois Urbana-Champaign / Louisiana State University / Grant Number 69A3552348333

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

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

**Principal Investigator(s):** Guoqiang Li

**Project Partners:** None

**Research Project Funding:** $145,188.00 ($96,787.00 Federal and $48,400.00 Non-Federal)

**Project Start and End Date:** 09/01/2023 - 08/31/2024

**Project Description:**

The objective of this one-year project is to design, manufacture, and program fiber reinforced shape memory polymer (FRSMP) rebars and test their shape memory effect. Unidirectional glass fiber tow and ultraviolet (UV) curing shape memory polymer with high glass transition temperature will be selected to fabricate the FRSMP rebars. Two types of FRSMP rebars will be manufactured and tested, one is straight rebar, which will be subjected to tension programming, and the other is curved rebar, which will be programmed by bending. The rebar programming can also be coupled with pre-stressing or post-stressing in pre-cast concrete (PC) construction, so that prior programming can be coupled with construction. It is expected, the FRSMP rebar, in addition to its advantages similar to conventional fiber reinforced polymer rebar such as high specific strength/stiffness and corrosion resistance, will help close cracks in the tension zone of PC beams and provide negative bending moment, extending the service life of PC beams.

**US DOT Priorities:**

The proposed project “Desing, Manufacturing, and Characterization of Fiber Reinforced Shape Memory Polymer Rebars” directly support the research priorities of DOT. One of DOT’s research priorities is on “Advanced Materials and Structures: Develop tools, technologies, and Management guidance to improve infrastructure durability, longevity, and sustainability through innovative materials and structures.” The fiber reinforced shape memory polymer (FRSMP) is a smart material and has potential to close cracks in concrete, extending the service life, which echoes the research priorities of DOT. This project also supports the RD&T strategic goals. One of the RD&T strategic goals is for “improving the durability and extending the life of transportation infrastructure”. Clearly, the corrosion resistance, together with its crack closing ability, makes FRSMP rebar reinforced precast concrete (PC) beams or columns have longer service life. In addition, this project supports the UTC goals. In response to the call by DOT, a consortium of five universities proposed “Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)” through advancing the technologies used in precast concrete (PC) construction. The FRSMP rebars to be developed in this project can be directly used in PC beams and columns by fully or partially replacing conventional steel rebars with FRSMP rebars. The smart FRSMP rebars not only overcome the corrosion problem facing steel rebars, but they also have the ability to serve as both reinforcement during everyday service, and a ‘suture’ to close cracks and reduce deflection on-demand once the smart FRSMP rebars are triggered for constrained shape recovery, enhancing the service life of the PC beams or columns.

Fiber reinforced polymer (FRP) has been widely used in repair, retrofitting, reinforcement, and reconstruction of reinforced concrete (RC) structures due to its high specific strength and stiffness, and corrosion resistance. In this proposed project, we plan to replace the conventional polymer matrix by shape memory polymer matrix. Besides all the advantages with FRP, fiber reinforced shape memory polymer (FRSMP) possesses additional advantages, particularly its ability to serve as ‘suture’ to close cracks in concrete through constrained shape recovery when the tension programmed FRSMP is triggered for shape recovery. This serves to further enhance the service life of transportation infrastructure such as FRSMP rebar reinforced concrete beams or columns. The PI of this project has a track-record to design and synthesize shape memory polymers with high glass transition temperature and high recovery stress, as well as track record in using FRP in concrete beams and columns. It is expected that this project, if successful, will open new opportunities for the application of smart polymers in precast concrete applications, and change the paradigm of using FRP in infrastructure.

**Outputs:**

The anticipated results in this one-year project include (1) Shape memory polymer (SMP) matrix with high recovery stress selected; (2) The pultrusion procedure to produce lab-scale FRSMP rebar established; and (3) Lab-scale FRSMP rebars available for evaluation in PC beams.

While the objective for the first year is to design, manufacture, and test FRSMP rebars, which can all be conducted in the PI’s lab, it is expected that the project provides opportunity for establishing partnerships with other institutions and DOT. For example, to test the performance of the FRSMP rebars in PC concrete beams, we may collaborate with the UIUC team because of their expertise and facilities on PC beams. We may also collaborate with Louisiana Transportation Research Center (LTRC) to test our FRSMP rebar reinforced PC beams using their facilities. With time goes by, and with the advancement of this research, more partnerships will be established with other institutions, and particularly State DOTs for technology transfer.

**Outcomes/Impacts:**

Because rebars are an essential component in PC construction, which is the focus of the TRANS-IPIC, the FRSMP rebars to be developed in this project will provide a feasible alternative for PC construction. It is expected that FRSMP rebars will be directly used in PC beams due to its capability to close cracks in the tension zone through constrained shape recovery of the tension programmed FRSMP rebars. Of course, the involvement of one full-time Ph.D. student and one half-time postdoc also contributes to human resource development.

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