# Exhibit D

**Research Project Requirement Template**

**Research project name: Unveiling synergistic effects of Nano-modification and CO2 curing on the durability and carbon footprint of precast elements.**

**Recipient/Grant (Contract) Number:** University of Illinois Urbana-Champaign / Purdue 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):** Mirian Velay-Lizancos (PI), Jan Olek (Co-PI), Raikhan Tokpatayeva (Co-PI)

**Project Partners:** None

**Research Project Funding:** $104,224.00 ($64,092.00 Federal and $40,132.00 Non-Federal)

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

**Project Description:**

CO2 curing of concrete, a process well-suited for precast operations, increases the strength and reduces the porosity while lowering carbon footprint in two ways: (i) directly through carbonation and (ii) by reducing the amount of cement required to achieve target performance. The addition of nano-TiO2 to cementitious composites was also shown to reduce porosity and increase the strength of cementitious composites. Furthermore, our previous studies showed that the combination of both nano-TiO2 addition and CO2 curing can increase the CO2 uptake and further reduce the porosity. However, the combined effect of both CO2 curing and nano-TiO2 addition on the transport properties was not studied, and nano-TiO2 is expensive; thus, this project aims to elucidate the combined effects of CO2 curing and nano-modification with respect to porosity, transport properties, and strength. This will enable the production of more durable, sustainable, and economical precast elements.

**US DOT Priorities:**

The project supports optimizing the application of new technologies and novel materials in precast concrete elements, which is crucial in advancing the precast industry toward a greener future. Enhancing durability and reducing the carbon footprint of precast concrete elements are two of the main paths toward this advancement.

According to the RD&T Strategic Plan, two primary purposes of U.S. DOT transportation research and development are (i) Improving the durability and extending the life of transportation infrastructure and (ii) Preserving the environment. Thus, this project fully aligns with the US DOT priorities and RD&T strategic goals.

**Outputs:**

The overall objective of the first phase [1st year] of this project is to improve the quality of precast elements while reducing carbon footprint through assessing and understanding the combined effects of CO2 curing (a process well-suited for precast production) and utilization of inexpensive nanomaterials (Nano-silica and Nano-carbon black) in terms of: (i) pore structure refinement, (ii) transport properties, (iii) strength, and (iv) microstructure. This experimental program will contribute to understanding the interaction between two approaches that can help reduce the carbon footprint of precast elements. The results of this 1st phase will guide us in optimizing combined use of these technologies, thereby harnessing their full potential to enhance the quality, durability, and sustainability of precast concrete elements while concurrently diminishing costs and minimizing the carbon footprint. The general aim of subsequent phases of this project will be to: (i) assess the effect of humidity during the carbonation process on the impact of nano-modification on the properties mentioned above and on the concrete's corrosion protection, (ii) establish a collaboration with the precast plant to investigate and to assess the integration of the CO2 injection process into their existing curing beds/rooms and to explore various techniques for dispersing nanomaterials to identify the most suitable method for application within precast plant settings, (iii) compare the lab results with precast plant results to better understand potential opportunities and challenges related to implementation of these combined approaches, and (iv) conduct economic and life cycle assessments of different approaches and their combination for comparative evaluation of the effects of applying CO2 curing for precast elements with nanomodified concrete vs. plain concretes.

The findings from this study, derived from extensive testing that evaluates porosity, transport properties, and strength characteristics, will lead to comprehensive understanding of the synergistic effects of CO2 curing and nano-modification on concrete properties. We expect that different nanoparticles will modify the hydration kinetics and morphology of the hydration products, subsequently influencing the efficiency of the CO2 curing process for precast elements. We firmly believe that unraveling this impact will prove pivotal in optimizing the simultaneous utilization of nano-modification and CO2 curing to create exceptional precast elements, all while enhancing cost-effectiveness by streamlining the process and mitigating unforeseen complications.

**Outcomes/Impacts:**

Phase I of the study is projected to yield initial guidelines, marking the first steps toward optimizing the concurrent application of nanomaterials and CO2 curing techniques, thereby enhancing the sustainability and durability of precast elements. The knowledge acquired through this project will serve as the cornerstone for formulating industry-specific guidelines and best practices. Coupled with the findings from subsequent project phases, these insights will enable the seamless integration of CO2 curing and nano-modification, facilitating the production of sustainable, high-quality precast concrete elements characterized by reduced carbon emissions and enhanced durability.

Upon the completion of all phases of the project we expect to work on the implementation of the previously described combined approaches within precast plants. This achievement will be complemented by the quantification of the reduction in the carbon footprint resulting from the proposed process. Furthermore, there is the potential for development of patents related to materials and innovative curing systems, driven by the project's outcomes and innovations.

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