Exhibit D

Research Project Requirement Template

Internal Curing of 3D Printed Engineering Cementitious Composites: Paving the Way for Sustainable and Durable Infrastructure in the Southwest Climates

Recipient/Grant (Contract) Number: 69A3552348306 (CY1-UNM-02)

Center Name: Southern Plains Transportation Center (SPTC)

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

Principal Investigator(s): Maryam Hojati, University of New Mexico

Project Partners: University of New Mexico

Research Project Funding: $80,000 (Federal) and $80,000 (Matching)

Proposed Start and End Date: 10/01/2023 to 9/30/2024

Project Description: Additive manufacturing (AM), or 3D printing, is considered the next industrial revolution, allowing for the flexible production of industrial products. This emerging technology can aid engineers and architects in creating complex representational models economically and quickly during the design phase of an infrastructure project. When it comes to selecting materials for 3D printing of infrastructures, Engineered Cementitious Composites (ECC) have several potential benefits. ECC is a novel class of high-performance fiber-reinforced material with demonstrated exceptional properties. This study aims to investigate the feasibility of using internal curing of ECC materials for 3D printing, on a small scale. The goal is to construct durable infrastructures by adapting novel 3D printing technology for the future of transportation construction. A complementary goal is to examine the internal curing potential of the ECC materials used for 3D printing. The specific objectives of this research are: (1) Advance the application of innovative manufacturing techniques, 3D printing in this case, in transportation infrastructure projects in low-humidity regions like New Mexico; (2) Modify ECC mixes developed by the PI to enhance their mechanical and durability performance by incorporating internal curing agents, specifically lightweight aggregates. In pursuit of sustainability, a 50% weight substitution of cement with suitable alternatives (fly ash and slag) will be pursued; (3) Investigate the effect of different types (local New Mexico pumice and expanded glass) and contents of internal curing agents (across three distinct substitution levels for normal weight aggregates, comprising 25%, 50%, and 100% replacement) on the performance of ECC for transportation infrastructure; (4) Ensure printable ECC mixes performance by thoroughly examining fresh properties including water content, extrudability, and buildability for 3D printing by 3D printing a zigzag pattern and wall; (5) Assess the feasibility of designing an ECC mix suitable for 3D printing infrastructure in arid conditions. This will be achieved by evaluating mechanical properties, including compressive, flexural, and tensile strength, across three distinct curing regimes. The goal is to establish an ECC composition demonstrating robust mechanical performance and durability within dry environments, enhancing its suitability for 3D-printed infrastructure applications; (6) Explore the sustainability and economic viability of the 3D-printing process and the ECC used for transportation infrastructure projects.

US DOT Priorities: The objectives of this study align well with the vision of the Southern Plains Transportation Center (SPTC) to address transportation infrastructure durability challenges in Region 6 with innovative and cost-effective solutions. The utilization of ECC holds the promising potential to

reduce CO_2 emissions and contribute to USDOT's strategic goal of Climate and Sustainability. ECC's unique properties, such as enhanced durability and crack resistance, can lead to longer-lasting structures with reduced need for frequent repairs and replacements. This longevity directly translates to lower material consumption and associated emissions from production. Moreover, ECC often incorporates supplementary cementitious materials like fly ash and slag, which are byproducts of industrial processes and can replace a portion of cement in the mixture. This substitution improves material performance and reduces the carbon footprint of the concrete. ECC's high ductility allows for thinner sections and reduced material volumes, further minimizing CO_2 emissions related to production and transportation. This study aims to investigate whether internal curing can enhance the curing process of 3D-printed ECC components in arid environments, particularly in regions like the southwest United States, where future climate change may lead to prolonged dry conditions. Additionally, this project seeks to empower historically underserved communities at the University of New Mexico (UNM) as a minority-serving institution. By producing highly trained transportation professionals, this project envisions assisting diverse groups leading efforts in the public and private sectors.

Outputs: Several valuable outputs are expected from this project. These include the exploration and potential development of internal curing methods for optimizing 3D printable cementitious mixes tailored to infrastructure construction. Through this investigation, the study anticipates yielding experimental findings, visual documentation in the form of images, and data files. These outputs will contribute to a better understanding of enhancing material properties through internal curing techniques. The findings will be documented in the final report and published in journal and conference papers, thus advancing knowledge in the field. Furthermore, this project is expected to advance the field of transportation infrastructure through three key initiatives: technology transfer, focusing on disseminating technological findings for practical use and environmental responsibility; education and talent development, including support for a graduate student; integration of educational materials into university courses and participation in national conferences; and community engagement, targeting community colleges and collaboration with research institutes and companies to promote innovation and sustainability in the transportation sector.

Outcomes/Impacts: The outcomes of this research project could bring changes and improvements to the transportation infrastructure through the use of innovative materials (ECC) and 3D printing of infrastructure components. 3D printing is expected to revolutionize the construction industry, reduce costs, and increase infrastructure life. The outcomes of this project are expected to advance transportation infrastructure in low-humid regions. Finally, this project will advance the DEIA goals of the SPTC and the USDOT.

Final Research Report: