Automated Curing and Strength Monitoring of Sensor-Embedded 3D Printed Transportation Infrastructure

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22CLSU12

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Louisiana State University

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Tran-SET

Louisiana State University

Total Project Cost:

$ 150,000

Automated curing of 3D printed transportation infrastructure

The main objective of this project is to address a major existing challenge with respect to the curing conditions and mechanical strength development of 3D printed infrastructure. Integrated curing techniques are proposed, and the impact of these techniques on the mechanical strength development of early-age 3D printed specimens will be studied. Embedded sensors in the 3D printed specimens will be used to monitor the electrical resistivity and temperature variations over time. The sensory data will then be used to quantify the efficiency of different curing methods and to estimate the mechanical strength at different ages and under different curing conditions. The proposed research addresses a major practical challenge for widespread adoption of construction 3D printing technology for automated transportation infrastructure construction.

Problem Statement

The anticipated reduction in the construction time and cost by the C3DP technology is associated with the fact that it minimizes the need for skilled labor, and also does not involve use of formwork. Absence of any formwork, while beneficial from the economical and logistics aspects, also imposes several technical concerns and challenges. In conventional construction, concrete is cast into pre-installed formwork which stays in place for several days. During this period, the formwork protects the moisture inside the fresh concrete, and significantly reduces the water evaporation rate. In C3DP, however, the absence of formwork leads to excessive water evaporation which negatively impacts the Portland cement hydration process. It is widely known that the lack of proper curing conditions for concrete results in a significantly lower mechanical strength, a poorer microstructure and a higher porosity leading to durability issues like higher shrinkage and a higher cracking risk. These consequences highlight the importance of proper concrete curing especially in the case of C3DP. Integrated curing methods which do not require human intervention, are needed to ensure the proper curing of 3D printed concrete. A proper curing, in turn, will improve the structural performance, durability, and service life of 3D printed infrastructure. Due to the anticipated higher variations in the curing conditions of 3D printed concrete, strength monitoring and estimation need to be addressed. Considering the promised fast speed in C3DP and a shortened construction phase, early-age strength development and monitoring is significantly important. A widely used strength estimation method, concrete maturity, is solely based on the temperature history of concrete – i.e., summation of the product of age and temperature. Since concrete temperature and relative humidity are both influential factors for cement hydration, the maturity approach seems to be insufficient for 3D printed concrete. This is because of the excessive water evaporation in 3D printed concrete and the anticipated impact on the cement hydration and strength development rates. Therefore, other strength monitoring and estimation approaches are needed for 3D printed concrete. The proposed project is focused on design, implementation, and studying integrated curing methods for C3DP, and using embedded sensors for monitoring and estimating the mechanical strength of 3D printed concrete. The project findings will provide valuable insights into the best curing practices for 3D printed structures, and the feasibility of using embedded sensors for estimating the mechanical strength of 3D printed structures over time.

Objectives

The proposed study is designed to achieve two main technical objectives: (1) to design, implement, and study curing techniques which can be integrated into the C3DP process, and therefore improve the strength development and long-term durability of 3D printed transportation infrastructure; and (2) to investigate the feasibility of using embedded sensors to monitor and estimate the mechanical strength of 3D printed concrete, under different curing conditions. A comprehensive experimental program will be carried out to investigate the impact of the proposed techniques on improving and monitoring the mechanical strength development of 3D printed concrete.

Figure 1. A 95-ft 3D printed concrete bridge in Nijmegen, Netherlands

Intended Implementation of Research

Workforce Development, Education, and Outreach: In the course of the proposed project, undergraduate and graduate students will be recruited and trained to contribute to the successful completion of the proposed research project. Workshops and training sessions on related topics will also be organized for students. As such, students will be educated and gain skills relevant to the C3DP technology and its great potential for developing resilient transportation infrastructure. As future engineers and decision makers in the transportation community, this knowledge and technology awareness of students could play a significant role in improving the quality and efficiency in the infrastructure development and maintenance processes.

The obtained results and conclusions of the proposed research study will be presented during the Tran-SET conferences and webinars, in order to increase awareness with respect to the current state of the art and existing challenges of implementing the innovative C3DP technology in the transportation related projects.

Anticipated Impacts/Benefits of Implementation

This project is focused on implementation and evaluation of new techniques for curing and strength monitoring for 3D printed structures, especially at early ages. The results of this study will provide preliminary data and a first step towards examination and verification of the proposed integrated approach. The experimental results will be provided to relevant entities such as LTRC and ACI, as well as construction 3D printing companies such as Contour Crafting Corporation; to encourage future partnerships and large-scale implementation and testing in the future.

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.

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