Resilient 3D-Printed Civil Infrastructure with Ultra-High Performance Engineered Cementitious Composites (UHPECCs)

Project Number:

21CLSU12

Start Date:

08/01/2021

Principal Inverstigator(s):

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Lead Institution:

Louisiana State University

Funding Source(s):

Tran-SET

Louisiana State University

Total Project Cost:

$ 60,000

Developing UHPECCs for 3D printing applications

The advent of construction 3D printing (3DP) technology has opened the possibility of revolutionizing construction productivity worldwide. However, one important barrier for broader adoption of construction 3DP in civil infrastructure is the difficulty to provide printed structural components with reinforcement to achieve sound structural performance under different loading conditions. As such, the implementation of intrinsically reinforced cementitious materials has the potential to address this barrier and yield significant benefits such as an enhanced structural capacity, durability, and resiliency. For this reason, novel ultra-high strength highly ductile cementitious composites such as Ultra-High Performance Engineered Cementitious Composites (UHP-ECCs) are excellent candidates for the 3DP of structurally sound civil infrastructure. This project proposes the development of UHP-ECC materials with rheological characteristics tailored specifically for construction 3DP application. Furthermore, this project aims to conduct a comprehensive evaluation of the hardened properties of printed UHP-ECC.

Problem Statement

One of the largest barriers for broader adoption of concrete 3D-printing in civil infrastructure is the difficulty to provide printed structural components with reinforcement to achieve sound structural performance under different loading conditions. As such, the implementation of intrinsically reinforced cementitious materials has the potential to address this barrier and yield significant benefits such as an enhanced structural capacity, durability, and resiliency. For this reason, the unique mechanical properties of UHP-ECCs position these novel composites as an excellent candidate for the 3D-printing of structurally sound civil infrastructure. While UHP-ECC is a promising material for 3DP implementation, several challenges still exist for its successful implementation. For instance, the fresh properties of these materials need to be adjusted in accordance with the innovative printing technique. In the current state of the art, flowability, extrudability, and buildability are investigated as the main characteristics of the printing materials in the fresh state. Flowability and extrudability are associated with the ability of the materials to flow smoothly from the source to the printing nozzle as a continuous paste and then extruded out, while buildability is related to the ability of the fresh material to retain its extruded shape under self-weight and the weight from the subsequently deposited layers. Aside from adjusting the fresh properties of cementitious materials for the 3D-printing process, evaluating the hardened properties of 3D-printed materials is also crucial. In the hardened state, it is important to consider that due to the layer-by-layer extrusion method, 3D-printed components exhibit several interfaces that produce different mechanical responses depending on the direction of loading. As such, the anisotropic behavior of these components needs to be taken into consideration and carefully studied. This project proposes the development of UHP-ECC materials with rheological characteristics tailored specifically for 3DP applications. Furthermore, the project aims to conduct a comprehensive evaluation of the hardened properties of 3DP UHP-ECCs.

Objectives

The main objective of this project is to develop and evaluate UHP-ECC materials for 3DP application. To this end, rheological characteristics of UHP-ECC will be specifically tailored to allow for 3DP functionality. Furthermore, this project aims to conduct a comprehensive evaluation of the hardened properties of 3DP UHP-ECC specimens compared to those of UHP-ECC specimens cast using conventional techniques.

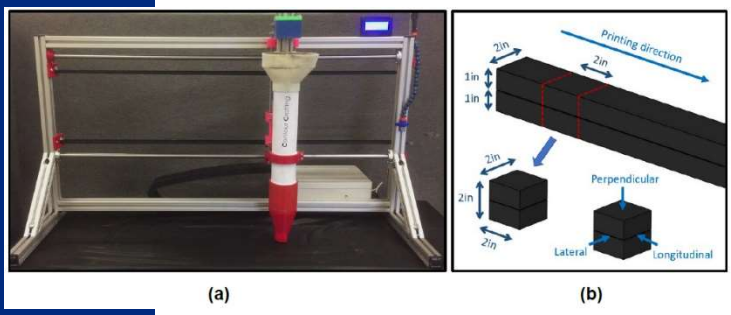

Figure 1. Laboratory 3DP System (a) Linear 3DP system (b) 3DP UHP-ECC cube specimen

Intended Implementation of Research

Workforce Development, Education, and Outreach: This research project will provide funding to one PhD student at Louisiana State University. This will help recruit and train future leaders in the Transportation Sector specializing in development of new materials for transportation infrastructure. The research team will also prepare educational material on UHP-ECCs to be incorporated in courses at LSU and share it with other universities. The educational material will also be summarized and disseminated to government entities and the industry. Results of this work will be also disseminated at national conferences such as TRB and ASCE.

The research team will prepare an implementation plan that describes a strategy to introduce the results into the state-of-the-practice and specifications of the DOTs. An evaluation plan will be also proposed to assess the implementation progress of the research findings.

Anticipated Impacts/Benefits of Implementation

The outcome of the research project will be several fully characterized UHP-ECC materials with 3D-printing functionality and 3D-printing techniques tailored specifically for successful UHPECC printing process. The developed ECC materials and 3D-printing systems will be available to be implemented in transportation infrastructure project in the region as well as in future research projects.

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.