Resilient 3D-Printed Infrastructure with Engineered Cementitious Composites (ECC)

Developing novel ECC that can be used in 3D-printing concrete structures

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$146,000

Engineered Cementitious Composites (ECC) is a class of Ultra-high-performance concrete (UHPC) and was developed decades ago by Dr. Victor Li. Since then, both material design and application have been revolutionized. ECC was designed in response to issues of the brittleness of conventional concrete and quasi-brittleness of Fiber-Reinforced Cementitious Composite (FRC). ECC was designed for specific applications where both strength and ductility of material matter, and it is known as bendable concrete or Strain Hardening Cement-based Composites (SHCC). ECC was designed using micromechanics and fracture mechanics principles by using low-fiber contents of short-fiber cementitious composites and for this innovative composite material, a ductile failure mode with a large strain capacity was observed. This material showed superior mechanical properties (i.e., high tensile ductility, tight crack width, large strength in tension and compression, low shrinkage, and creep), with self-healing characteristics which can improve the durability of this material. The tensile ductility of ECC is about 200 to 500 times that of normal concrete or FRC (2 to 5% strain capacity in tension). The crack width in ECC is usually less than 100 micrometers during strain-hardening, which is notably smaller than the size of cracks in FRC and conventional concrete. Moreover, this material is considerably strong primarily against deterioration occurring in the concrete structures, including alkali-silica reaction, sulfate attack, freeze and thaw, and corrosion.

Problem Statement

Concrete materials exhibit two well documented weaknesses: low tensile strength and highly brittle nature. As such, concrete materials rely on steel reinforcement to produce sound structural members ensuring sufficient tensile load carrying capacity, safety, and reliability. While steel reinforcement is fundamental for the structural performance of reinforced-concrete elements, steel rebar is the main cause of reinforced concrete structures deterioration due to the action of corrosion (Figure 1a). In turn, steel rebar significantly limits the durability potential of modern infrastructure. For instance, iconic buildings such as the Pantheon (built without steel reinforcement) are still standing after (Figure 1b); yet modern reinforced concrete structures have a hard time standing for over one hundred years. One solution is to provide concrete materials exhibiting high tensile strength and ductility which eliminate the need for rebar. As such, rebar-free structures could eliminate the corrosion deterioration mechanism and allow for great durability enhancements. Moreover, such materials would be ideal with emerging construction techniques such as 3D-printing where steel reinforcement is impossible.

Objectives

The main goal of this research project involves designing and developing novel ECC that can be used in 3D-printing concrete structures by utilizing readily available ingredients in Region 6. This study will offer the region with the most recent stage in the development of this novel cementitious composites that will be available for the structures, repair, and retrofit of transportation infrastructure. Moreover, the feasibility of 3D-printing ECC materials for digital construction will be assessed.

Figure 1: 3D-Printing of Concrete

Intended Implementation of Research

Education and Workforce Development: This research project will fund one Ph.D. student at University of New Mexico (UNM). This will help prepare future leaders in the Transportation Sector specializing in development of new materials for transportation infrastructure. The research team will also prepare educational material on ECCs to be incorporated into courses at UNM and other universities. The educational material will also be summarized and disseminated to government entities and industry professionals. Results of this work will be also disseminated at national conferences such as TRB and ASCE.

Outreach: This project will extend a research opportunity in summer 2020 for one undergraduate student to introduce him/her to research in Transportation and Advanced Materials. Moreover, the developed educational material prepared in this project will be shared with our partner community colleges to recruit students to Transportation. In addition, educational information explaining the outcomes of this project will be offered to research institutes and companies interested in emerging innovative technologies for the Transportation Sector collaborating with the highway agencies in Region 6.

Anticipated Impacts/Benefits of Implementation

The outcome of this research project will be several described ECC materials that will be readily applicable for implementation in local infrastructure as well as 3D-printing technology. The main deliverables of this project are: 1) a final report will be prepared including the problem description, objective, scope, methodology, results, conclusions, and recommendations.

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.