An Innovative Reinforcement Approach for Rebar-Free 3D Printing of Transportation Infrastructure

Project Number:

21CLSU01

Start Date:

08/01/2021

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Lead Institution:

Louisiana State University

Funding Source(s):

Tran-SET

Louisiana State University

Total Project Cost:

$ 90,000

Developing an innovative reinforcement approach for rebar-free 3D printing

Construction 3D printing (C3DP) is an emerging revolution in the construction industry and is viewed as a platform technology with various application domains such as infrastructure development, disaster relief, low-income housing, and extraterrestrial construction. C3DP enables automated on-site or off-site construction of customized structures or structural elements and can significantly reduce the construction time and cost, while improving the construction quality. Nevertheless, adoption of C3DP by the industry is still limited. A major existing challenge is incompatibility of conventional concrete reinforcement techniques with the robotic layer deposition process. The main objective of this project is to investigate an innovative configuration for a rebar-free construction 3D printing process for resilient civil infrastructure development. The proposed configuration includes using a self-reinforced printing material as well as a discontinuous vertical reinforcement technique which can be fully automated. To this aim, twisted steel fibers will be used to develop a structural self-reinforced printing material. Inserting steel mini-rods into the layers will be investigated as an additional strengthening method. These steel rods are designed to act as vertical reinforcement and to address the possible influence of interlayer adhesion on the mechanical performance of 3D printed elements. This project will result in development of a fully characterized printable self-reinforced mixture as well as comprehensive experimental data on the performance of an alternative reinforcement technique under different loading conditions.

Problem Statement

Despite many promising advantages of C3DP and the considerable number of studies on different printing materials as well as innovative robotic systems, adoption of C3DP by the industry is still limited. A major existing challenge is incompatibility of conventional concrete reinforcement techniques with the robotic layer deposition process. Several approaches for reinforcing 3D printed structures have been used by researchers. These approaches are not examined thoroughly yet, and often require additional manual tasks during the process, which is in conflict with the main advantages of C3DP as an automated process, namely, reducing the construction time and labor. For example, in one proposed approach, the steel reinforcement or mesh is installed manually, and then specially-designed nozzles are used to extrude concrete layers around the rebars. In another proposed approach, continuous steel cables are embedded in the extruded layers during the extrusion process. The main advantage of this technique is its integration into the concrete printing process and eliminating the need for an additional timeconsuming reinforcement implementation step. However, this approach only provides tensile reinforcement in the printing direction. As such, it is usually used in conjunction with a timeconsuming post-tensioning process orthogonal to the interlayer interface. Besides, the poor bonding between the steel cable and the cementitious layers has been identified as an issue and needs to be addressed.

Objectives

The main objective of this project is to evaluate an innovative, rebar-free C3DP process for resilient infrastructure development. The proposed configuration includes using SFRC as a selfreinforced printing material, as well as a discontinuous vertical reinforcement technique. The vertical reinforcement technique includes insertion of mini-rods during the layer deposition process. A comprehensive experimental program will be carried out to investigate the fresh state properties of the printing mixture as well as the mechanical performance of the reinforced 3D printed specimens.

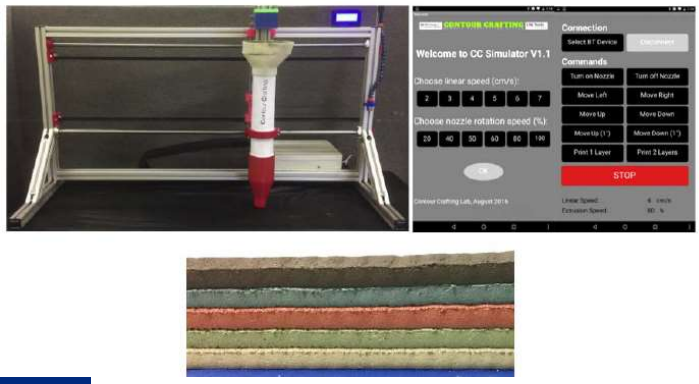

Figure 1. The linear concrete printing system and its user interface (top) and a multi-material printed sample using the printer (bottom)

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 construction 3D printing technology and its huge 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. In addition to recruiting and training undergraduate and graduate students, the results of this study will be used to enhance multiple undergraduate and graduate level courses at the Louisiana State University, and to prepare educational content to familiarize students with the construction 3D printing technology and its various advantages for the transportation industry and infrastructure development.

Anticipated Impacts/Benefits of Implementation

This project will result in development of a fully characterized printable steel fiber reinforced concrete and comprehensive experimental data with respect to the performance of the proposed reinforcement approach under different loading conditions. The current project is an important first step towards automated construction of structural elements without the need for manual insertion of conventional steel rebars. The results of this study will be published as a journal paper, and also presented at relevant events such as a Tran-SET conference, ACI convention, and TRB annual meeting. In addition, following the Tran-SET guidelines, a research report, an implementation report, and a final report will be generated and submitted during the project period.

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.