Design of 3D Printable Eco-Concrete by Utilizing Rheology Modifiers for Sustainable Infrastructure

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Lead Institution:

University of New Mexico

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$ 110,000

Developing 3D printable Eco-concrete for sustainable infrastructure

3D printing technology has become more commonplace in diverse industries in recent years. The popularity of this technology in the construction industry has been increasing; however, there are some challenges related to designing 3D-printable construction materials and adjusting their fresh properties for the 3D-printing process. Rheological properties, including viscosity, yield stress, and thixotropy, are the fundamental parameters to be considered for 3D printing applications. They significantly influence the key properties of 3D-printed concrete in the fresh and hardened states, including buildability, extrudability, and mechanical characteristics. Several researchers have utilized chemical admixtures(retarders/accelerator/superplasticizers/rheology modifiers) to achieve critical rheological demands. However, these are non-renewable, oil-based products containing many undesirable toxic matters that include a prospective danger towards the environment and can also cause the reinforcement's corrosion.

On the other hand, organic admixtures have the potential to replace chemical admixtures as an alternative, and they are abundantly available renewable materials. This study utilizes self-degradable additives (corn starch and cassava starch), supplementary cementitious materials (silica fume, nano-clay), and viscosity modifying admixture (methylcellulose). These admixtures will be used individually and in different combinations to evaluate their potential effects on the rheology, green strength, printability, and mechanical characteristics of the 3D-printable concrete. Fresh properties will be measured using a flow-table test. A rheometer will be used to study the plastic viscosity, yield stress, and thixotropy evolution over different intervals. The green strength will be examined using the direct shear and uniaxial compressive strength tests for different ages. The printability of the selected mixes will be assessed in terms of extrudability and buildability.

Problem Statement

Extrusion-based 3D printing is a novel manufacturing process, where the slurry or paste materials are extruded through a nozzle layer-wisely to make a 3D object by using a designed digital path. It is believed that 3D printing will be the next industrial revolution because of the quick and cheap production of objects from simple to complex designs and geometries. Over the last few years, several 3D-printing technologies have also been developed for building and construction. Compared to conventional construction methods, 3D printing has the potential for automation, reduced construction cost (in terms of labor and formwork), time, material waste, and energy; and fabrication of geometrically complex structures. One of the critical limitations for the broader adoption of concrete 3D printing in civil infrastructures is the difficulty of providing the required printability characterization in the fresh state of the materials. Although 3D concrete printing technology has the potential to digitalize conventional construction, there are a lot of concerns that need to be addressed. Most of these concerns are associated with designing a printable matrix that possesses sufficient fresh properties. Flowability, extrudability, and buildability are the fundamental properties in the fresh state, considered mainly by the researchers. The current state of the art in 3D concrete printing suggests the use of different forms of chemical admixtures(retarders/accelerator/superplasticizers/rheology modifiers) to achieve critical rheological demands. However, these are non-renewable, oil-based products containing many undesirable toxic matters that include a prospective danger towards the environment and can also cause the reinforcement's corrosion. On the other hand, organic admixtures can replace chemical admixtures as an alternative, and they are abundantly available renewable materials. Therefore, the main aim of this proposal is to design a 3D printable eco-concrete by utilizing rheology modifiers to achieve the sufficient fresh properties required for a printable concrete.

Objectives

This proposal is an experimental study to evaluate the fresh properties of 3D-printed concrete elements and investigate the feasibility of using different types of rheology modifiers (including different types of starches, nano clay, methylcellulose, and silica fume) in 3D-printing of the transportation infrastructure project such as bridges.

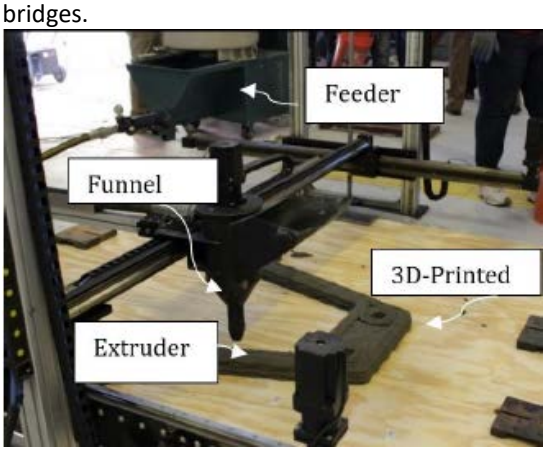

Figure 1. UNM Dana C. Wood Materials and Structures Lab 3D-Printing Systems: 3D-Printing of Concrete

Intended Implementation of Research

Workforce Development, Education, and Outreach: This research project will provide funding to one Ph.D. student at the University of New Mexico (UNM). This will help recruit and train future leaders in the Transportation Sector specializing in developing new materials for transportation infrastructure. The research team will also prepare educational material on ECCs to be incorporated in courses at UNM and share it with other universities. The educational material will also be summarized and disseminated to government entities and the industry. This work will also be disseminated at national conferences such as TRB and ASCE. This project will offer a research opportunity in summer 2020 for one undergraduate student to introduce him/her to Transportation and Advanced Materials research.

Anticipated Impacts/Benefits of Implementation

The outcome of this research project will be several characterized ECC materials that will be readily available for implementation in local infrastructure and 3D-printing technology.

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.