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3-D Printed Concrete Structures: From Materials, Design, to Digital Fabrication

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2019 Research and Creative for Undergraduate Students (RCEU) Proposal

3-D Printed Concrete Structures: From Materials, Design, to Digital Fabrication

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Project Summary

Provoked by recent advancements in additive manufacturing, 3D printable concrete (also known as to Additive Manufacturing of Concrete, or AMoC) has been explored as an alternative method to construct concrete structures. AMoC has the potential to address several major challenges faced by current concrete industry: (1) it eliminates the use of formwork (mold) and vibration that are typically necessary for consolidating wet concrete. This can significantly reduce material and labor costs involved in the formwork construction, particularly for in situ cast concrete; (2) the highly automated construction process presented by AMoC can reduce the material waste, cut down construction time, and reduce human error; (3) in addition, AMoC allows a whole new approach for concrete design – the composition and property of printed material can be parametrically varied from one location to another, tuning to the optimal structural and energetic performances. **Fig. 1** shows a conceptual presentation of a space habitat constructed using waterless 3-D printed concrete.

The objective of this project is to study the design of (cementitious) materials, structures, and construction processes to enable large-scale additive manufacturing of civil infrastructures and components. Emphasis will be placed on structures that are not easily constructible using conventional building techniques, e.g., structures having highly sophisticated geometrical profiles and those that serve in hostile environments (marine and space constructions).

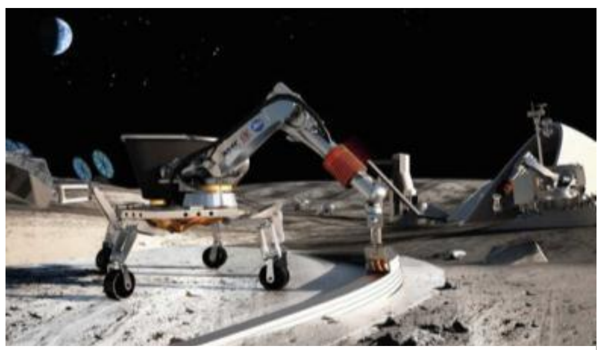

Fig. 1 Architectural render of space habitats AM

Research Plan

Three tasks are proposed with potential collaboration with the NASA Marshall Space Flight Center (MSFC): (i) firstly, a suite of candidate materials with various mechanical, thermophysical, and rheological properties will be studied for AMoC, with the objective of establishing a candidate material database. Then, (ii) the mechanical and rheological properties of the candidate materials will be elucidated as functions of the materials constituents and curing time. The evolving microstructure of the interlayer in printed samples will be characterized and then refined through adjusting the viscoelastic property and phase change of the material. Lastly, (iii) practical considerations will be addressed including the formulation of parameters including pump pressure, printing speed, and tool path etc.

Student Duties

Prepare material samples; learn to perform mechanical and thermophysical experiments for cementitious based materials. Learn to set up experiments and instrumenting samples with sensors. Learn to process and analyze experimental data.

Tentative 10-week Schedule

(1) Weeks 1-2, familiarize with the lab environments, safety training, learn to prepare materials (i.e., concrete mortars, cement paste etc.);
(2) Weeks 3-4, design experimental test matrix and fabricate the material samples needed for mechanical and thermal testing;
(3) Weeks 5-6, learn and perform mechanical and thermal experiments in the laboratories;
(4) Weeks 7-8, analyze the experimental data;
(5) Weeks 9-10, possible opportunities to trial print a prototype structure on NASA's ACME-2 concrete 3-D printer.

Expected Student Background and Requirements

Students should have good background in general physics, materials; knowledge of mechanics of materials and civil engineering materials is advantageous; typically students with a major in Civil Engineering, Mechanical and Aerospace Engineering, or Chemical Engineering should be ok. Pre-exposure to analytical instrumentation is a plus.

It is expected that the students will work full-time (32-40 hrs/week) for 10-12 weeks during summer 2019. Students who consider pursuing the RCEU program may not register more than 6 credit hours of class during smr 2019 (i.e., two classes over the summer, or one class each mini-semester). Office space located in Technology Hall (OKT) and computers will be made available to the enrolled students. The students will have access to the newly established structural hazard mitigation and intelligent materials laboratory located in the high-bay area of Tech Hall.

Results and Deliverables

Students will learn state-of-art characterization techniques for building materials. Students are expected to be exposed to a combination of experimental and analytical techniques, including SEM, XRD, TPS, accelerated durability testing and finite element analysis (FEA) software.

Mentor Supervision and Interaction

The faculty mentor will oversee the project throughout the performance period, including supervising the student and design the testing protocols associated with this project to ensure all project objectives are achieved. The mentor will examine all student's work and provide the assistance and resources needed. The student will report (in written or oral format) to the mentor periodically on a weekly base, and the mentor will ensure the student is progressing as planned. It is expected that a brief research report will be generated towards the end of the project.