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

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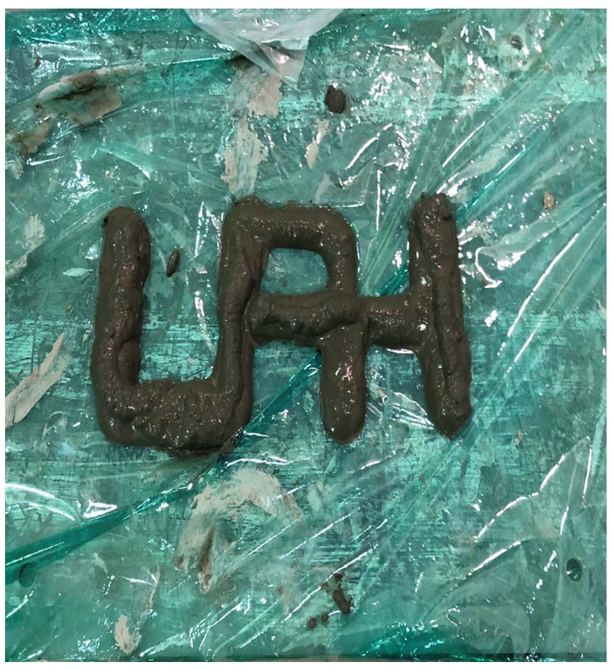
Introduction

Additive manufacturing involves building a 3-D object layer by layer. This process drastically reduces manufacturing time compared to traditional methods. From this process, a 3-D CAD model can be converted into a machine command language called gcode which allows the model to be sliced and printed one layer at a time. Our research explored this process and applications of 3-D printing concrete structures.

Method

Our method for the extrusion of concrete was through a linear extruder tube. A stepper motor connected to a worm gear drives a piston down a plastic tube filled with concrete through a nozzle. The nozzle connects to a hose that connects to a secondary nozzle and onto the print bed. We modified a commercial 3-D printer, the Lulzbot Taz 6, to use as the main platform for controlling the secondary nozzle. A custom mount for the second nozzle was fabricated for integration to the Taz 6. A wooden frame was constructed to hold the main extruder approximately 2 feet above the test bed. For software, we adjusted the gcode to account the thicker layers required for a concrete extrusion.



Key Findings and Results

There were many factors to consider while developing the proper mixture for concrete printing. The mix had to be sufficiently flowable in order to properly extrude. In addition to flowability, the mixture must be stable enough to support additional layers, but the most important factor is curing time. It must be balanced so that it does not cure to the point preventing extrusion while being strong enough to allow for layering. After testing various mixtures of concrete, the mix with a smaller concrete to sand ratio yielded a mixture that maintained flowability as well as structural integrity. The mix was able to flow through the tube and stay intact allowing it to layer properly while printing.

Mix Design	
Component	Quantity
Sand/Cement Ratio	0.5
Water/Cement Ratio	0.35
Superplasticizer per 350 g Water	0.8 g
Retarder per 350 g Water	2 g

Impact and Conclusions

Additive manufacturing has many useful applications in various industries especially when dealing with concrete. Some major applications include disaster relief shelters and military housing in combat zones. Concrete 3-D printed structures provides an alternative to construction which has benefits of less build time, efficient, and eco-friendly. Our research was a proof of concept in the idea that various mixtures of concrete can be printed from a CAD model.

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