Compressive and Flexural Strength of 3-D Printed Ultra High-Performance Concrete

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Research question

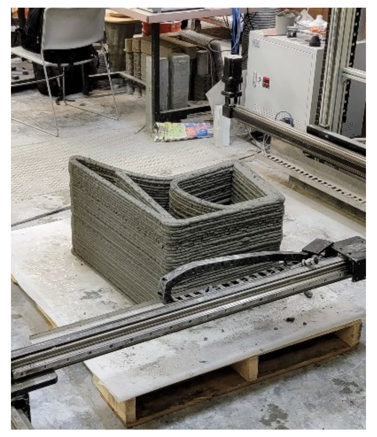
The research team is looking at the viability of 3-D printing ultra high performance concrete (UHPC) with respect to flexural and compressive strength as a multifunctional construction or building material. To address this question, two components of the project must come into alignment; the mixture strength and printability. In line with sustainability, the team is focused on utilizing cementitious replacement materials to reduce the amount of cement used in UHPC. This project serves as a stepping-stone to future 3-D printing research and expanding the application of 3-D printed concrete for use in the build environment.

Background

This project follows the success of 3-D printed concrete that The School of Sustainability has previously done. A 3-D printed chair was re-created by the team and is shown in the pictures to the right. The mixture used to 3-D print a concrete chair, consisted of only sand for the aggregate. The use of a sand-only aggregate will serve as a foundation for this project.

The use of cementitious replacement material for this project is based upon previous research that aims to reduce cement demand through the addition of fly ash, limestone, and slag. Using replacement materials reduces the costs and carbon footprint of UHPC.

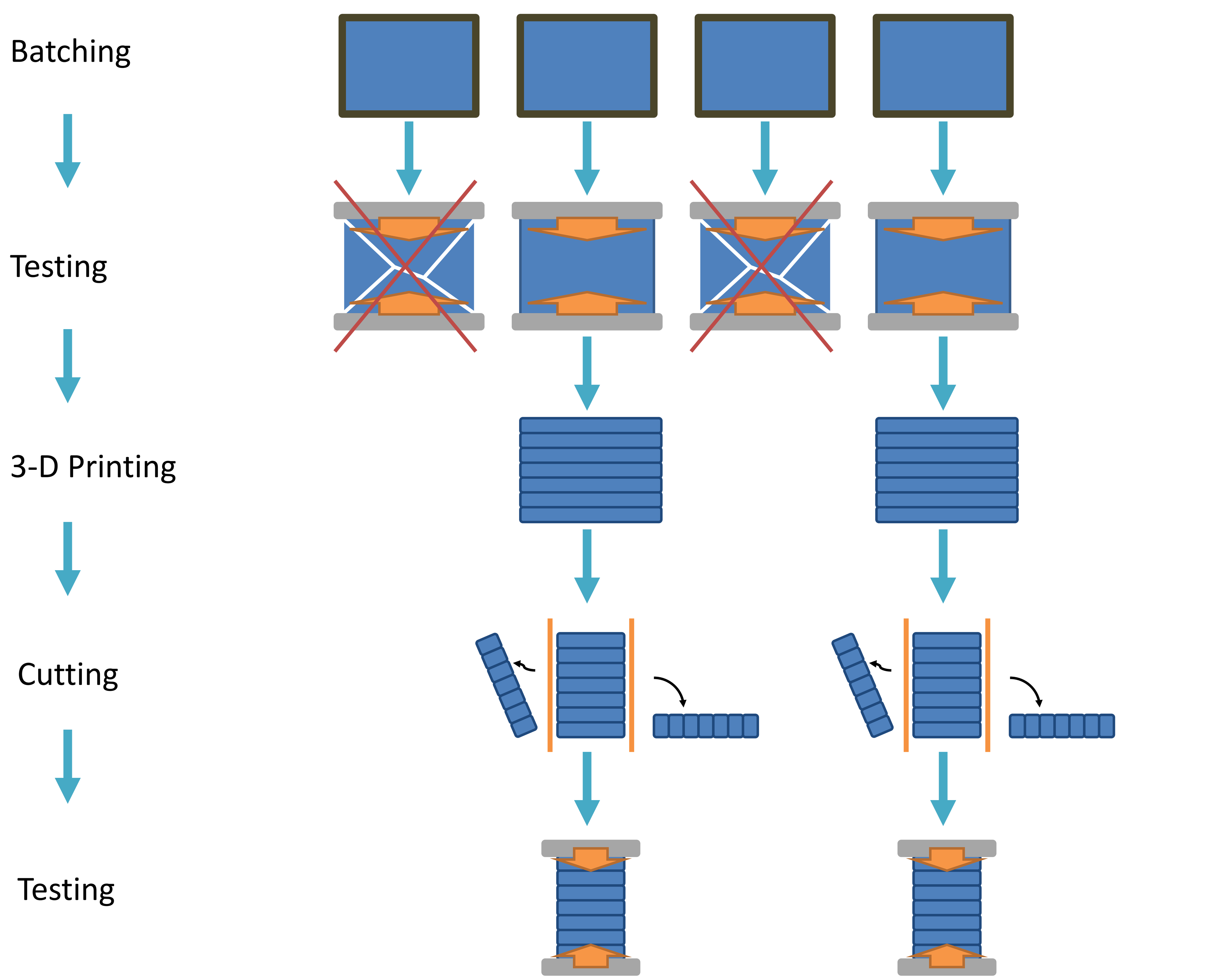
This poster serves to summarize a portion of a larger project underway by the PhD student, Avinaya Tripathi, under Dr. Narayana Neithalath's mentorship. At present this project is still ongoing.



Obstacles Faced/Overcome

Some of the biggest challenges faced by the team, centers around the auger used to 3-D print the material. The auger used impacts both the parameters of the research and scalability. It is easy to compare this to pumped concrete. Typical concrete pumps, with a 5-inch system, can utilize 2-inch aggregates. In industry, the addition of steel fibers works with concrete pumps. In our case, we were greatly limited on the amount of steel fibers that can be added due to auger failures. Additionally, if the mixture was too thick, the auger was unable to effectively pump the material. The key difference between our system and that of pumped concrete is that our system favors thicker material with a low slump, because it leads to higher stack-ability. While pumped concrete utilizes formwork, a moderately higher slump is preferred. This redefines the characterization of workability for concrete used in 3-D printed processes.

Methods



Batching: Multiple concrete mixtures are cast into approximately 2-inch cubes.

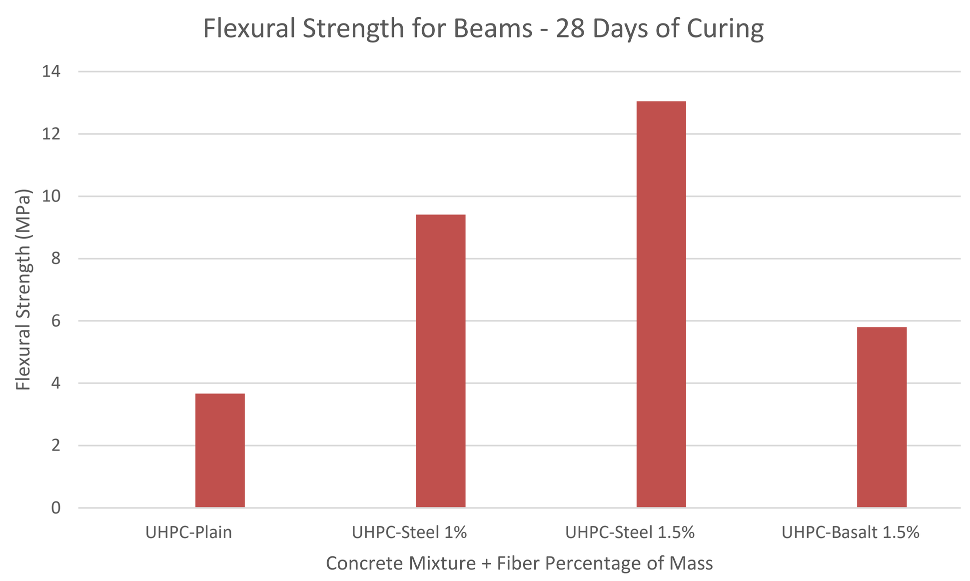
Testing: The batched cubes are tested for compressive strength. Cubes that achieve compressive strength of 100 MPa or more move onto the next step.

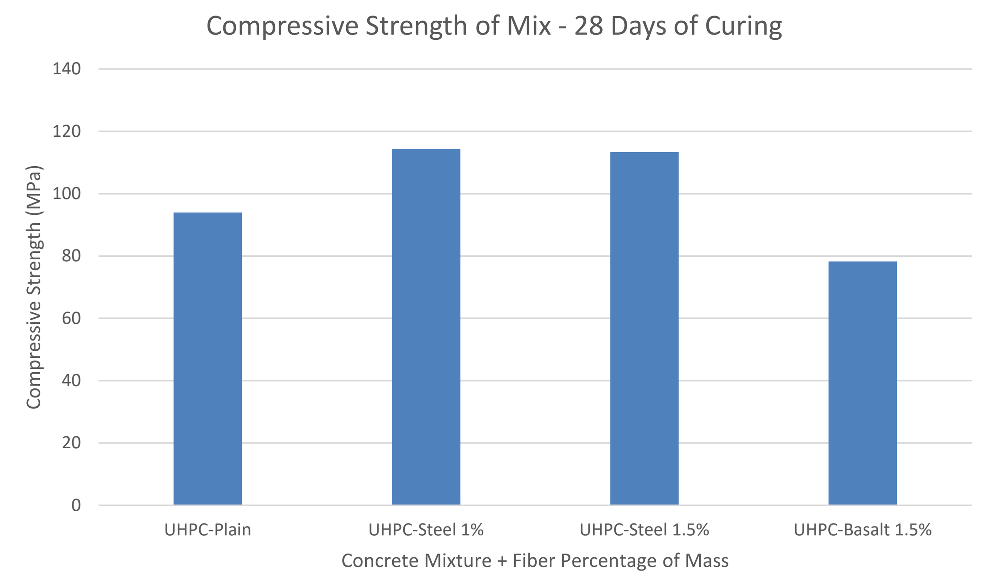
3-D Printing: Concrete batches that perform at UHPC compressive levels are 3-D printed into large rectangular cubes. (See photo at right)

Cutting: 3-D printed specimens are cut into cubes and beams for testing.

Testing: 3-D printed specimens that are cut to size are tested for both compressive (cubes) and flexural (beams) strength.

Findings To Date





Red Graph
The top graph depicts the average flexural strength of the best mixture to date. With 1.5% steel fibers by mass added to the mixture a flexural strength of over 12 MPa was found.
Blue Graph
The bottom graph depicts the average compressive strength of the best mixture to date. The addition of steel fibers in both cases presented compressive strengths of approximately 110 MPa.

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