Interlayer Interface Characteristics in 3D Printed Cement Paste

Michael Kosson[1] and Florence Sanchez, PhD[2]

1: Vanderbilt University, Chemical and Biomolecular Engineering
2: Vanderbilt University, Civil and Environmental Engineering

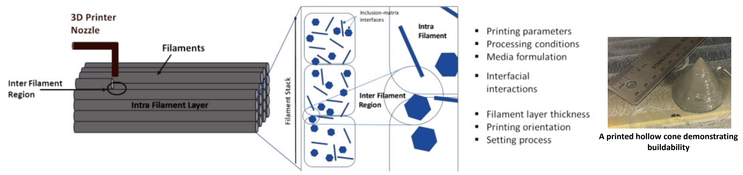
RETH International Workshop, October 22nd - 23rd, 2018

I. Motivation

- 3D printing of cementitious materials can reduce waste and formwork associated with traditional concrete construction while increasing safety, productivity, and freedom for customization.
- 3D printing may open new possibilities for the exploitation of local resources for construction associated with space colonization.
- The microstructure of printing interfaces and their effects on bulk properties are not well understood.

II. Challenges of Layer-by-Layer Printing

- Additive: Adding one layer at a time
  - Creates a layered structure
  - Causes staircasing surface finish effect
- Interlayer interfaces may play crucial role in bulk material properties.



A printed hollow cone demonstrating buildability

- Parameters affecting interlayer interfaces:
  - Thickness of layer
  - Print orientation and raster pattern (build direction)
  - Setting process and strength growth
  - Printing parameters and conditions
  - Ink formulation
  - Ink chemistry

III. Objectives

- To characterize the interfaces between layers of 3D printed cement paste for different printed patterns.
- To study the effect of interfaces on the bulk material properties of 3D printed cement pastes.

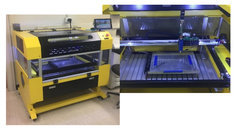
IV. Printed Cement Pastes

- Cement pastes with different printed patterns:

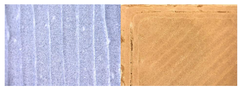
Concentric **Rectilinear** **Cast**

Profile view of concentric filaments

Profile view of rectilinear filaments



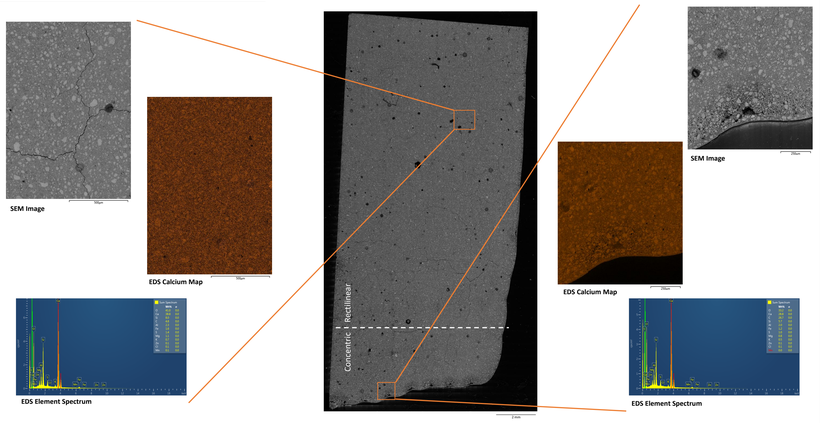
Floor model 3D printer and printing platform



Printed cement paste filaments with different morphology visible at interfaces

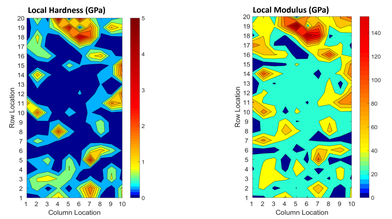
V. Results

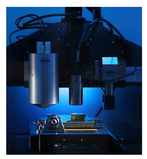
Microstructural Analysis



- Increased porosity and preferential cracking seen at interfaces, especially near edges of samples.
- No significant calcium migration or silicon displacement.
- Unhydrated cement particles are dispersed randomly.

Micromechanical Properties



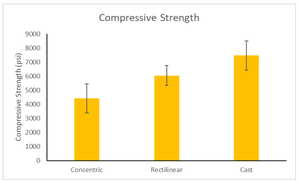


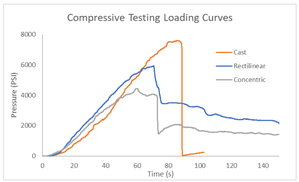
Nanoindenter testing stage

- Nanoindentation grids, converted into heat maps, provide local mechanical properties that are related to SEM images for phase information.

V. Results (cont.)

Mechanical Testing

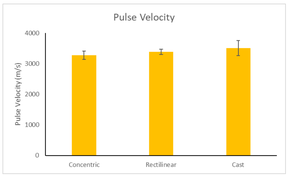


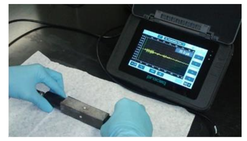


Compressive Testing Apparatus

- Compressive testing showed that concentric and rectilinear samples are about 40% and 20% weaker respectively than cast samples.
- Loading curves suggested that, unlike cast samples, 3D printed samples retained residual ductility after initial failure.

Ultrasound Pulse Velocity





Pulse velocity testing apparatus

- Printing pattern did not significantly change pulse velocity in preliminary results.

VI. Future Work

- Continue chemical and microstructural characterization.
- Continue local nano/mechanical characterization.
- Characterize porosity of interfacial regions using SEM and micro-computed tomography techniques.
- Design composite materials incorporating nano-materials to improve interface characteristics.

VII. Acknowledgements

This material is based upon work supported by the National Science Foundation (NSF) under Grant No. CMMI-1563389 and Vanderbilt University TIP VRA and is part of a broader collaboration with Tennessee Technological University and Purdue University.