Effect of Interlayer Time-Lapse and Workability Retention on Printed Concrete Performance

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3D printing of concrete: An extrusion-based additive manufacturing process that deposits consecutive linear mortar filaments on top of each other to gradually build an object

How is printed concrete different from cast concrete?

- Presence of intentional interlayer joint in printed concrete
- Higher anisotropy

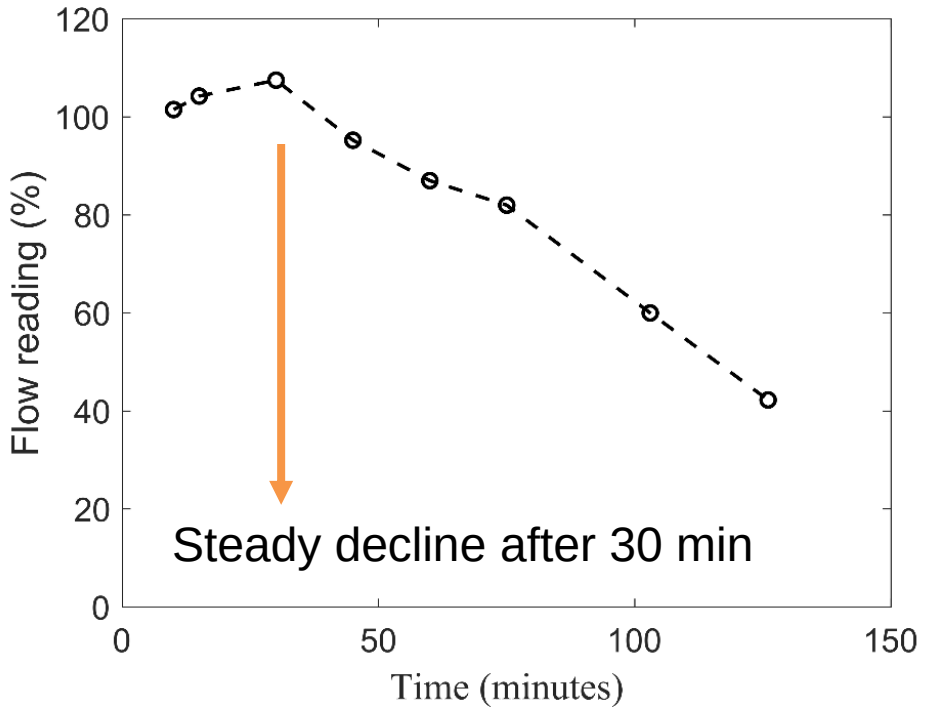
Research Objective:

- To study the effect of interlayer time-lapse on the mechanical properties on printed concrete including the fracture properties of concrete interlayers.
- This study suggests a modified compact tension (CT) test which is suitable for the printed layer height
- Investigate the correlation between concrete workability retention with the interlayer bonding

This work correlates the change in fracture properties, mechanical performance, and workability retention with the interlayer time-lapse between two consecutive concrete layers.

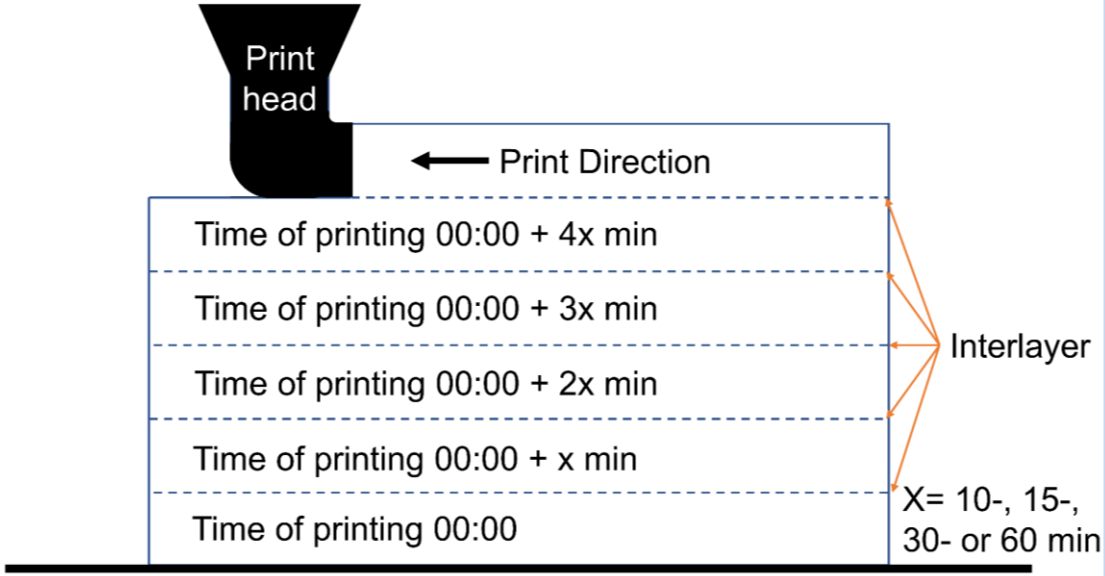
Material

Dry mortar mix developed by Quikrete
Initial setting time: 5 hours



Workability Retention

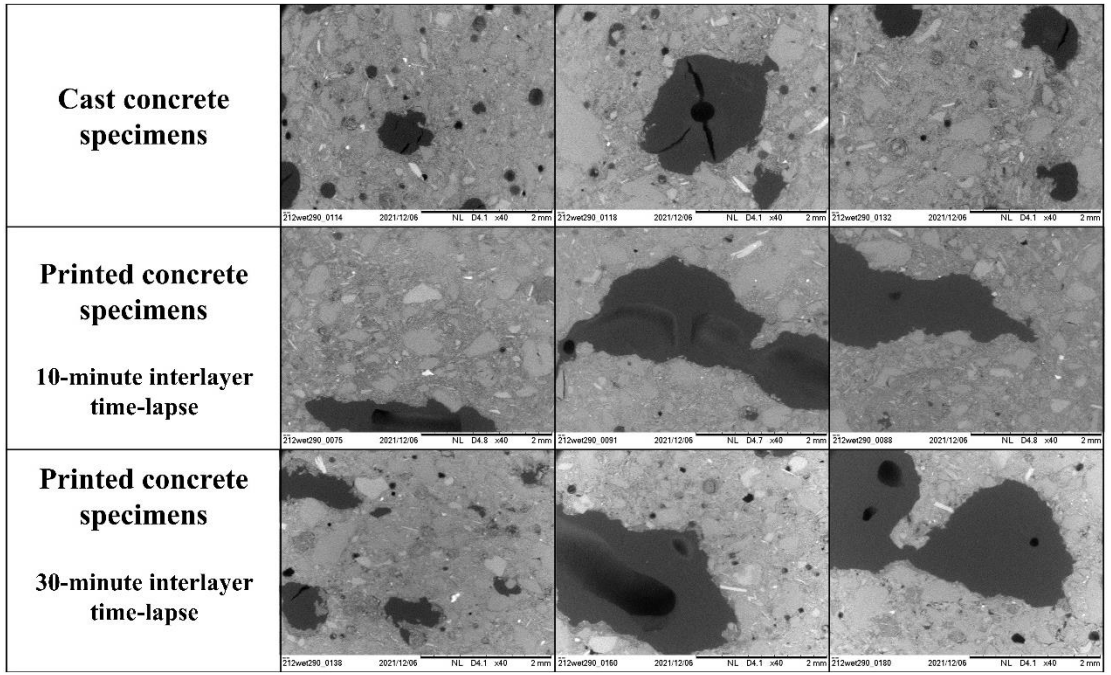
Sample Preparation

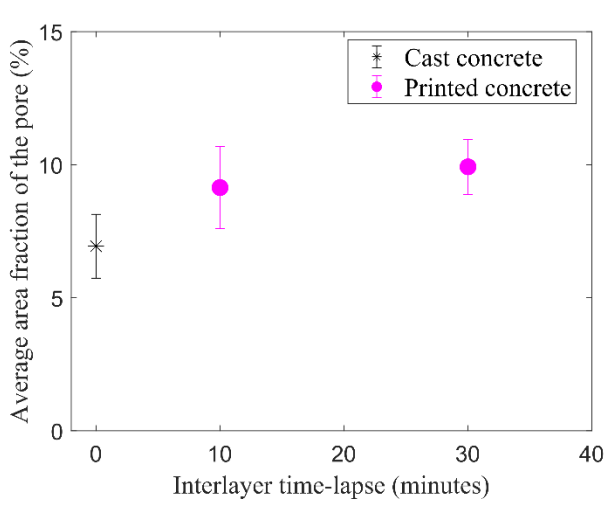


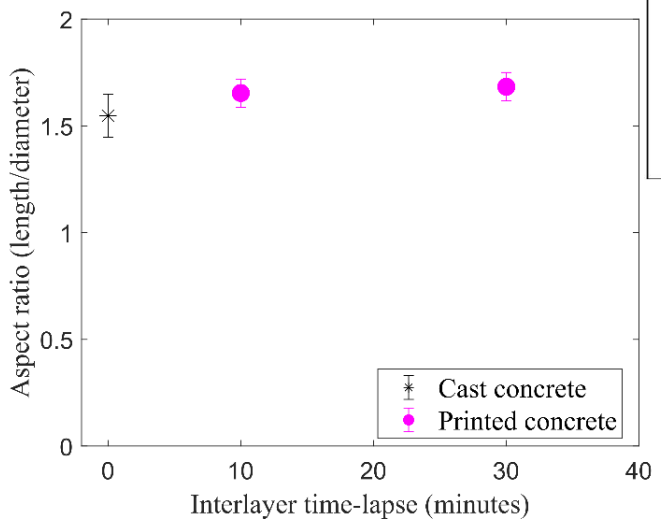
Printed concrete samples were cut into specimens required for compressive strength, flexural strength and compact tension test

Effect of interlayer time lapse on concrete porosity

- SEM images of resin impregnated samples at 40X magnification were used
- Printed concrete has more irregular and elongated pore structures in printed concrete compared to cast concrete

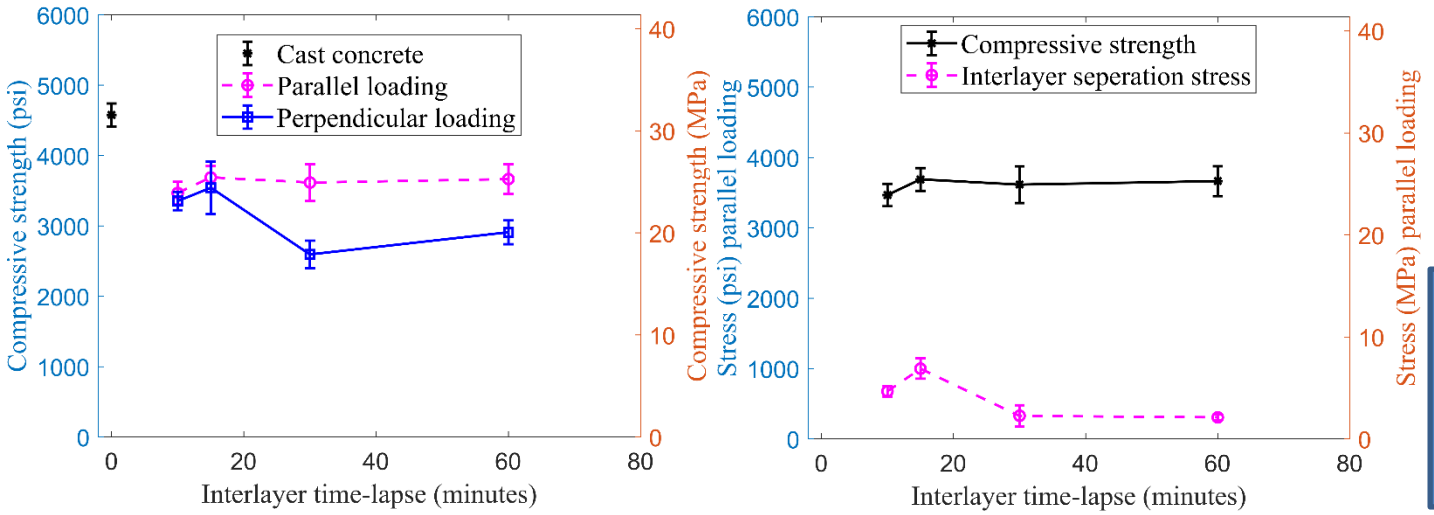


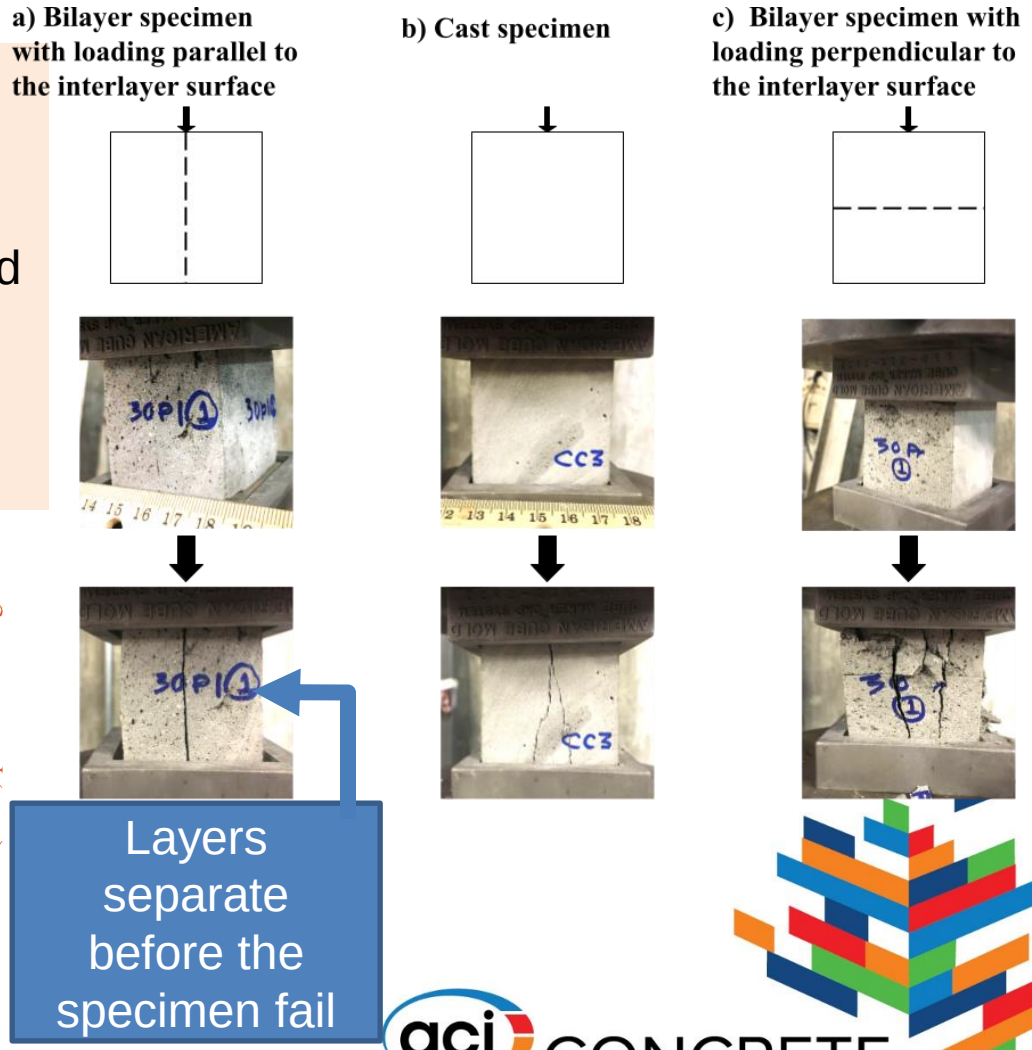




Effect of interlayer time lapse on compressive strength

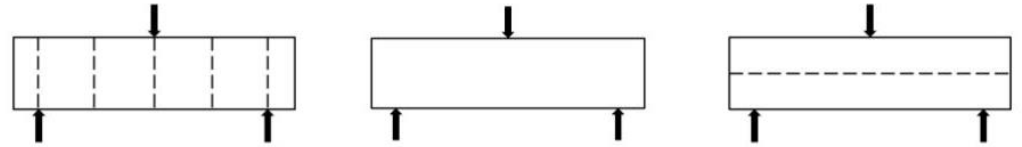
- Concrete exhibits different breaking patterns for cast specimens, parallel-loading printed specimens, and perpendicular-loading printed specimens
- Printed concrete specimens show lower strength compared to cast concrete
- Interlayer separation stress can be used as an indicator of the interlayer zone's tensile strength.





Effect of interlayer time lapse on flexural strength

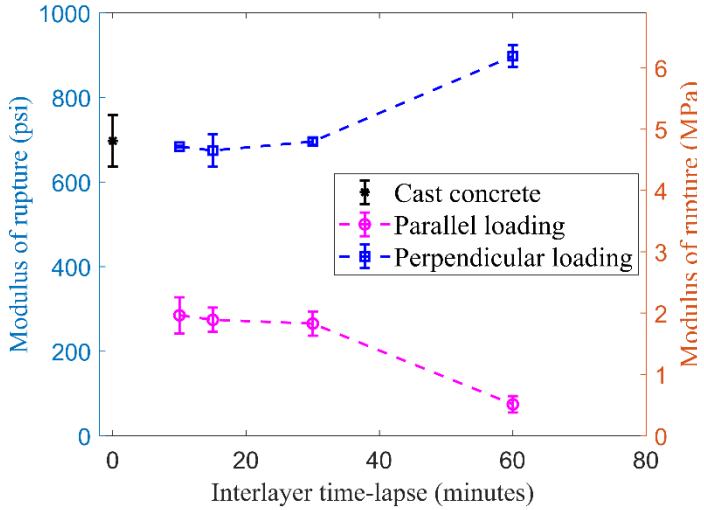
- Printed specimens with perpendicular loading show higher flexural strength with longer interlayer time-lapse
- Printed specimens with parallel loading show lower strength compared to cast concrete
- The crack pattern of the bending specimens is influenced by interlayer
- The crack length increases with interlayer time lapse (c)

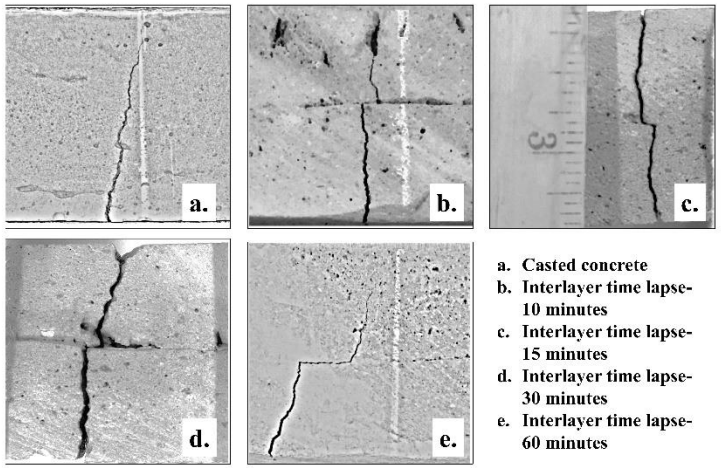


a) Printed specimen with loading parallel to the interlayer surface

b) Cast specimen

c) Printed specimen with loading perpendicular to the interlayer surface

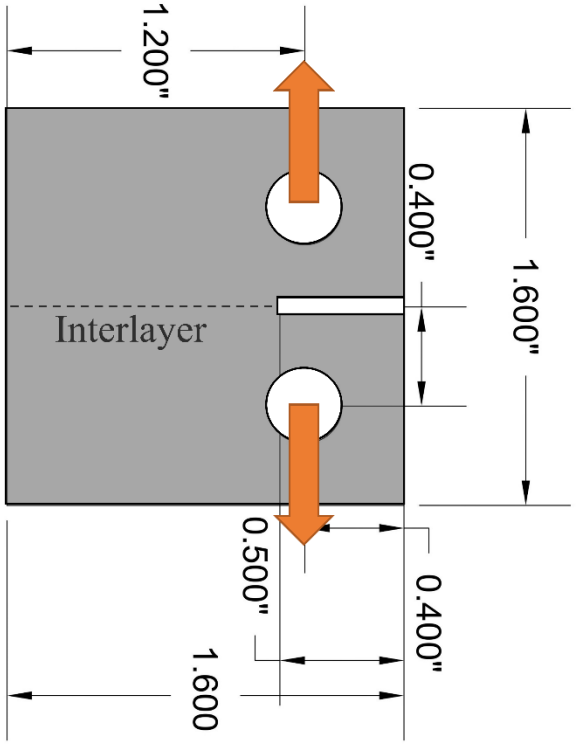


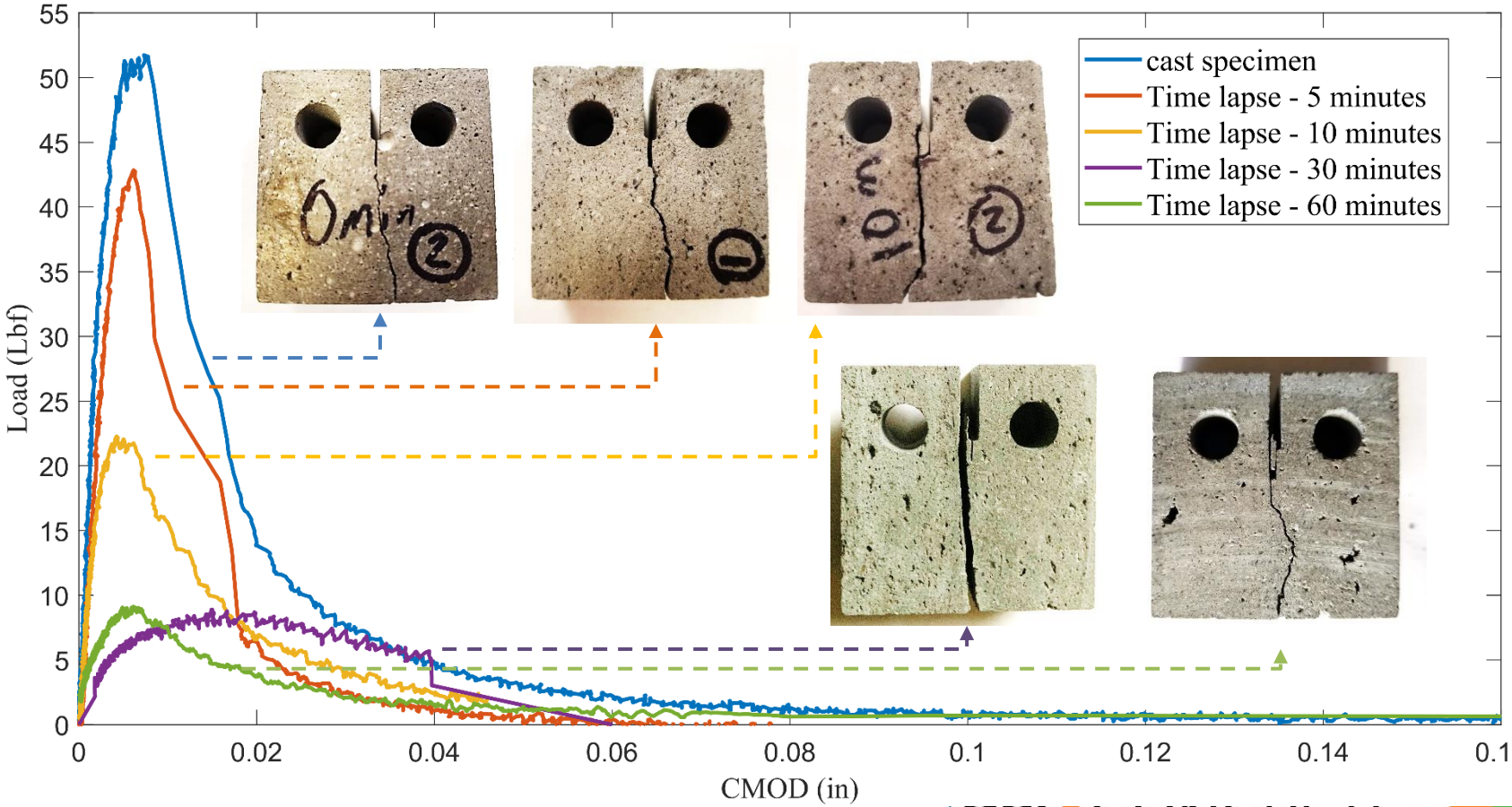


a. Casted concrete
b. Interlayer time lapse- 10 minutes
c. Interlayer time lapse- 15 minutes
d. Interlayer time lapse- 30 minutes
e. Interlayer time lapse- 60 minutes

Effect of interlayer time lapse on fracture properties

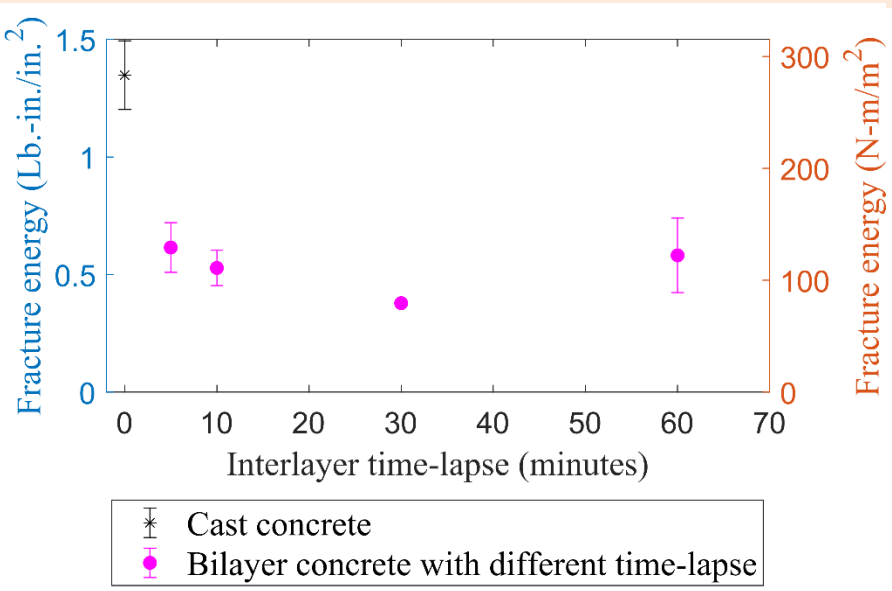
The test applies tensile force on a notched concrete specimen and measures crack mouth opening displacement (CMOD) to determine the fracture energy and fracture toughness

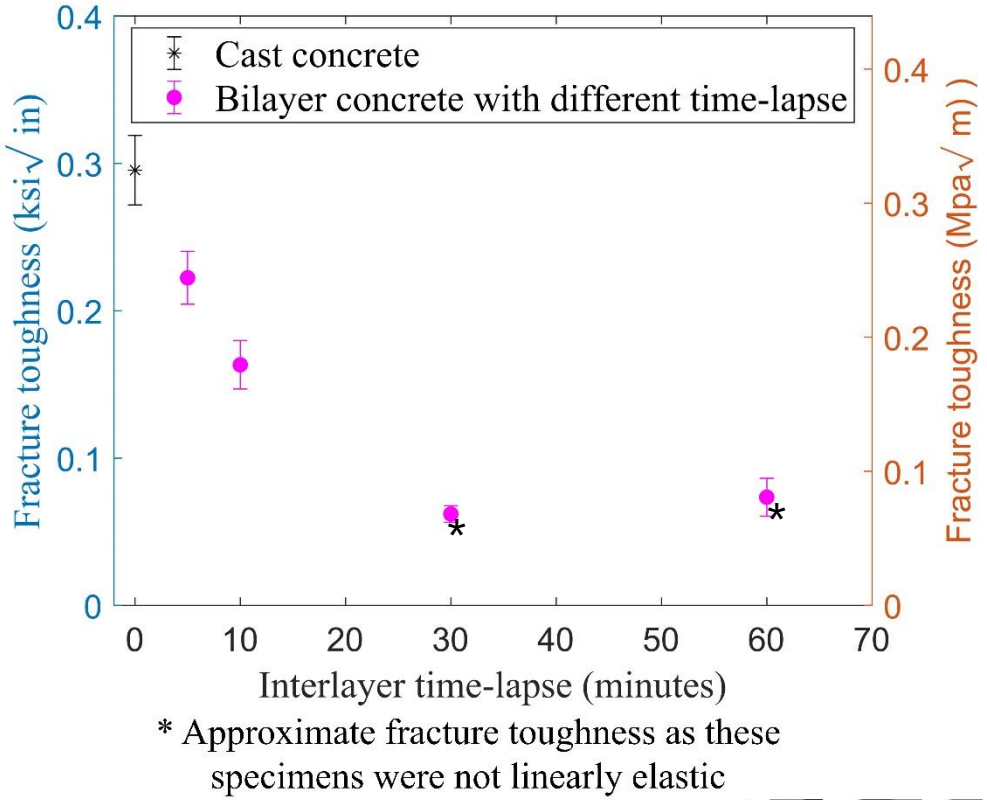




Effect of Interlayer time lapse on fracture properties

- Fracture behavior of printed concrete changes with longer interlayer time lapse
- The fracture toughness gradually decreases with a longer interlayer time-lapse
- Fracture energy of printed concrete is lower than cast concrete





Conclusions

1) Porosity and pore structure changes in printed concrete compared to cast concrete
2) Interlayer time-lapse affects concrete properties differently based on the alignment of interlayer with respect to loading direction and the test types
3) Although concrete fracture behavior changes with the interlayer time-lapse, fracture energy does not
4) In this study, the interlayer bonding strength declines with 30-minute and 60-minute interlayer time-lapses. It aligns with the decline of the workability retention trend
5) The workability retention of the mix can be used to predict the optimum time span for 3D printing.

Acknowledgement:

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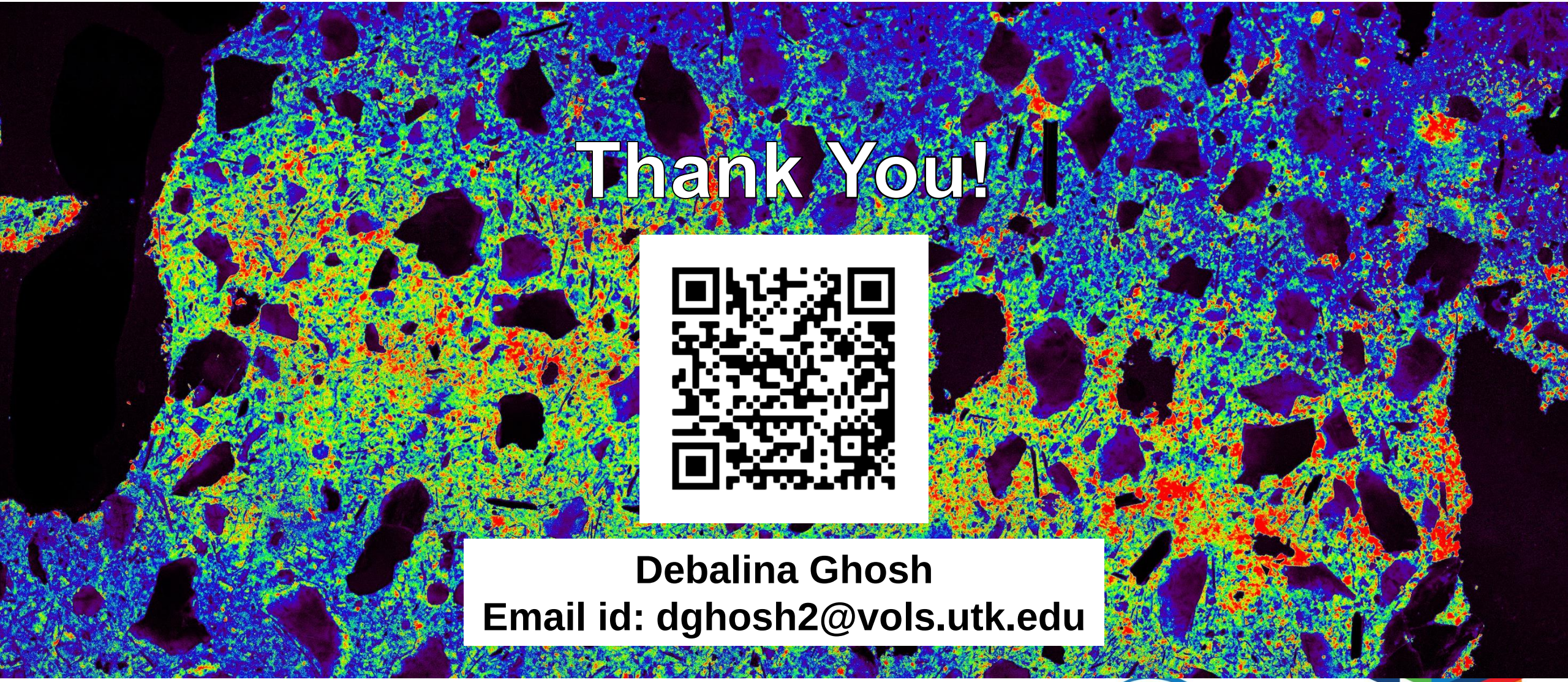

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