Influence of Toolpath Design on the Structural Performance of 3D Printed Concrete Gyroid Walls

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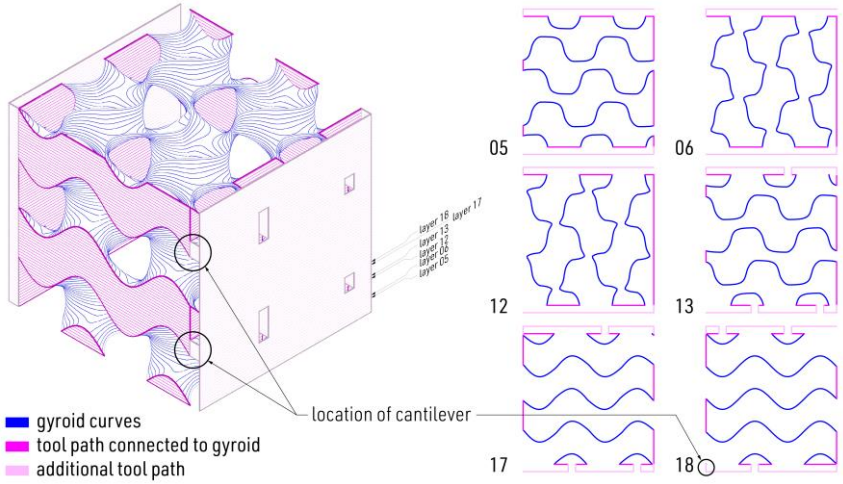
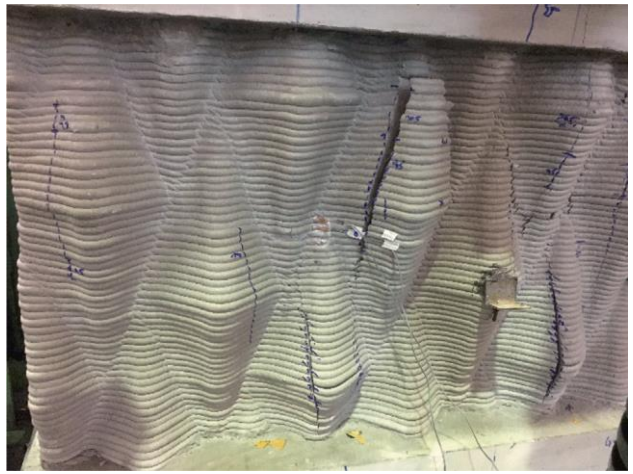


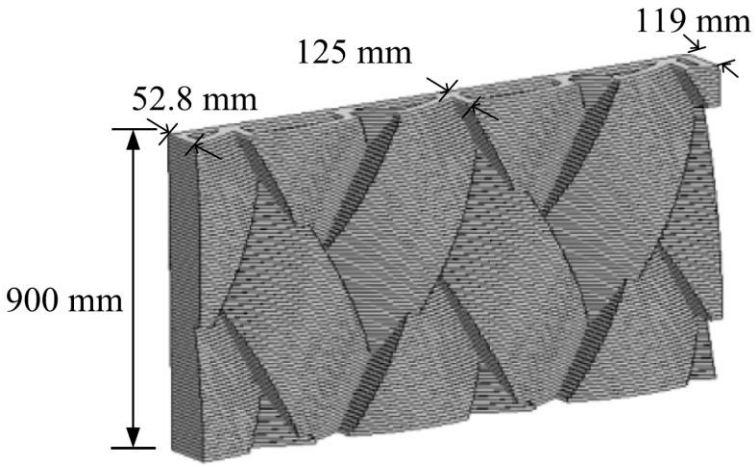
3DPC Background




Examples of printed structures, Bos 2016



Diamond Wall, Daungwilailuk 2021

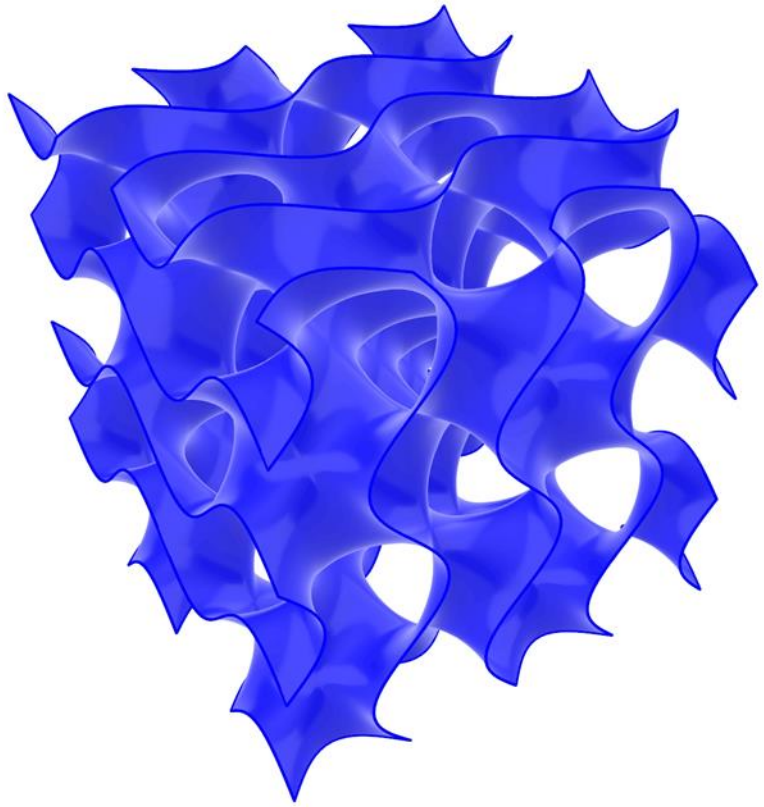


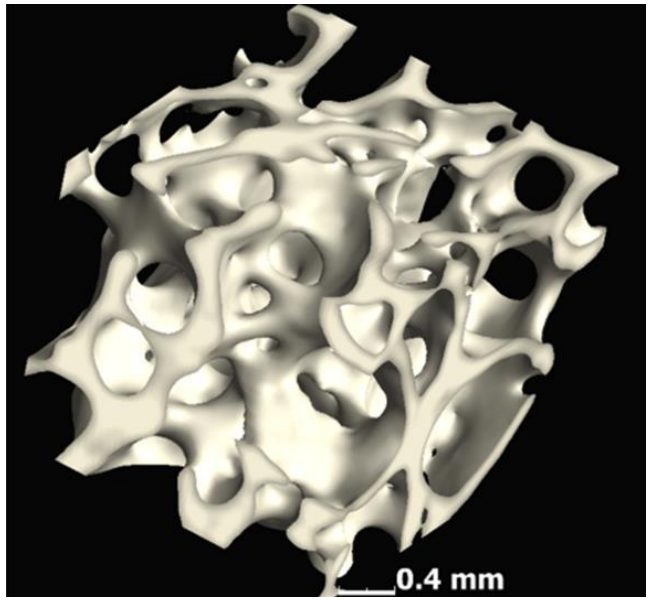
Carp Scale Wall, Tanapornaweekit 2022

Gap: Creation of complex wall shapes that have beneficial structural forms

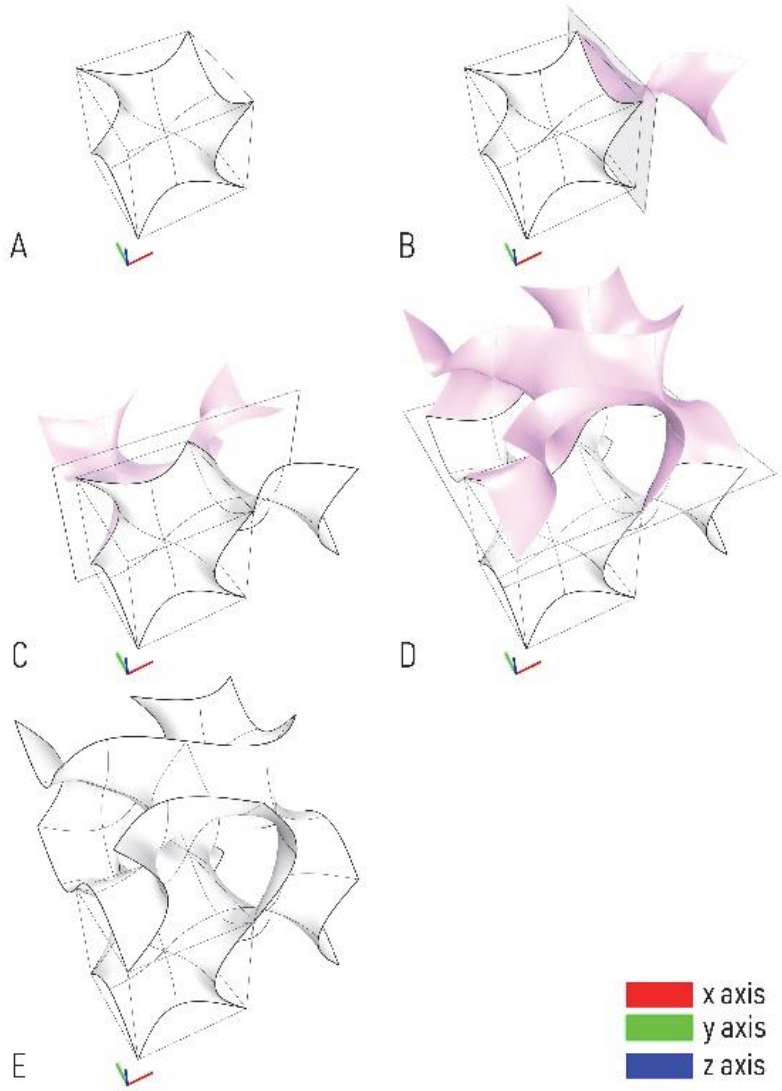
Gyroid Background

Triply Periodic Minimal Surface (TPMS)



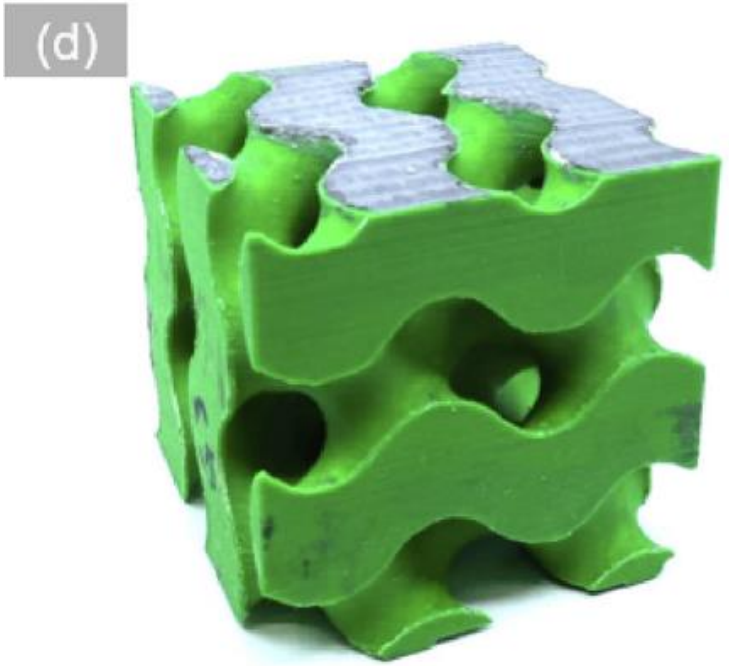


Trabecular bone CT scan, Plessis 2021



Gyroids in Concrete

Plastic gyroid reinforced concrete beam, Skoratko 2022

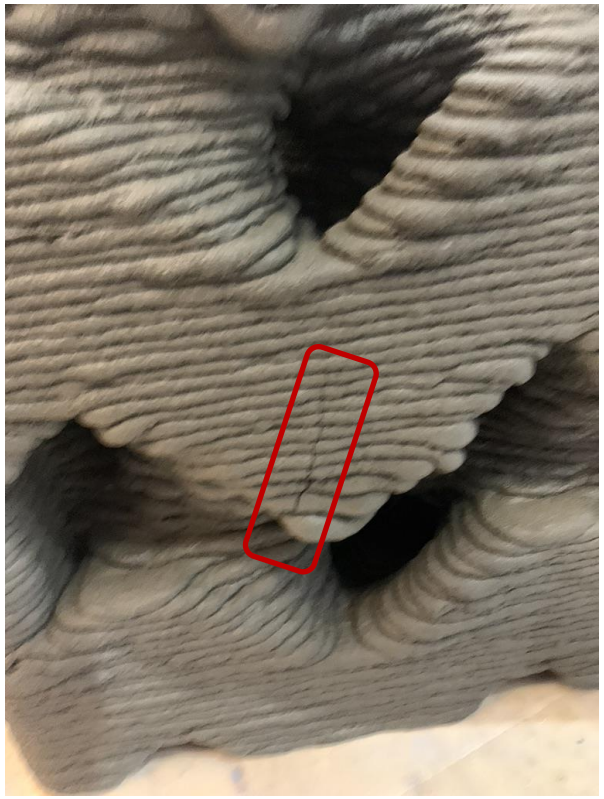


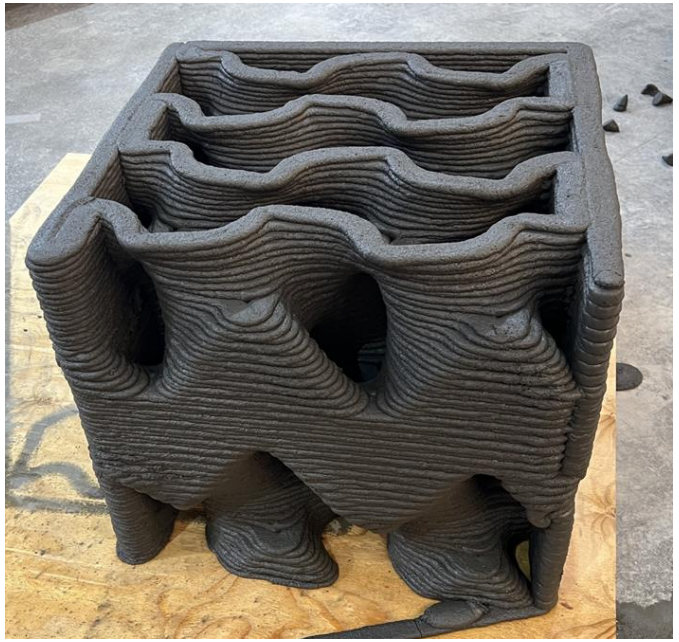
Plastic mold for cement paste gyroid, Nguyen-Van 2021

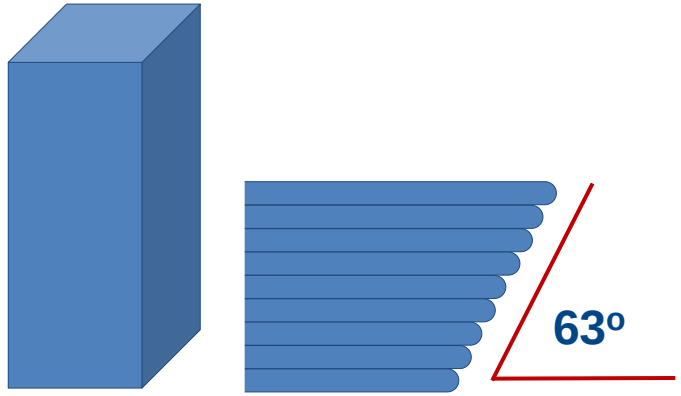
3DPC gyroid with material support, Conrad

Can a 3DPC gyroid wall be directly printed with no supports?
What does an efficient toolpath look like?
How do material properties impact wall performance?

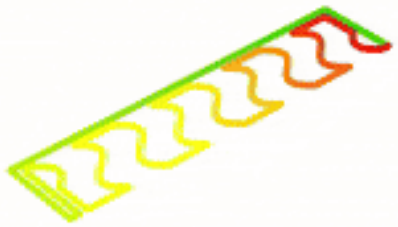
Design of Geometry







Toolpath Selection



Closed Toolpath

900 mm x 210 mm x
1800 mm envelope

+ Constant Interlayer Delay

- Requires More Material

Open Toolpath

900 mm x 210 mm x
1800 mm envelope

+ Uses less material for same footprint

- Interlayer delay variable across toolpath

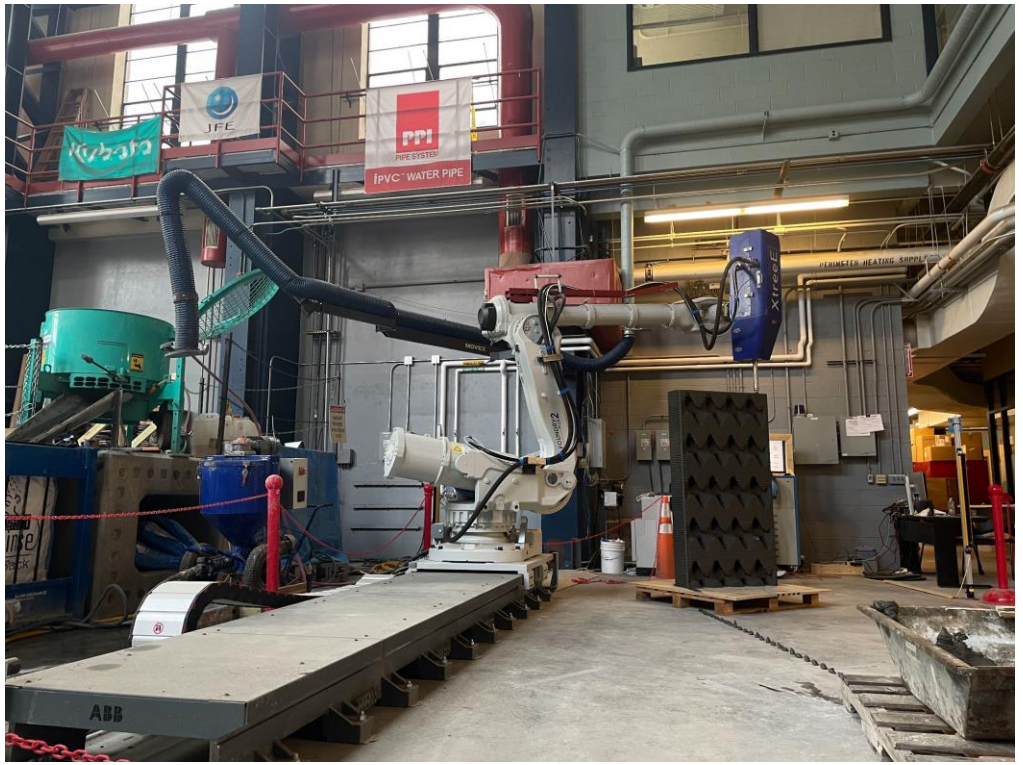
Which is Stronger? More Efficient?

Mixture Parameters

- w/cm = 0.35
- Cement Paste Volume = 52%
- SCM Content by Weight = 30%
- Maximum Aggregate Size = 2 mm
- Flow Diameter = 17 cm
- Open time = 30 min

Printing Setup & Procedure

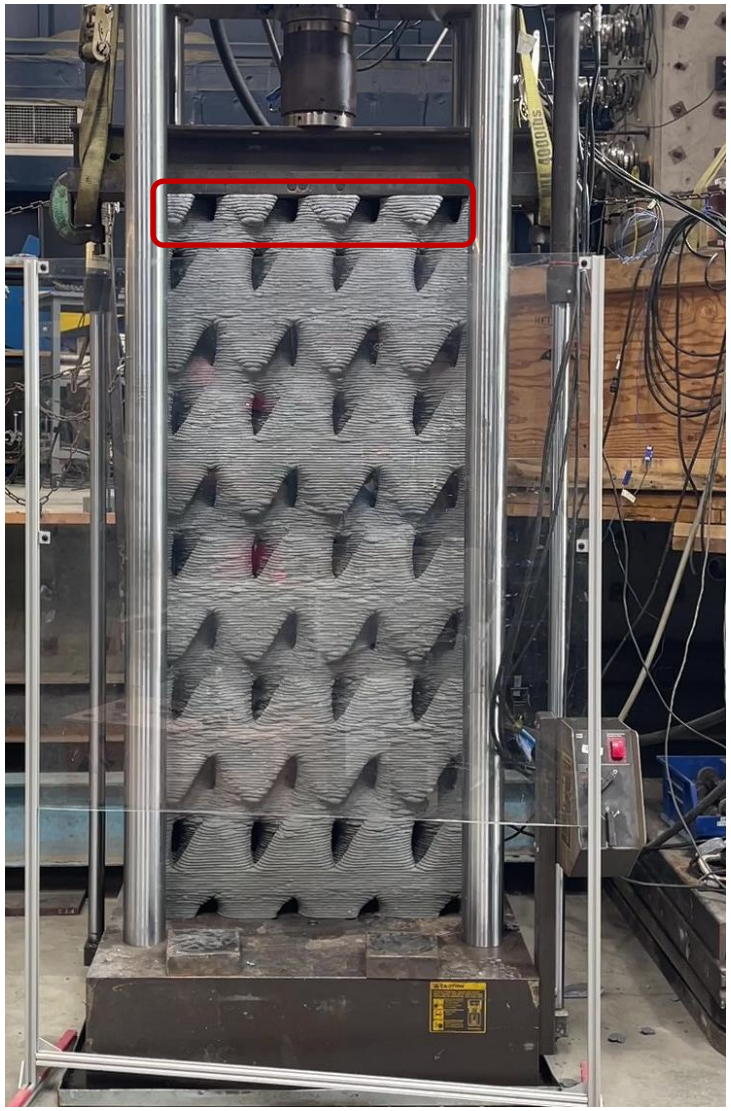
- 7 Axis ABB robot arm
- XtreeE printhead and feed
- 2-part system, accelerator added at nozzle
- 50-70 Liter batches for continual throughput
- 1 hr 45 min printing time

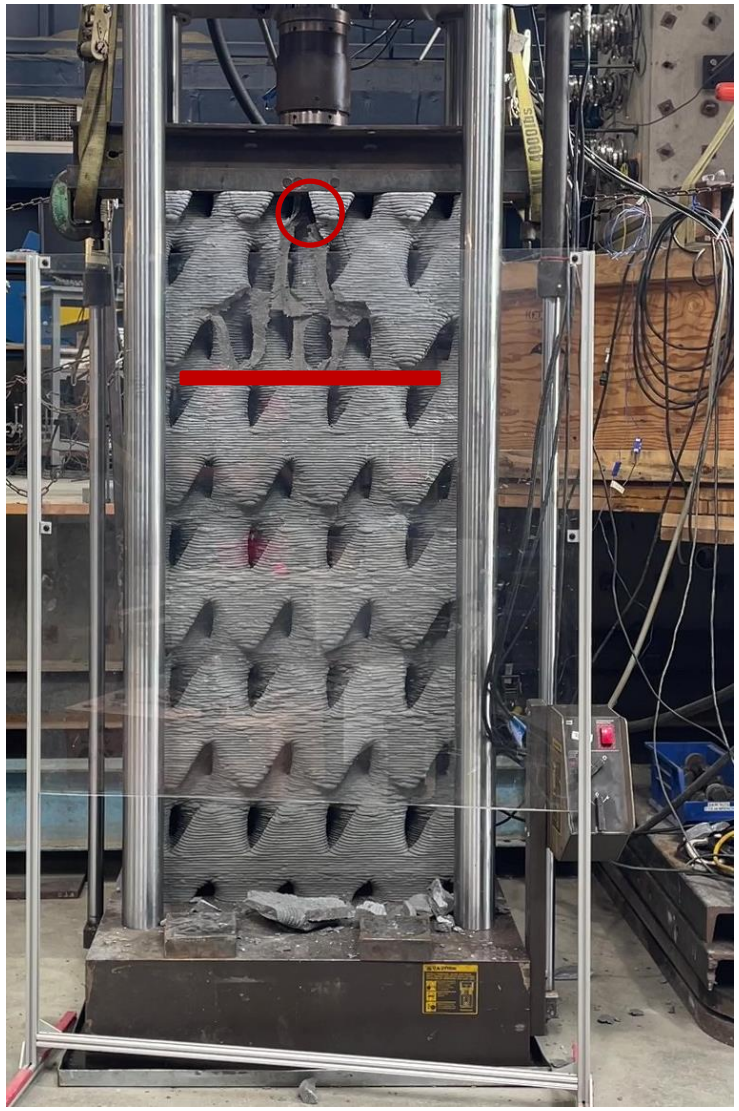


Wall Compression Testing

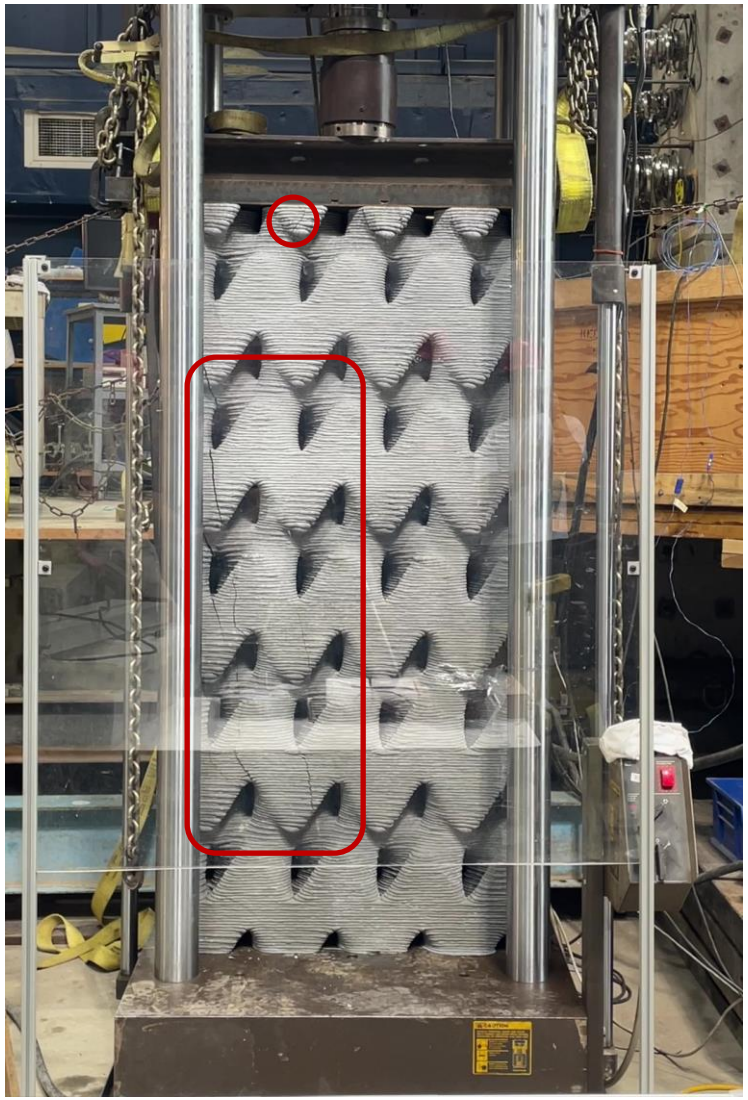
- 2 walls printed
- 28-day strength
- Uniaxial compression test
- Displacement controlled 1.27 mm/min

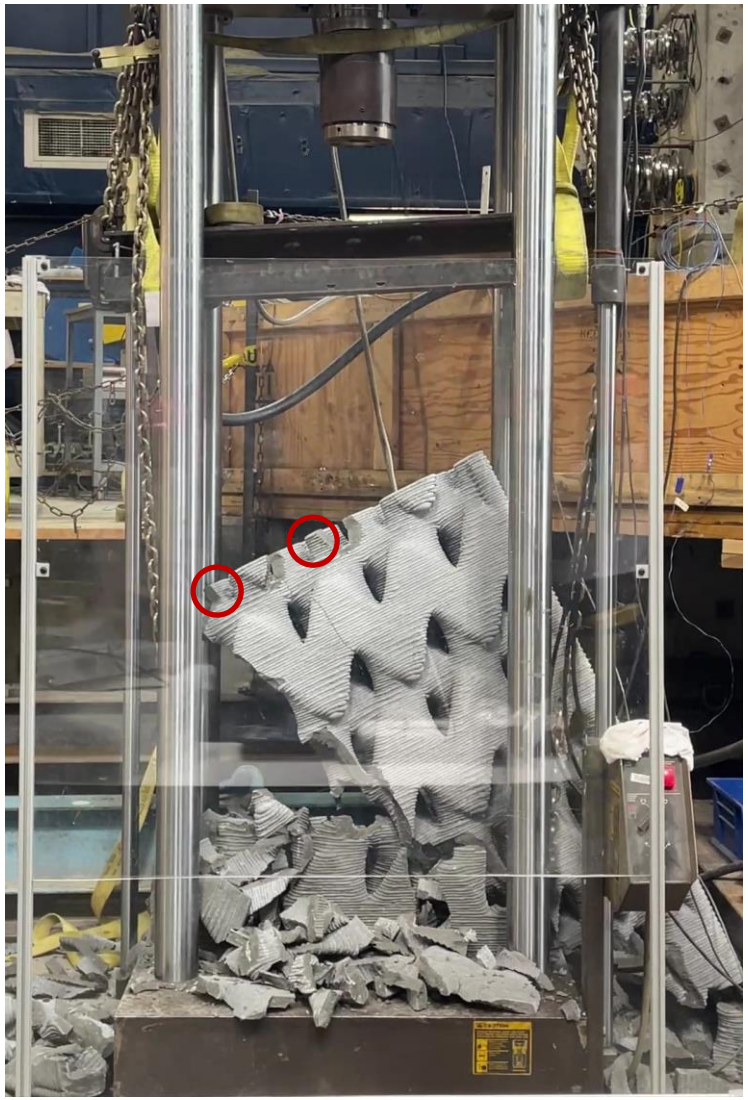
Closed Toolpath Testing & Failure



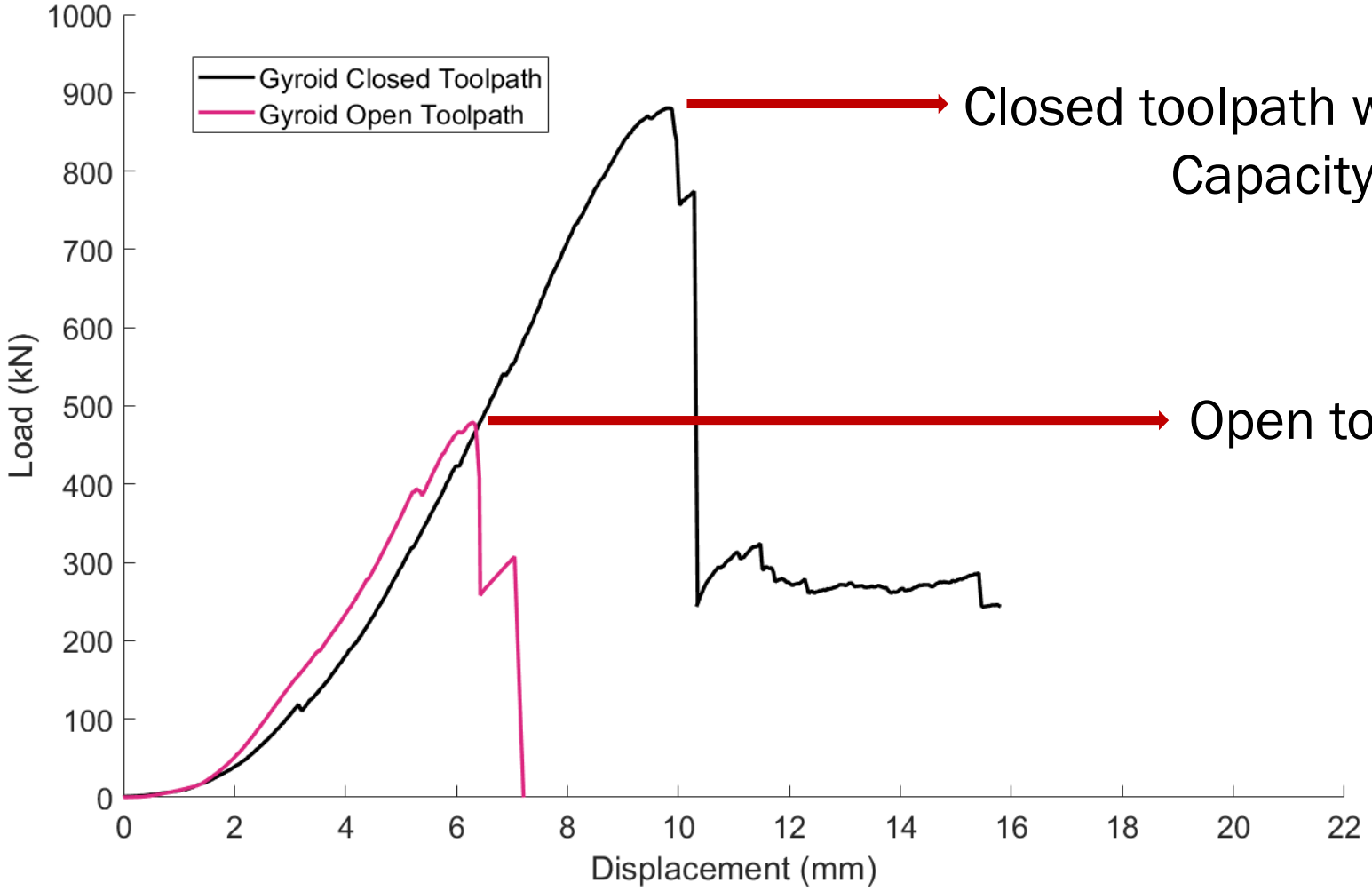


Open Toolpath Testing & Failure





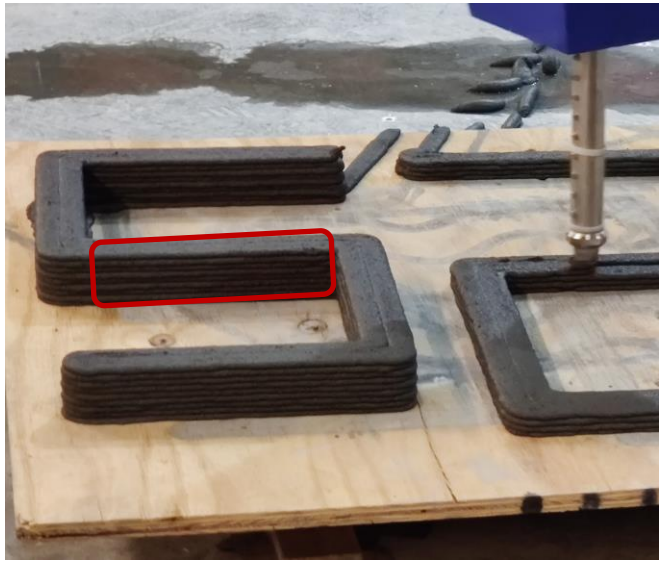
Gyroid Toolpath Mechanical Strength

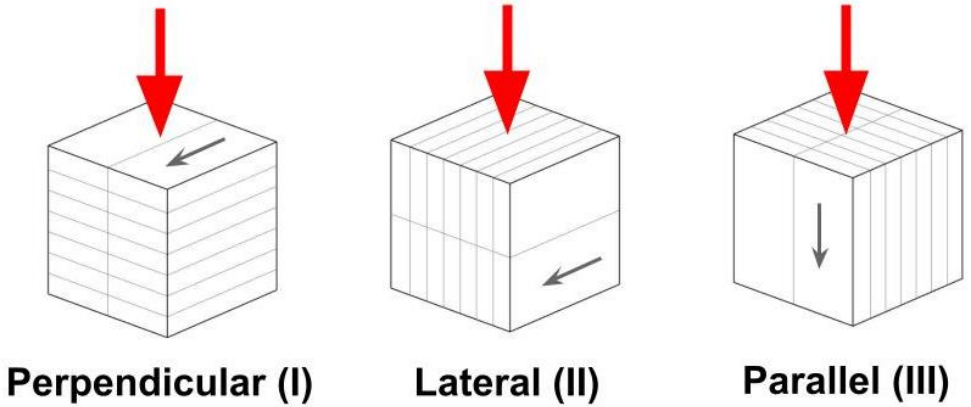


Closed toolpath wall: 880 kN, 480 kg
Capacity/wt. = 1.83

Open toolpath wall: 480 kN, 380 kg
Capacity/wt. = 1.26

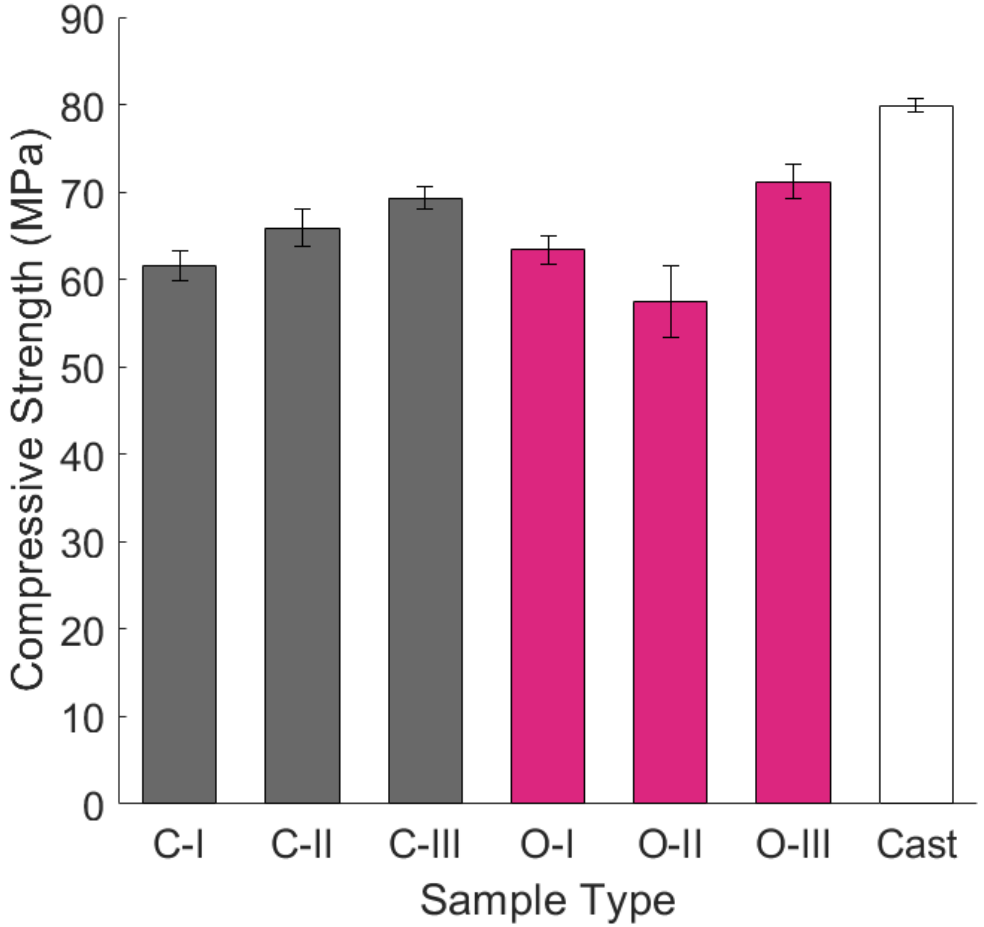
Small-Scale Compression Testing

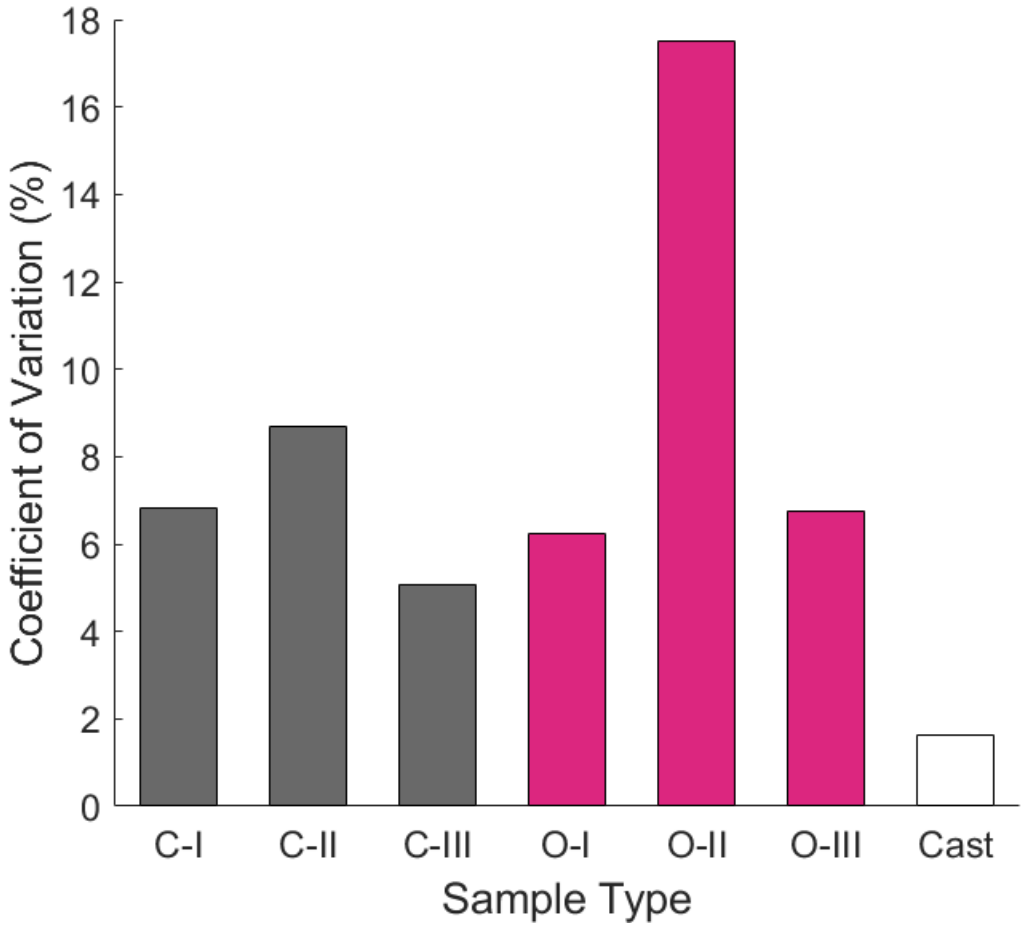


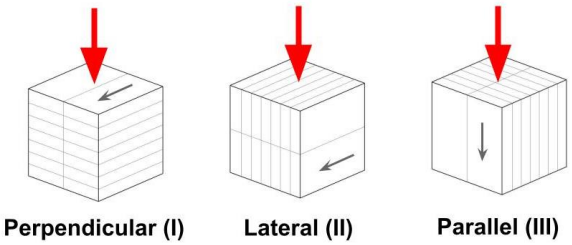


- 50 mm cubes
- Six cubes per orientation
- Open & closed toolpaths, and cast

Small-Scale Compression Results

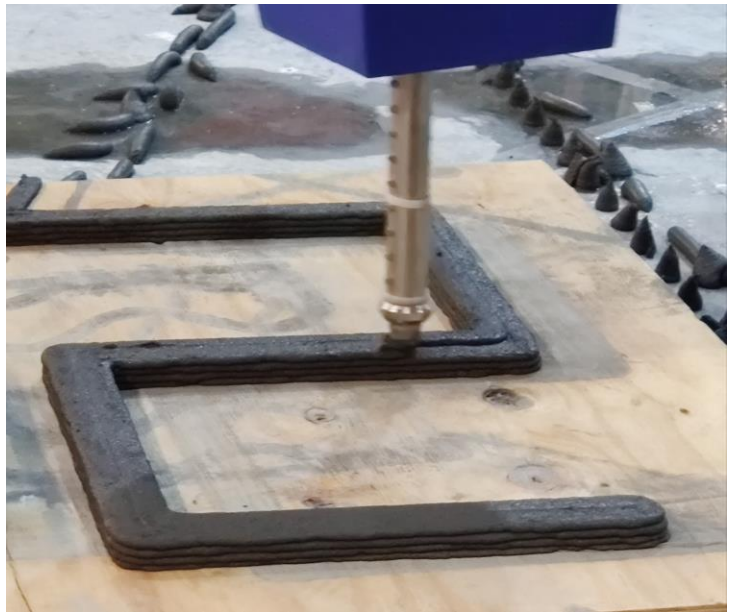


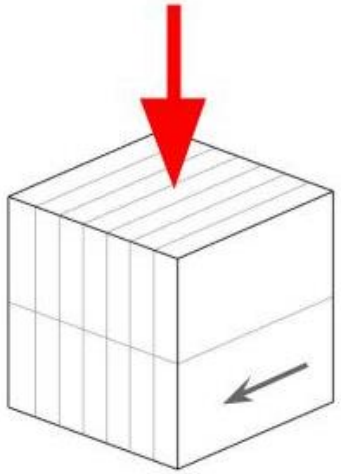




Weakness in O-II Samples

- No confinement during printing lets mortar spread out laterally
- Literature shows orientation II can be weak due to mortar spreading
- Can be impacted by interlayer delay





Lateral (II)

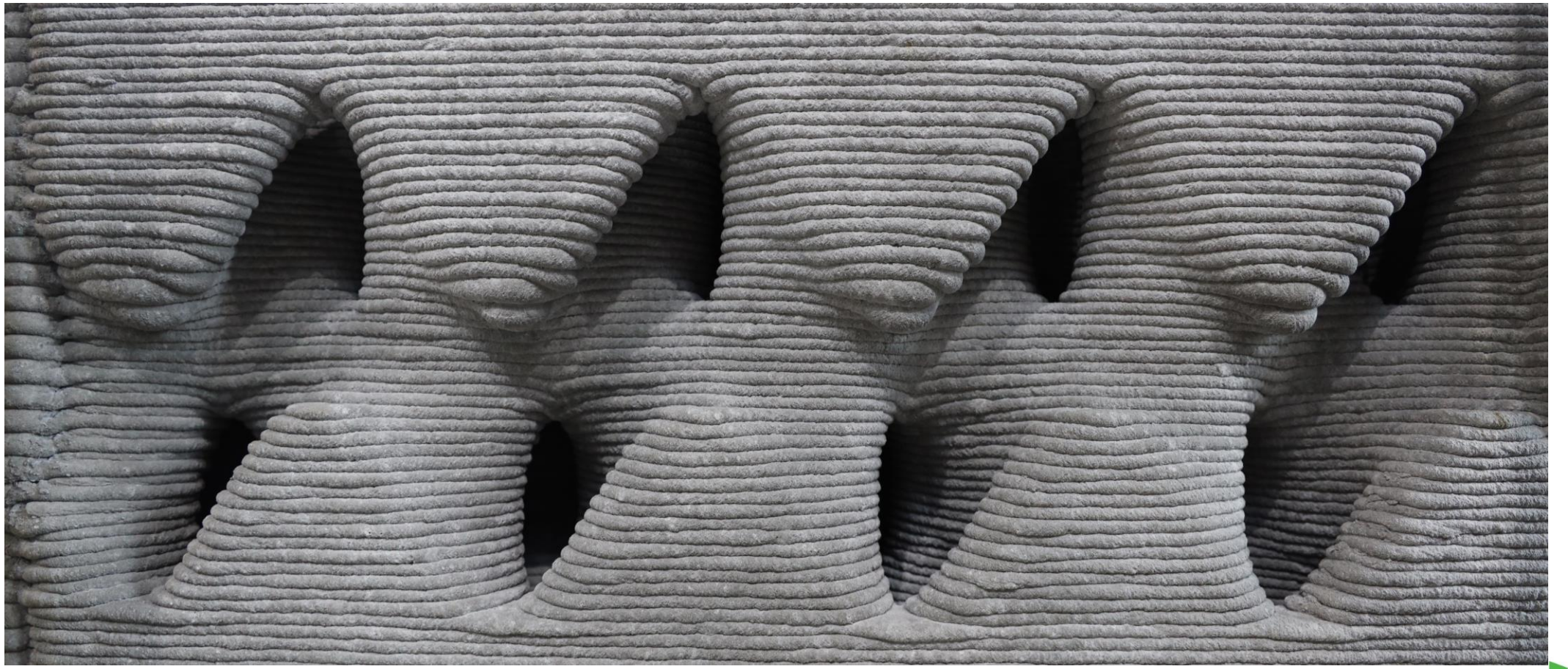
Failure Mode, Properties, and Performance

Possible relation between failure of open toolpath wall and weakness of samples under lateral loading

Conclusions and Next Steps

- Successful printing of gyroid shape with 3DPC
- Overhang design and cutoff of gyroid can limit maximum strength
- Toolpath impacts performance, Open toolpath weaker
- Finite Element Model under construction
- Testing of third wall and fresh state underway

Thank You



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