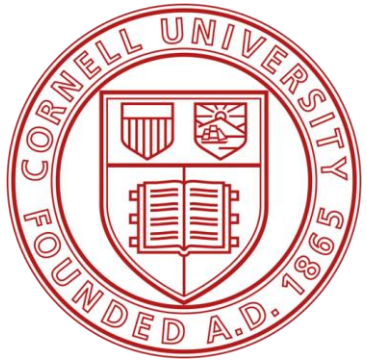
Bio-Inspired 3DCP with Low-Carbon Footprint

Moneeb Genedy & Sriramya Nair

School of Civil & Environmental Engineering, Cornell University

Lawson Spencer, John Conrad & Sasa Zivkovic

Architecture, Art, and Planning, Cornell University



Outline

- Large-Scale 3D Printer
- Materials & Mixture Design
- Design and Concept
- Printing of Gyroids
- Mechanical Testing
- Conclusions

Large-Scale 3D Printer

ABB, IRB 6650S-90/3.9
- 12.8 ft Reach

XtreeE, xFEED
- Mortar Pump System

XtreeE, xHEAD
- 3D Print Extruder

Mortarman, Mix 360
- Mixer

Min. Mixing Volume: 50 L

Materials & Mixture Design

- w/cm = 0.35
- Cement Paste Volume = 52%
- SCM Content by Weight = 30%
- Aggregate Maximum Nominal Size = 2 mm
- HRWR to achieve Flow Diameter of 17 cm
- Accelerator is injected at the nozzle

28 day compressive strength: 10,800 psi

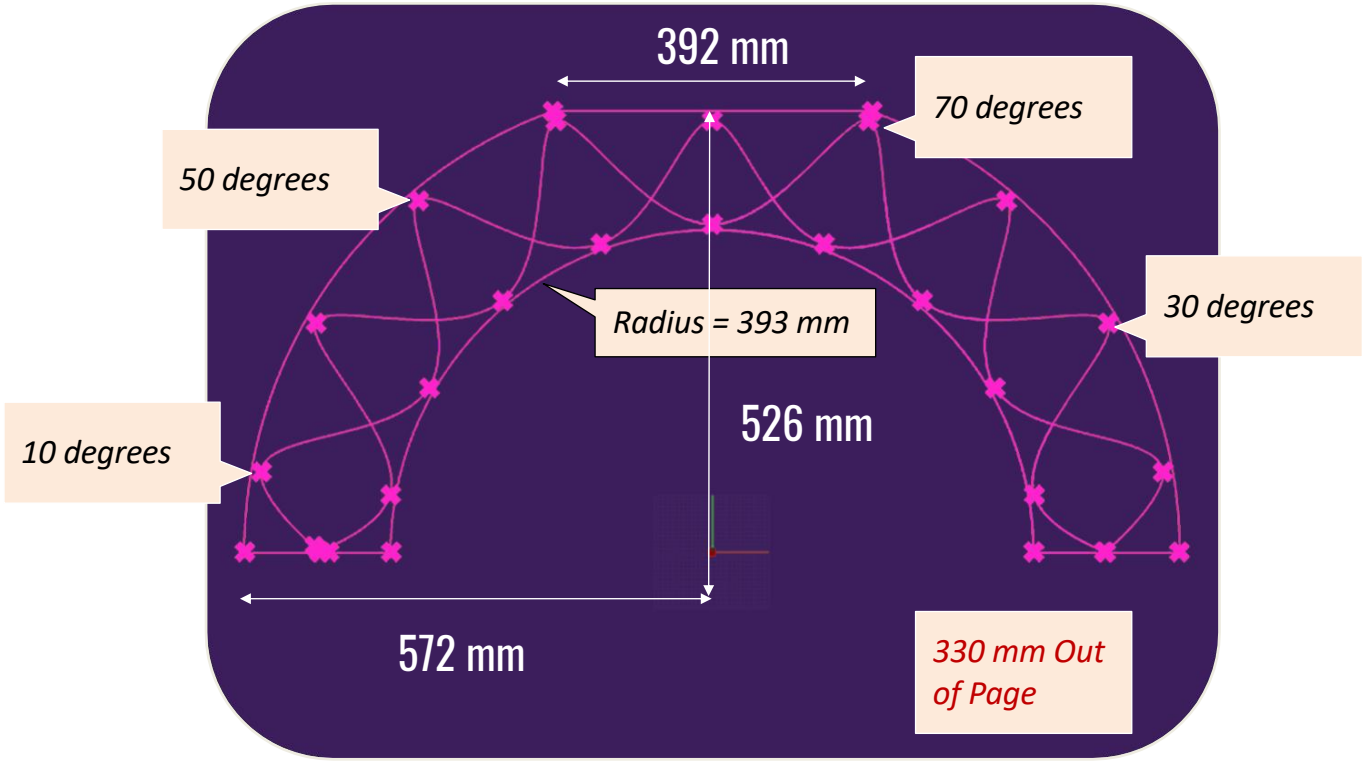
28 day flexural strength: 800 psi

Design and Concept

Stacked Layers
32 inches printed in one continuous session

Design and Concept

Designed by students in Sustainability and Automation: The Future of Concrete Industry



Low Carbon Footprint?

- w/cm = 0.35
- Cement Paste Volume = 52%
- SCM Content by Weight = 30%
- Aggregate Maximum Nominal Size = 2 mm

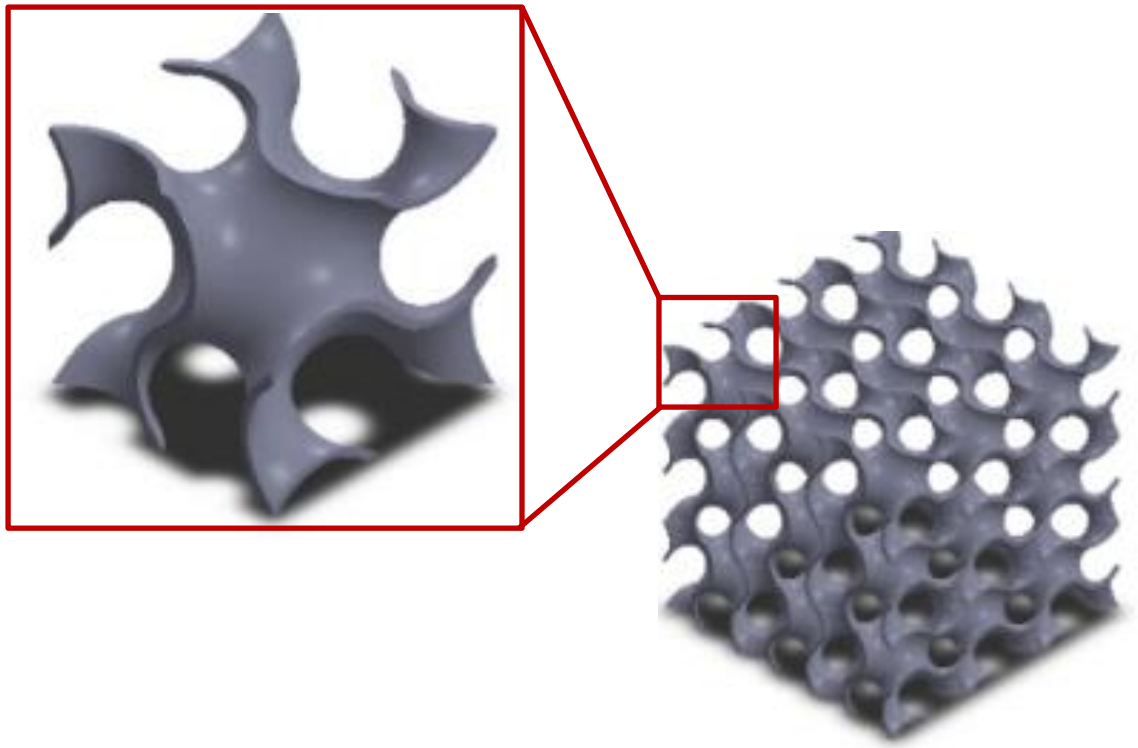
Main Contributor to GHG Emissions

⇧ Paste Volume Needed for Pumpability

Lower carbon footprint can be achieved by shape optimization enabled by 3D printing.

2-part system offers the freedom to quickly and efficiently construct free-form structures.

Gyroid Geometry and Design



Gyroid Unit and Array

Why Gyroid?

Efficiently distributes high compressive load.

Challenge?

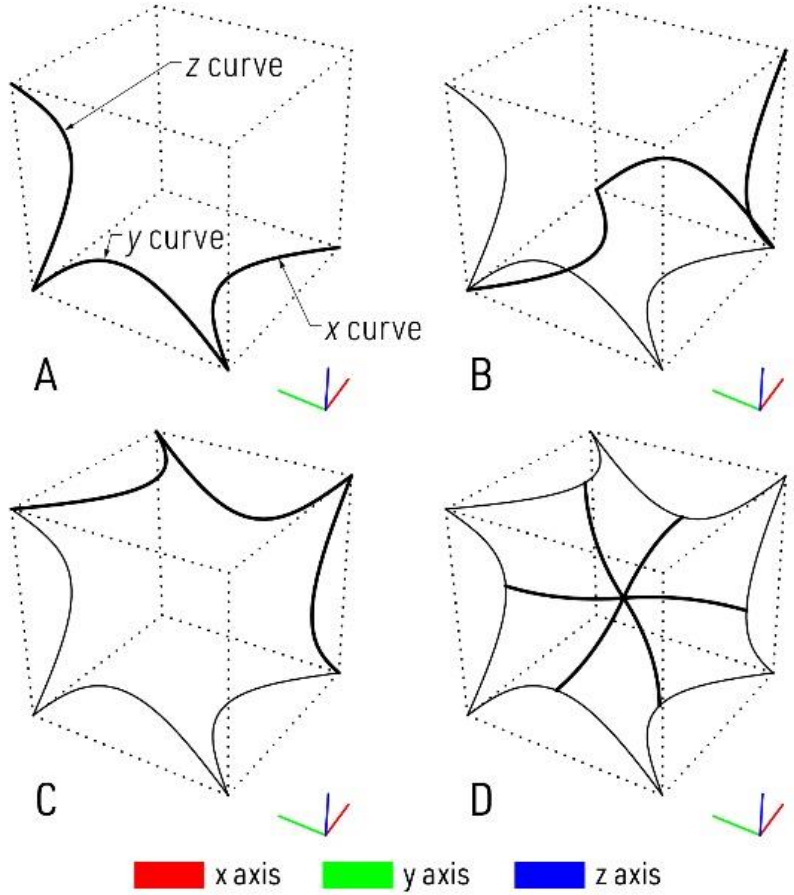
Effective printing of steep cantilevers

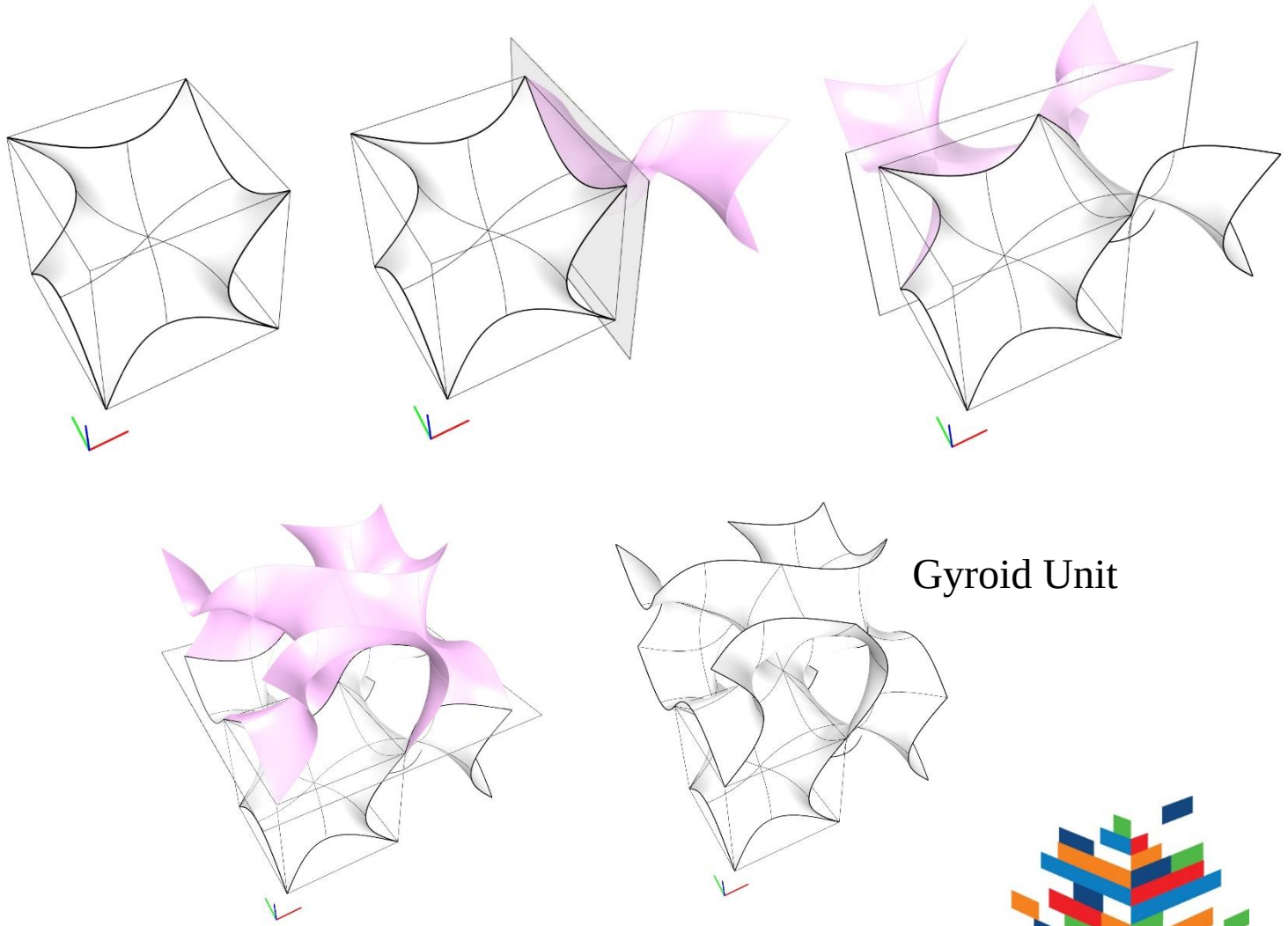
Benefits?

Lowers the volume of concrete required to carry the same load.

Lower overall carbon footprint

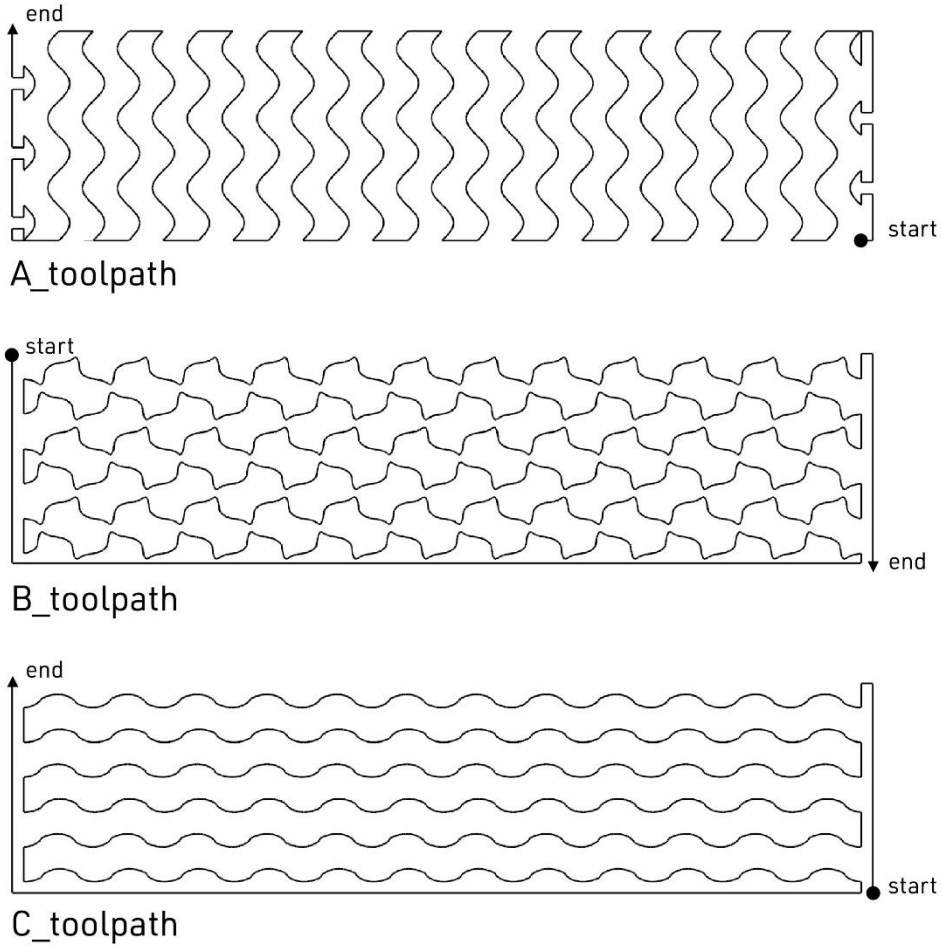
Gyroid Geometry and Design

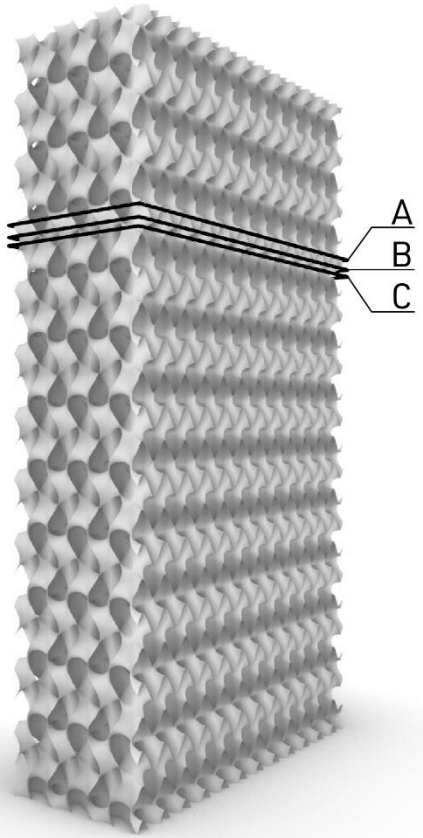




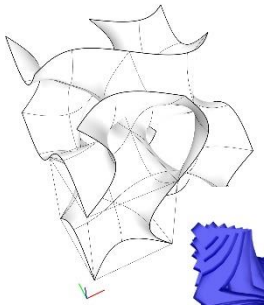
Gyroid Unit

Development of continuous tool path

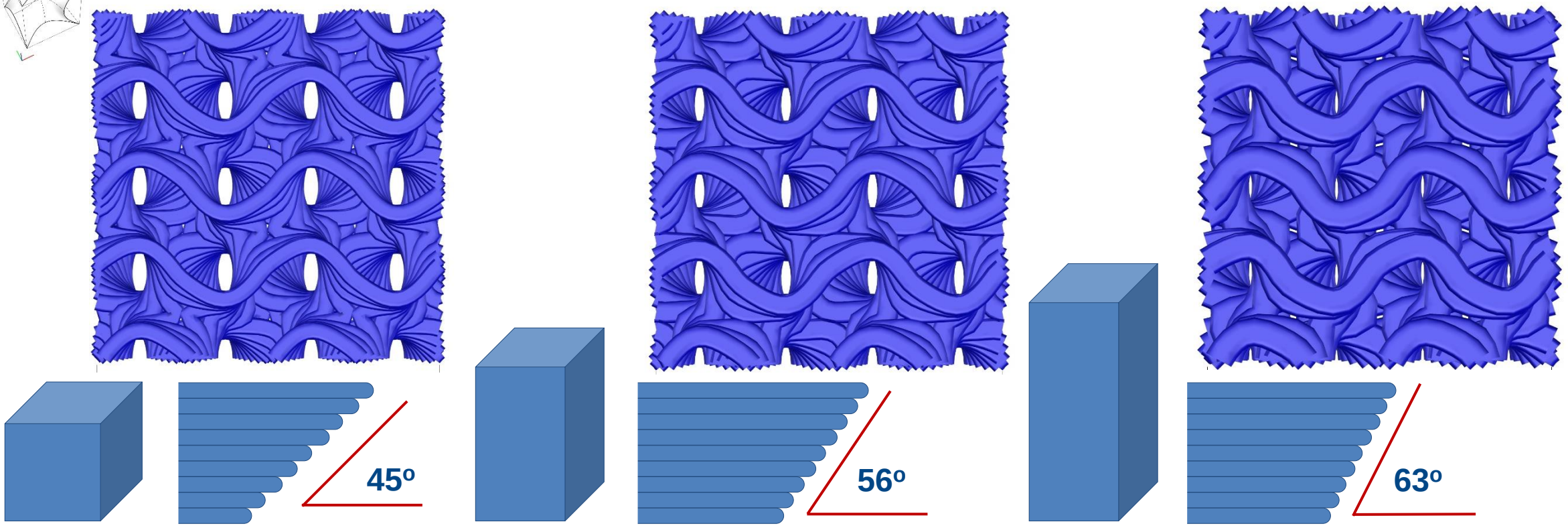




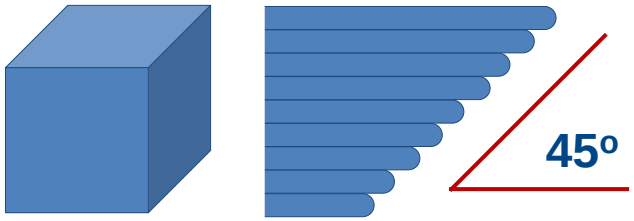
Density limitation test



Gyroid geometries with 3 different densities were printed to determine the maximum overhanging angle

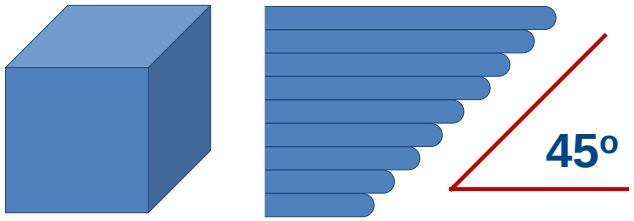


Density limitation test



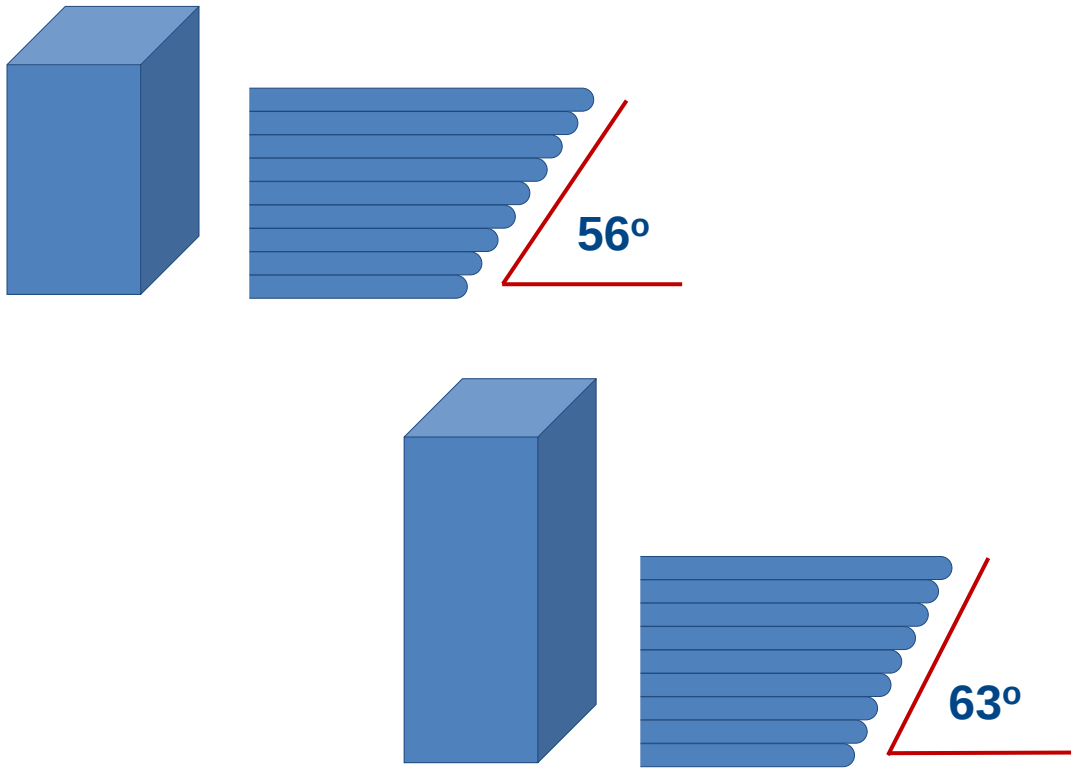
Tool path plays an important role!

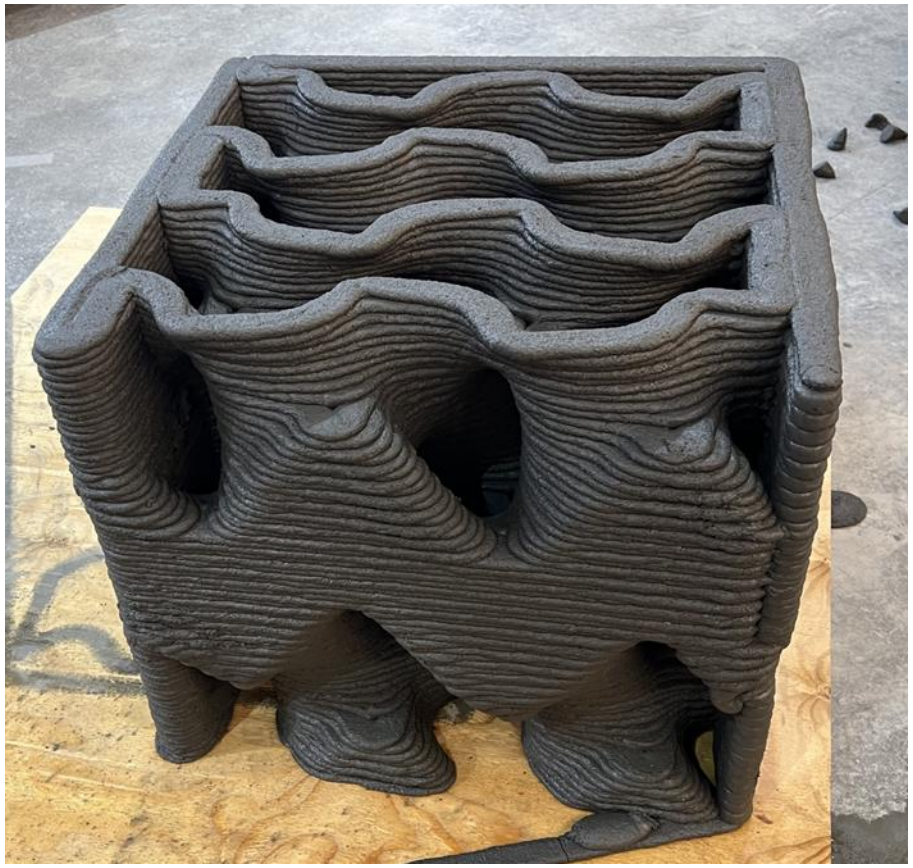
Density limitation test



Cracking was observed in one overhang after a few hours.

Density limitation test

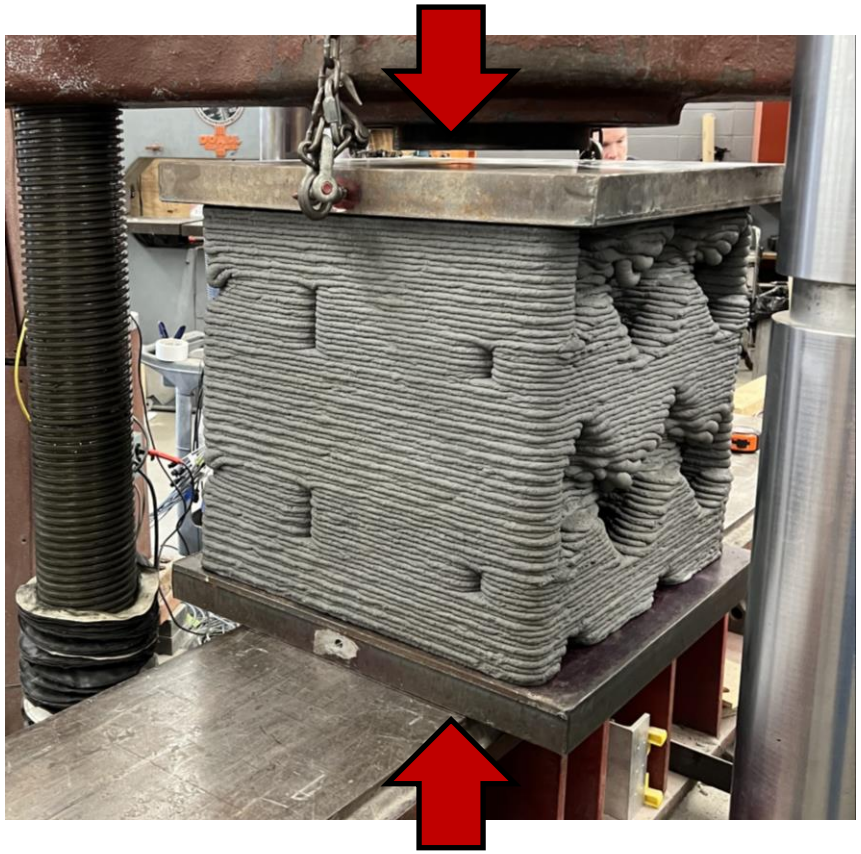


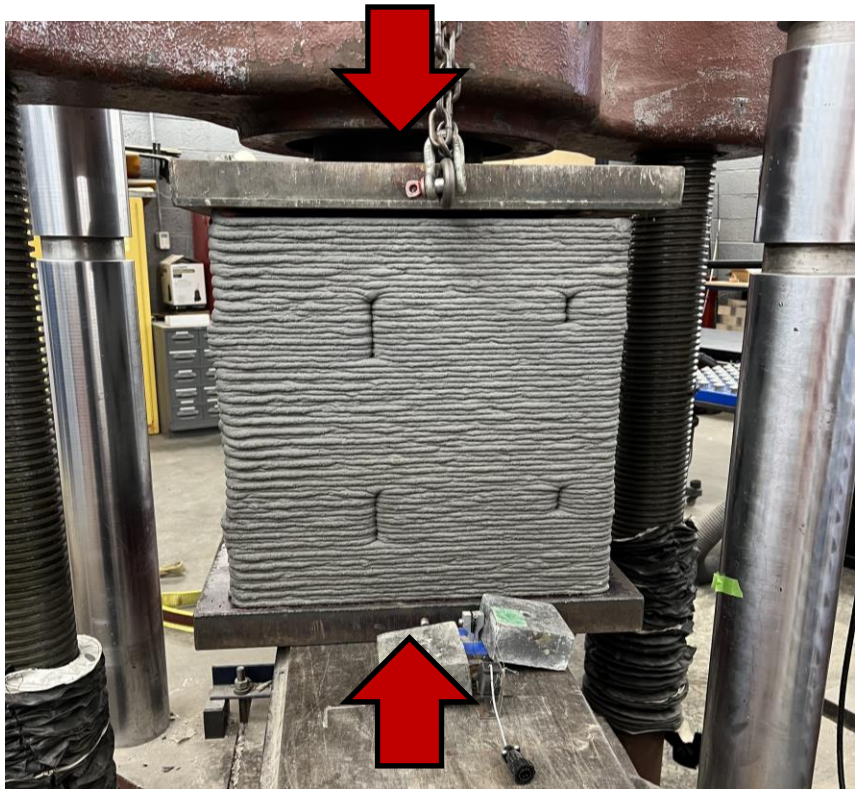


No collapse was observed with overhanging angles of 56º and 63º

Test Setup

Displacement rate of 0.05 in/min



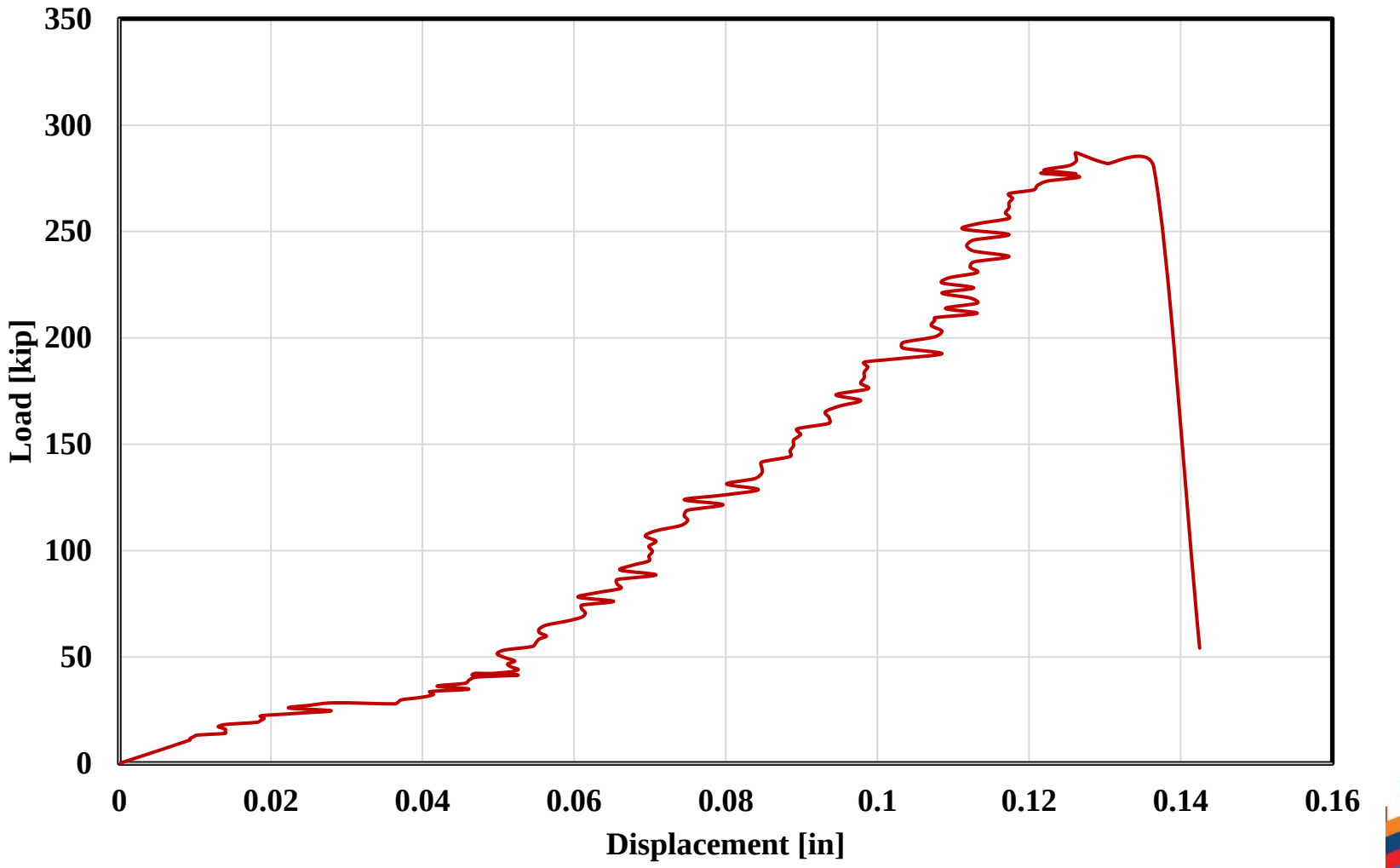


Mechanical Testing

Results

Ultimate Load
270 ± 20 kip

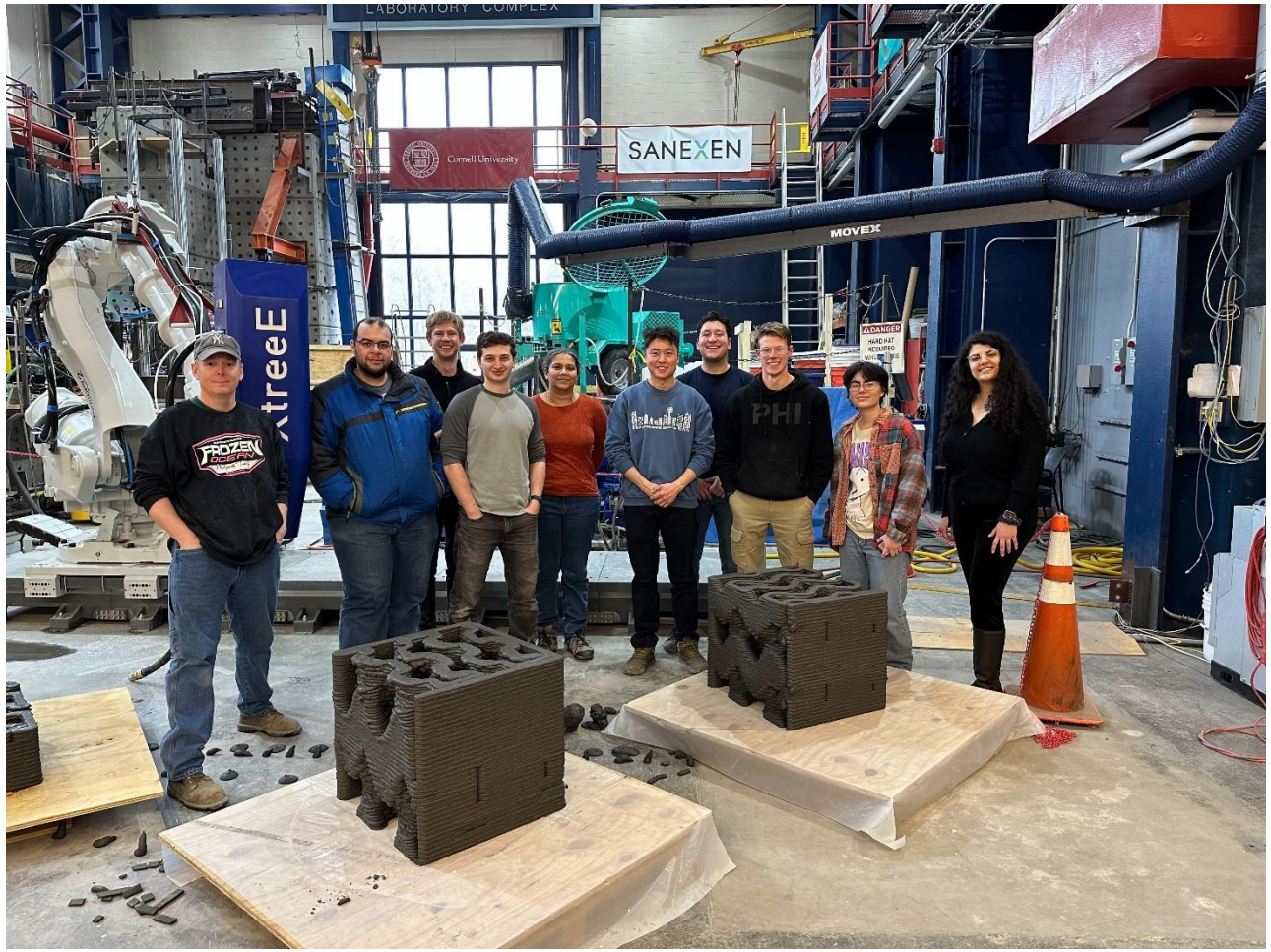
Capacity/wt :
900 ± 70



Conclusions

- A bi-component X-TreeE system was used with an in-house developed mortar mixture.
- A continuous tool path was developed for printing of gyroids
- Density tests were conducted to determine the maximum feasible overhang angles.
  - 56^{o} and 63^{o} angle overhangs were printed without any difficulties.
- With a capacity/weight of 900, instead of printing only the formwork for walls, printing a gyroid system enhances the load carrying ability of the walls.

Thank you!



nair.cee.cornell.edu