Stress Strain Properties of Auxetic Structures

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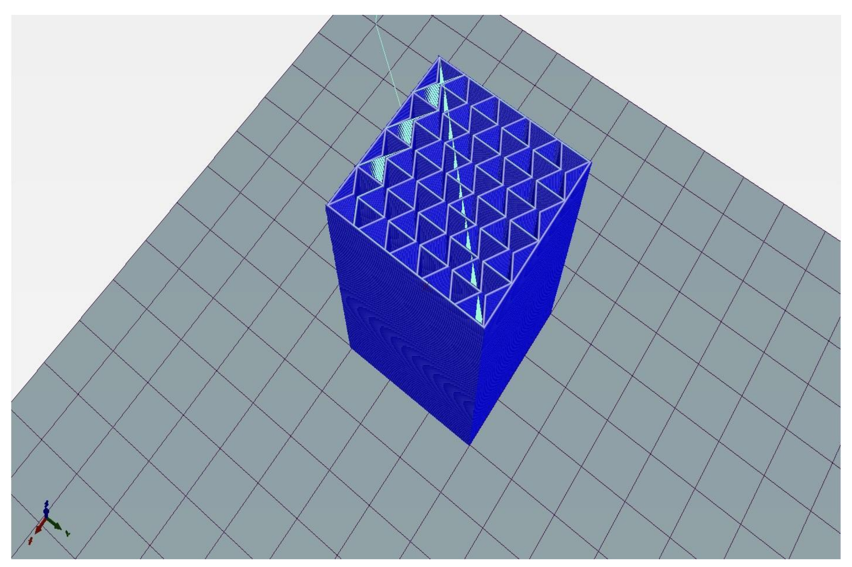
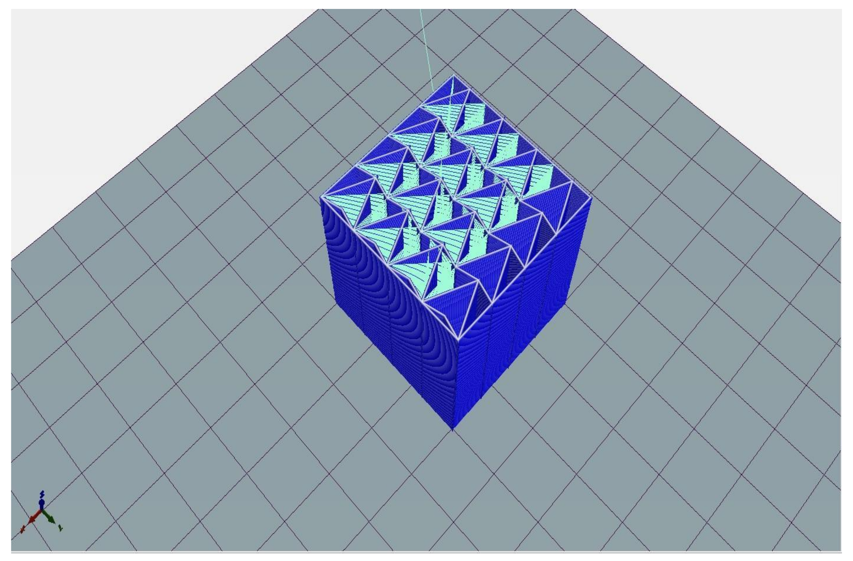
Research question: Does a metamaterial with more Auxeticity imply greater Stress handling Capabilities?

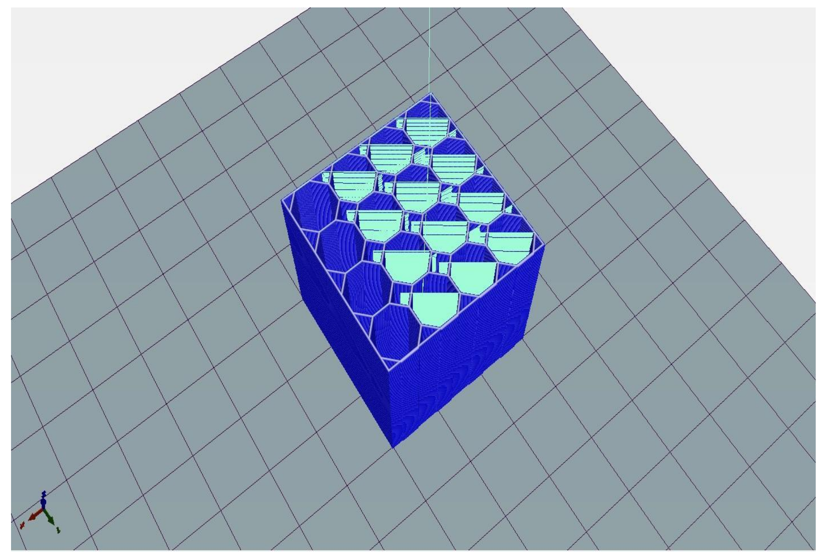
Background: Auxetic Structures are a relatively new concept which was first introduced in 1991 by Evans. In traditional and pattern less materials, there would be a positive Poisson's ratio which would mean under vertical compression, the thickness of the material will expand horizontally. In metamaterials with a certain auxetic pattern, the material would contract under compression. There are different categories of Auxetic Materials: Re-entrant, and Chiral patterns. Re-entrant patterns are those which allow the structure to collapse inwardly to a degree whether that means having some room for small deformation or just the tendency for the pattern to do so. Chiral Patterns are structures that have a rotation mechanism that causes the auxetic property. Main research into these patterns have been small deformations and study on their Young's Modulus and Poisson's ratio.

Research Abstract: The main goal of this project is to be able to confirm whether certain patterns are auxetic as some literatures claim and to obtain their Stress-Strain diagrams for comparison. Having searched through multiple different auxetic patterns, the 3 patterns have been chosen for their ease in 3D Printing. A lot of difficulty was encountered with 3D printing using TPU filament and Samples had to be 3D printed by creating G-Code directly instead of the traditional method of an STL file. Both Grid Samples and Re-entrant Samples were created using this method. Using a Universal Testing Machine, 3 Grid Samples and 2 Re-entrant Samples were compressed to obtain their Stress Strain Diagram. Note that the ends of the Diagrams do not represent fracture but rather the maximum limit of 500 N force applied. Important characteristics such as Young's Modulus and Yield Strength show that the Re-entrant pattern is better than the Grid pattern. Additionally, The re-entrant pattern shows auxeticity in smaller strains.

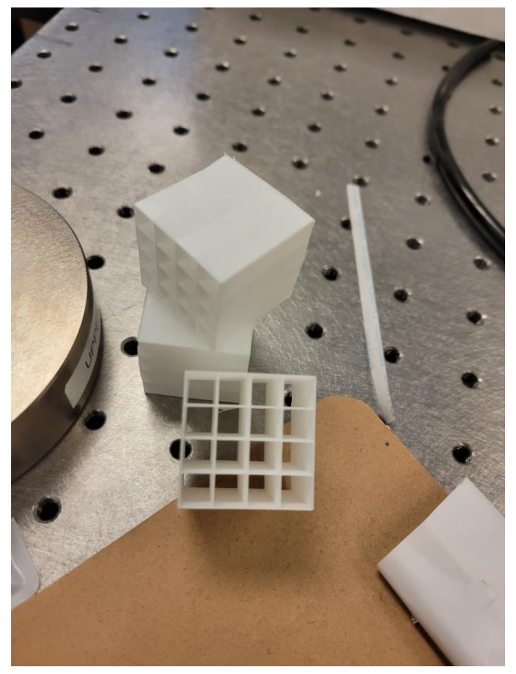
Samples created using Full Control G-Code developed for Re-entrant, Arrowhead and Octogonal respectively

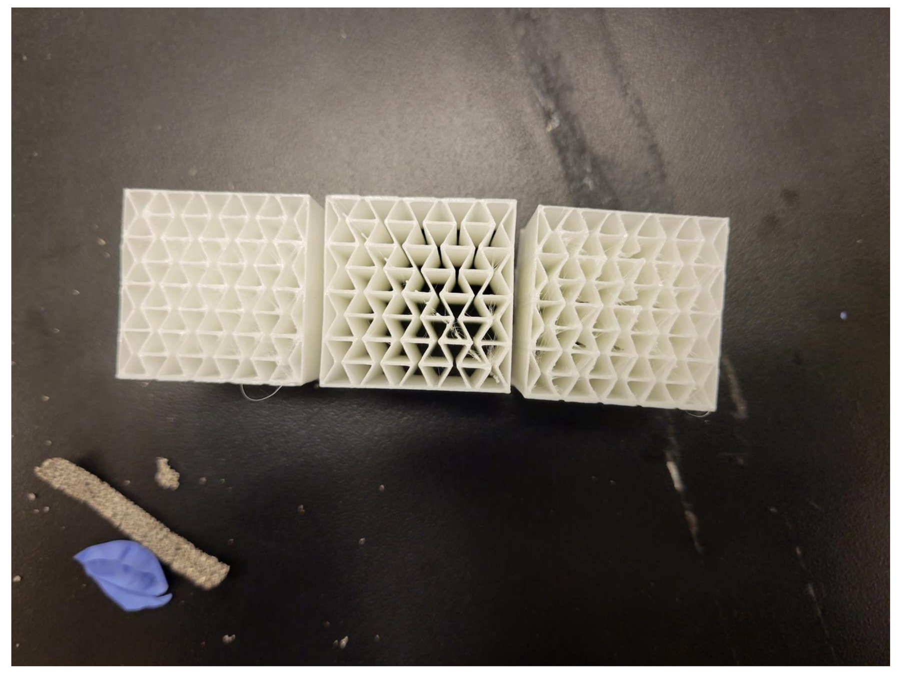


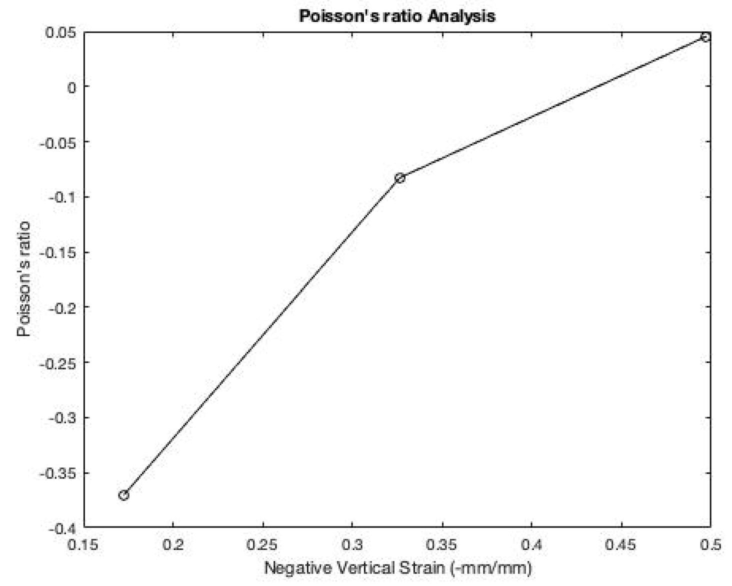


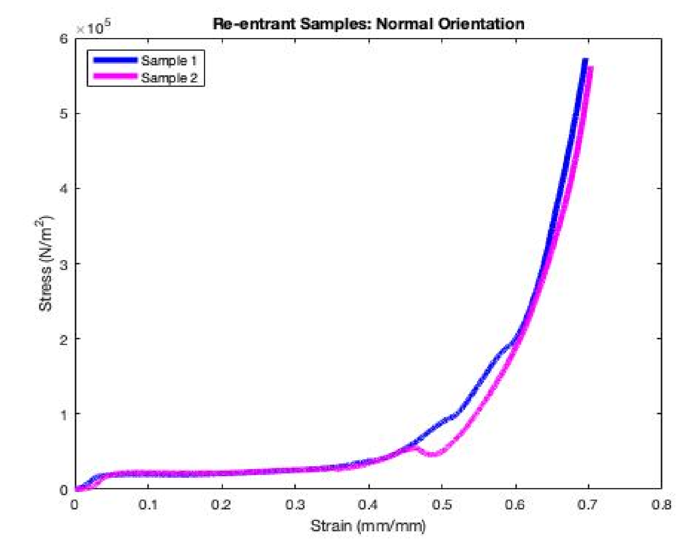


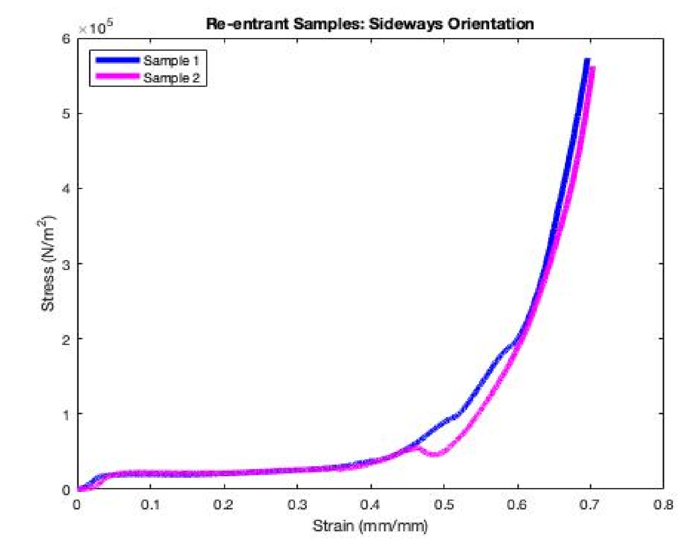
Due to 3D Printing difficulties using TPU and time constraints, only the Re-entrant and Grid pattern were printed and tested. Samples were compressed using a Universal Testing Machine to obtain Stress-Strain Diagrams and were manually compressed and measured for their Poisson's ratio

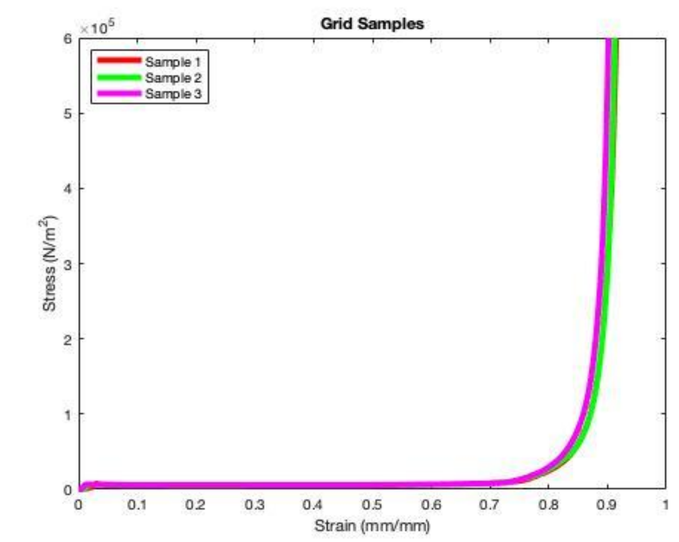


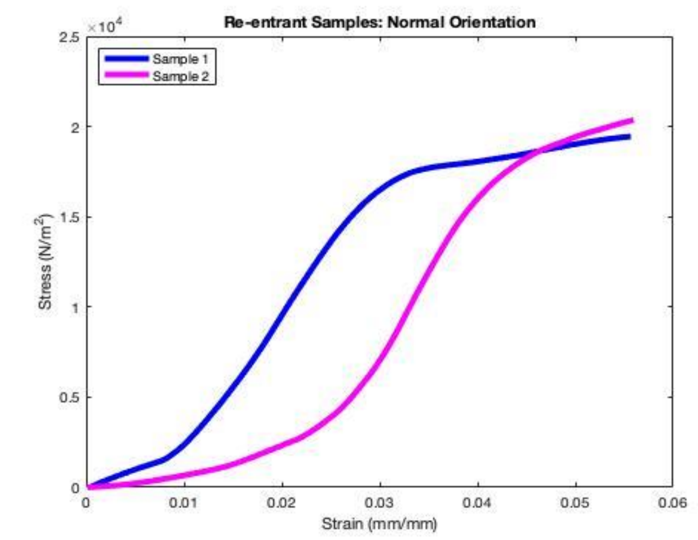


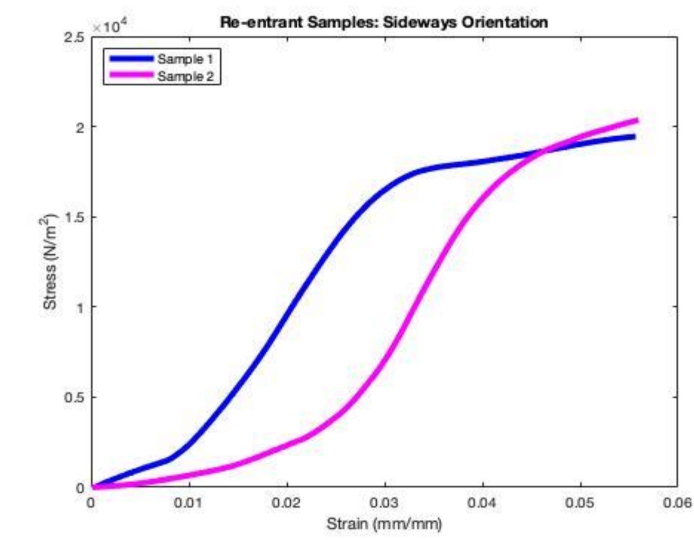


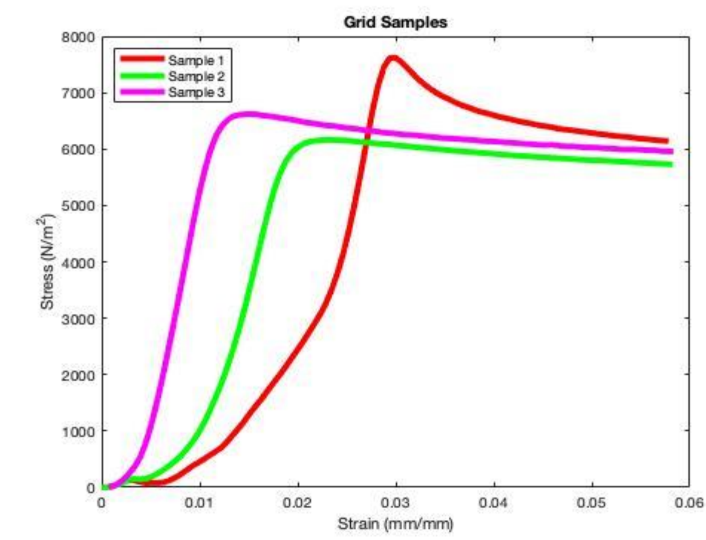












Re-entrant Vertical
E = 628.7 kPa
σ_y = 18723.45 Pa
ε_y = 0.0455

Re-entrant Horizontal
E = 628.7 kPa
σ_y= 18697.45 Pa
ε_y = 0.04435

Grid Samples
E = 470.5 kPa
σ_y = 6552.09 Pa
ε_y = 0.0204

Against the Grid Samples, the Re-entrant patterns provide stronger Stress handling Capabilities based on comparisons on their Young's Modulus (E), Yield Strength (σ_y) and Strains (ε_y)

Future Work should take into consideration:

- Volume of TPU used
- better methods for measuring Poisson's ratio, i.e. Strain gages, Speckle Spray

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