DESIGN AND DEVELOPMENT OF AUXETIC STRUCTURES FOR IMPACT APPLICATIONS

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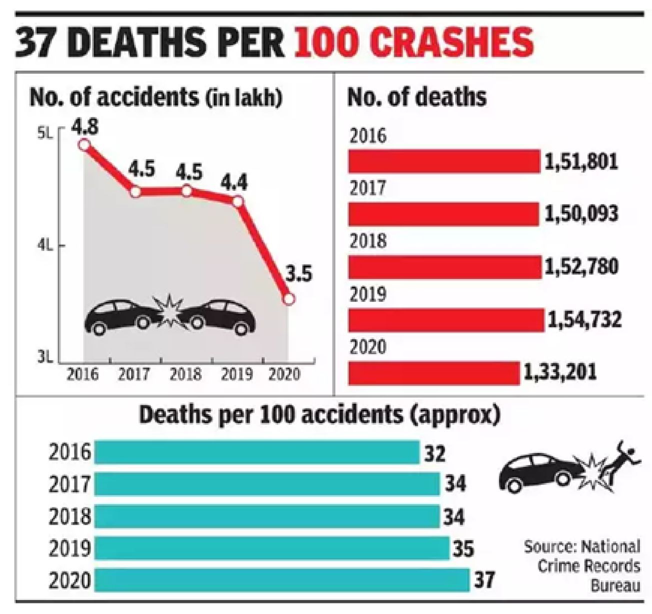
Introduction

- Traumatic brain injuries resulting from road accidents and sports activities are a growing concern that warrants attention.
- These injuries can have devastating effects on people, especially those aged 5 to 29, are the most vulnerable.
- Approximately 1.3 million individuals lose their lives annually due to road accidents, and between 20 and 50 million people sustain non-fatal injuries.
- In the US, sports and recreational activities account for 10% of the 1.7-3.8 million traumatic brain injury cases each year.

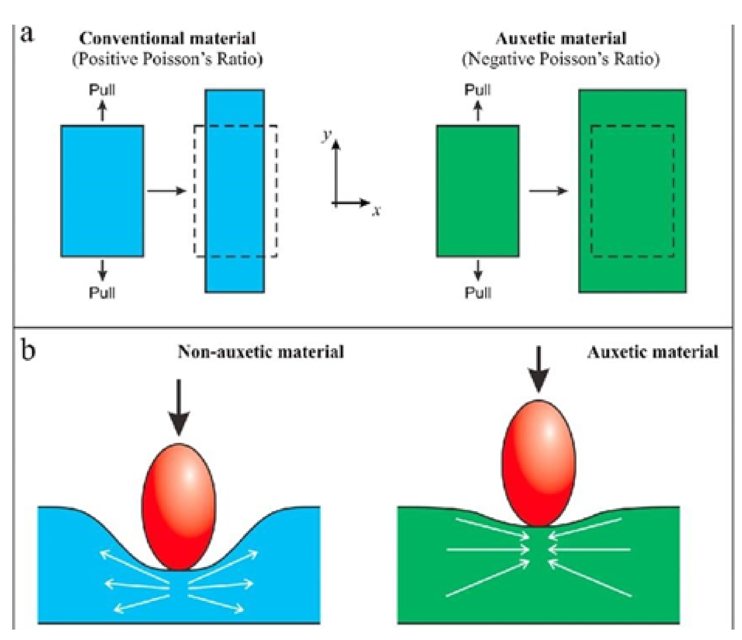


NCRB statistics

To mitigate the impact of head injuries and safeguard the brain from harm, safety equipment like helmets is crucial. Although helmets have been proven to be highly effective in reducing the risk of head and brain injuries, there is a need to enhance their efficacy even further.

Auxetic Structures

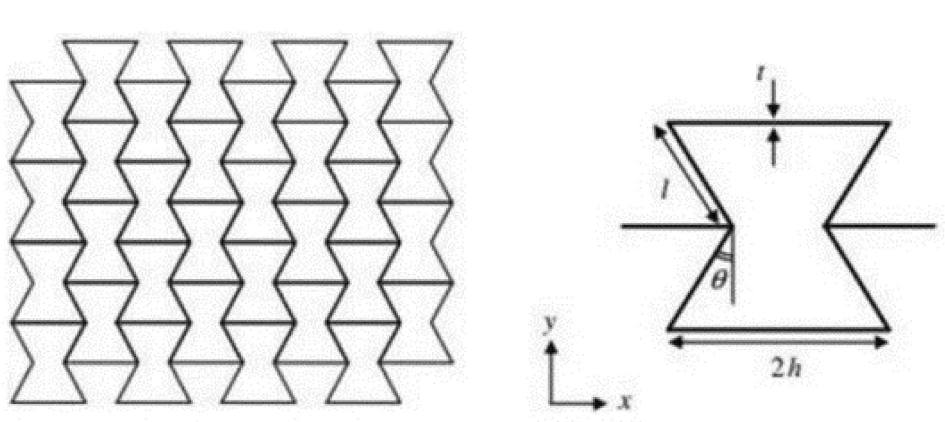
- Auxetic materials are those having a negative Poisson's ratio.
- Exhibit negative Poisson's ratio (NPR) due to unit cell configuration.
- Enhanced impact energy absorption performance, exhibit superior bending performance, and better indentation resistance.
- These properties makes auxetic materials particularly useful in the manufacturing of safety equipments, such as helmets and bullet proof vests.



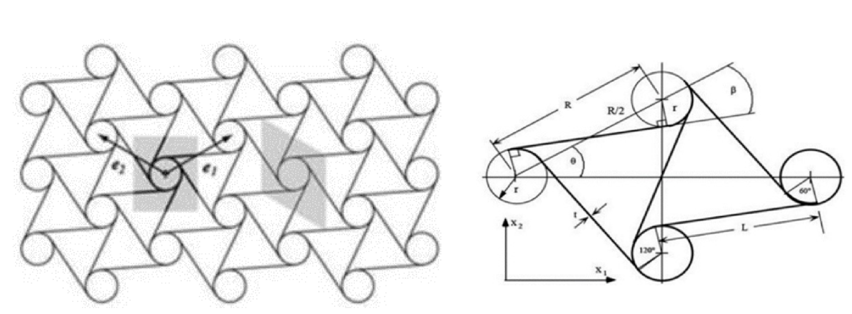
Behavior of conventional vs auxetic material
a) Tensile load b) Response to impact (Ji et al, 2018)

Different unit cell configurations

Auxetic structures are defined through the unit cells. There can be many types of unit cells and new kinds of unit cells are being witnessed with coming time. However, the most popular are, Reentrant models and Chiral models.



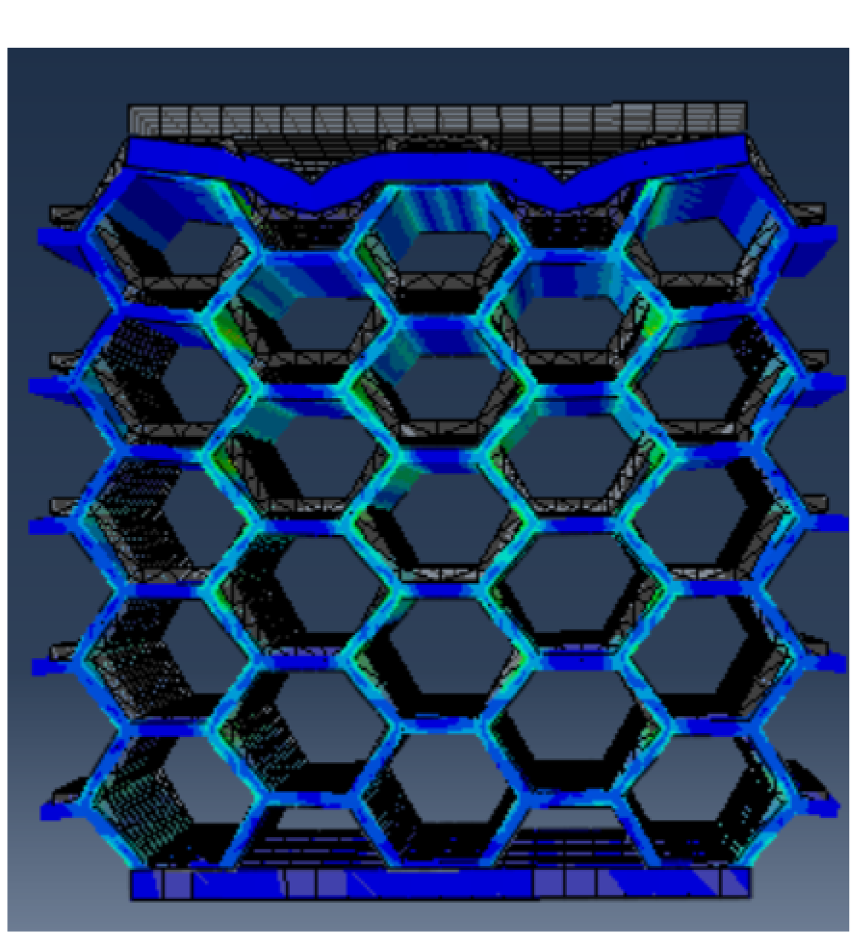
Reentrant unit cell (Francisco et al, 2022)



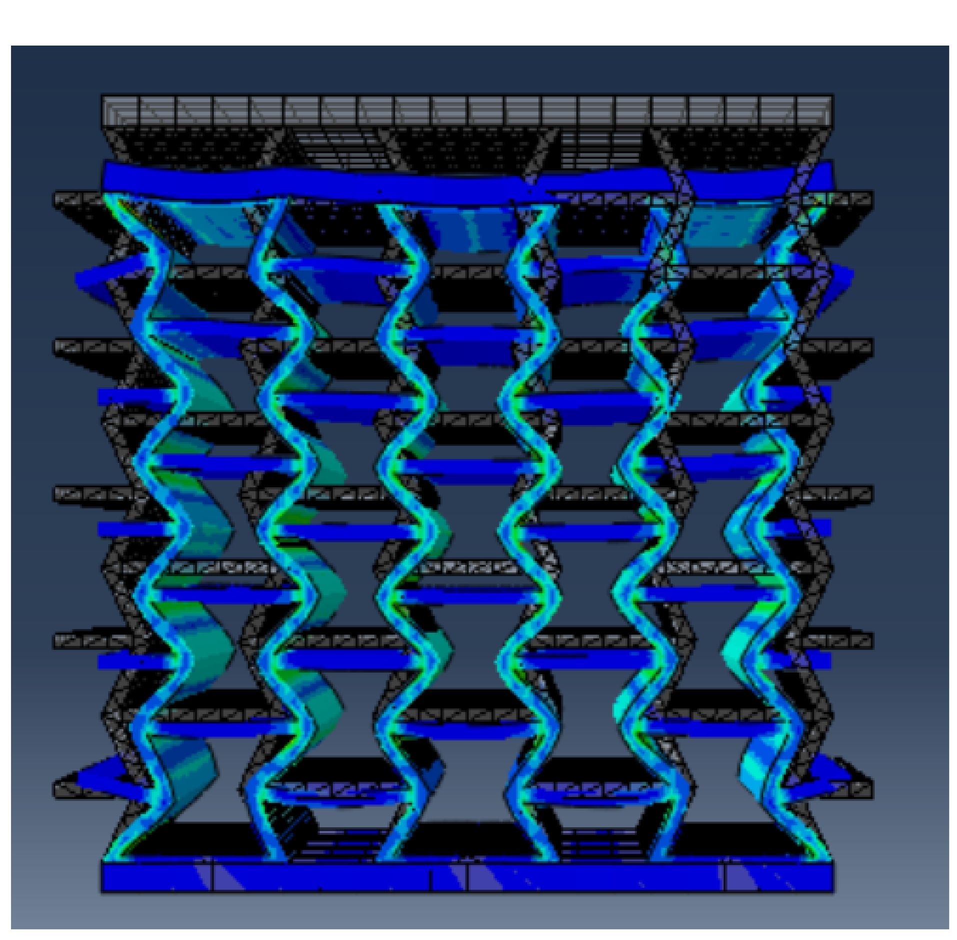
Chiral unit cell (Francisco et al, 2022)

Simulations

- Two kinds of unit cells are taken, conventional honeycomb unit cell, and reentrant unit cell (NPR) and simulations were performed on ABAQUS.
- Poisson's ratio for both the unit cells are calculated
- Stress and Deformation for both kinds of unit-cells is analyzed

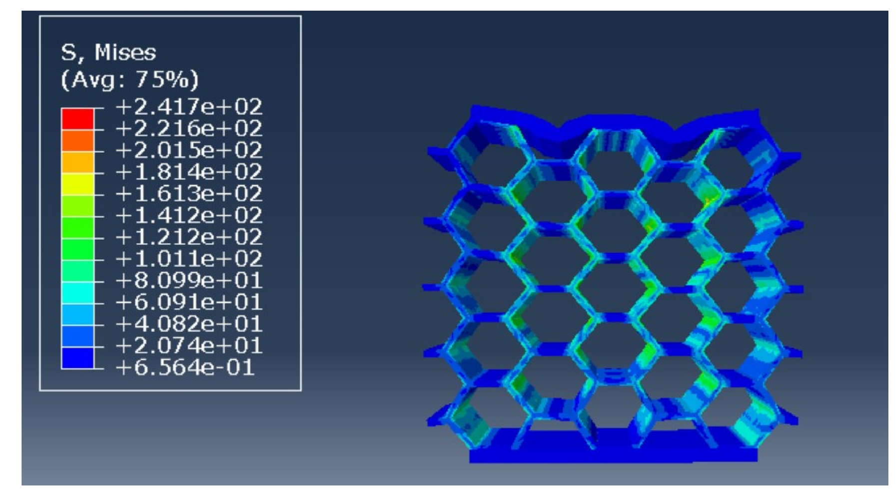


Honeycomb unit cell showing positive Poisson's ratio (PPR)

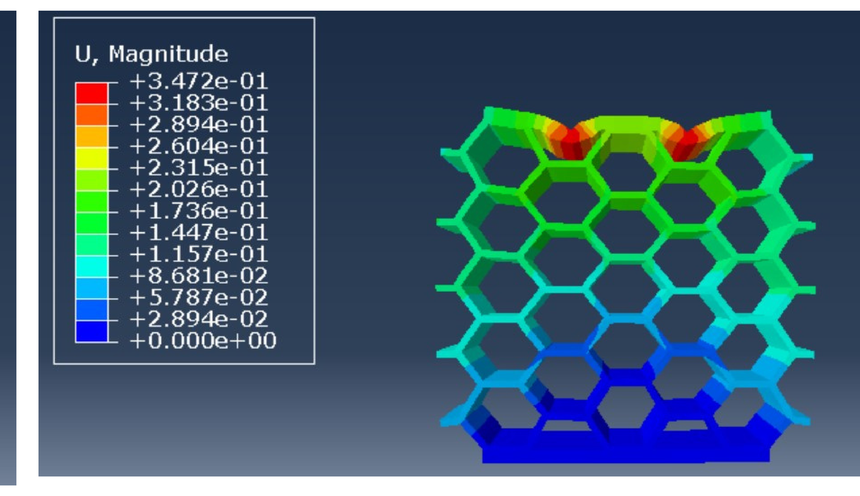


Reentrant unit cell showing negative Poisson's ratio (NPR)

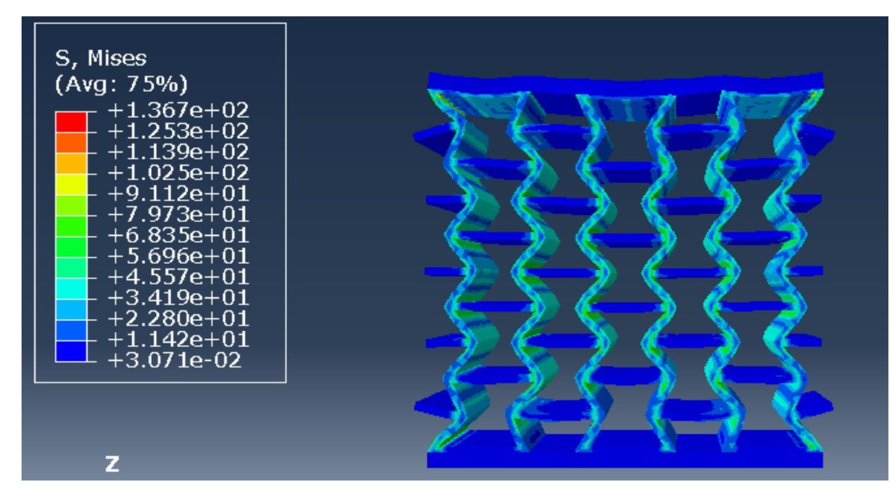
Stress Distribution and Deformation



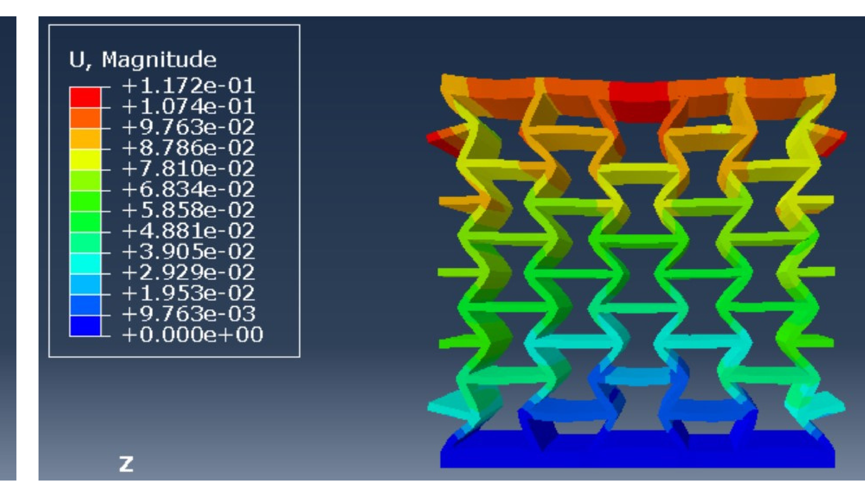
Honeycomb unit cell stress distribution



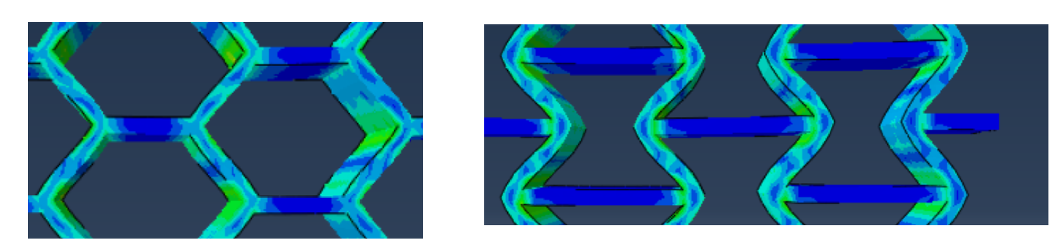
Honeycomb unit cell deformation



Reentrant unit cell stress distribution



Reentrant unit cell deformation



Higher stress concentration areas for both cases

Results

- Calculated Poisson's Ratio

Unit cell type	Poisson's ratio
Honeycomb	0.868
Reentrant	-0.585

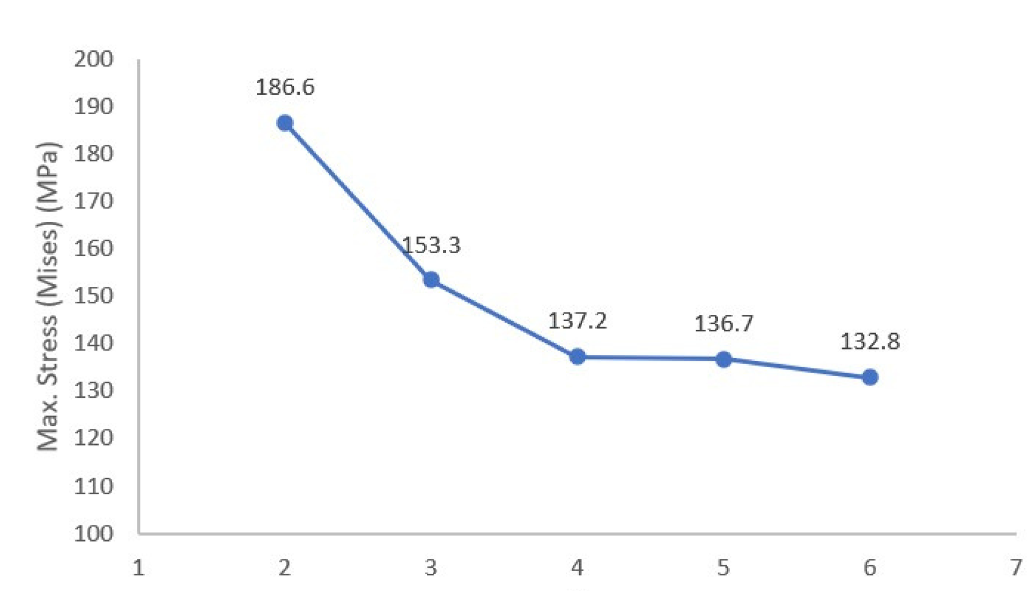
As the Poisson's ratio of reentrant unit cell is negative, it would be having better resistance to indentation and less maximum stress leading to better performance as compared to honeycomb unit cell.

- Comparing maximum stress and lateral deformation

Unit cell type	Max Stress (Mpa)	Lateral deformation (mm)
Honeycomb	241.7	0.192
Reentrant	136.7	-0.119

- Optimal thickness for Reentrant structure

The reentrant structure's maximum stress was analyzed for varying numbers of layers. As the number of layers increased, the maximum stress decreased until it converged and an optimal thickness was achieved.



Conclusion

- Poisson's ratio for reentrant cell is negative. So, it would be preferable to use reentrant cell in impact applications.
- More stress is generated in honeycomb structure as compared to reentrant structure.
- Less deformation is observed in case of reentrant structures indicating better indentation resistance.
- At around 5 layers, the difference in maximum stress is not much, 5 layers can be said to be optimal thickness

Future work

- There can be a lot of unit cell structures and further research will come up with unit cells having better properties.
- Optimality test for number of layers has been conducted. But there remains other parameters like angle, thickness, and length of unit cells.
- After performing choosing right material and optimal values of parameters, the structures will be 3D printed and mechanical tests will be performed on them.
- These structures, after testing will be employed in the use with helmets.