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Simulating the Properties of 2D Auxetic Structures

MAE 263F

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Purpose of the Simulation

- **Inspiration of testing Auxetic Structures**
- **Comparison of Auxetic structures**
 - Structures of a Negative Poisson's ratio
 - Triangular
 - Star-grid
 - Inverted Hexagon: “Bow-tie”
- **Impact**
 - Observe the properties of Negative Poisson
 - Test shock absorption and stiffness
 - Use as a Robotic cover/skin



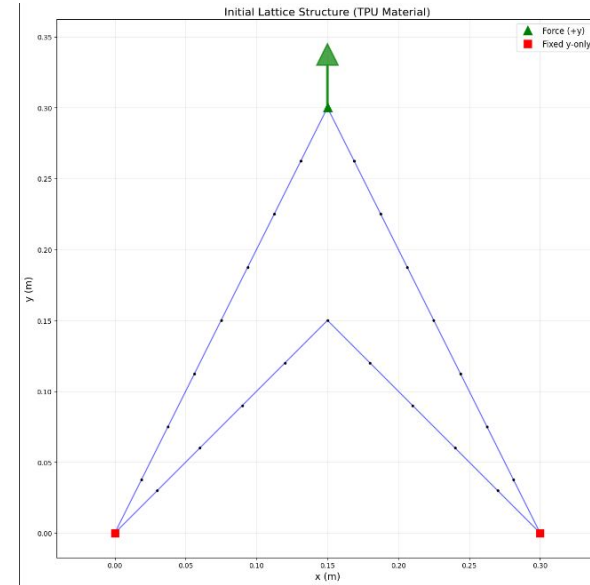
Initial Parameters of the lattices

- **Larger Scale**
 - more accurate to actual behavior of auxetic structure
 - Scale: 15:1
 - described on the table
- **Measurements Observed**
 - Deformation over time
 - Strain
 - Effective Poisson's Ratio
 - Work done on the system

Unit Cell Size	300 mm
Cross-section radius	15 mm
Young's Modulus	26 MPa
Density	1200 kg/m ³
Pattern Size	5x5
Nodes per Beam	6 Nodes
Force Applied	200 N

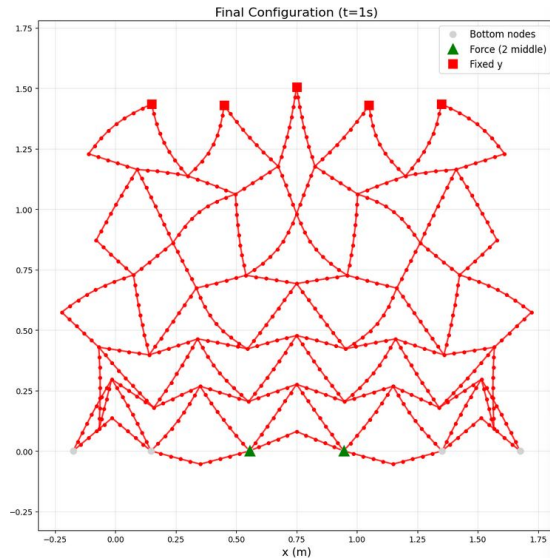
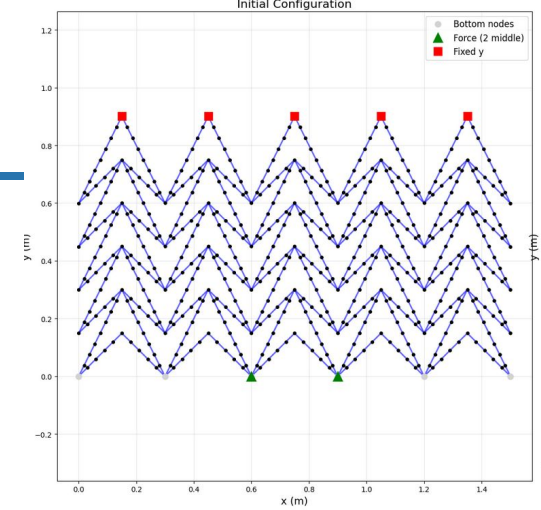
Method

- Forming Lattice based on Unit Cell to pattern and connect
 - Form nodes to along the edges
- Apply material and structural properties
- Simulation with the Newton-Raphson Method
 - Forces: Bending, Stretching, Applied Load
- Measure values over time:
 - Height and Width of the lattice (deformation)
 - Measure the Poisson Ratio
 - Measure work done on the system

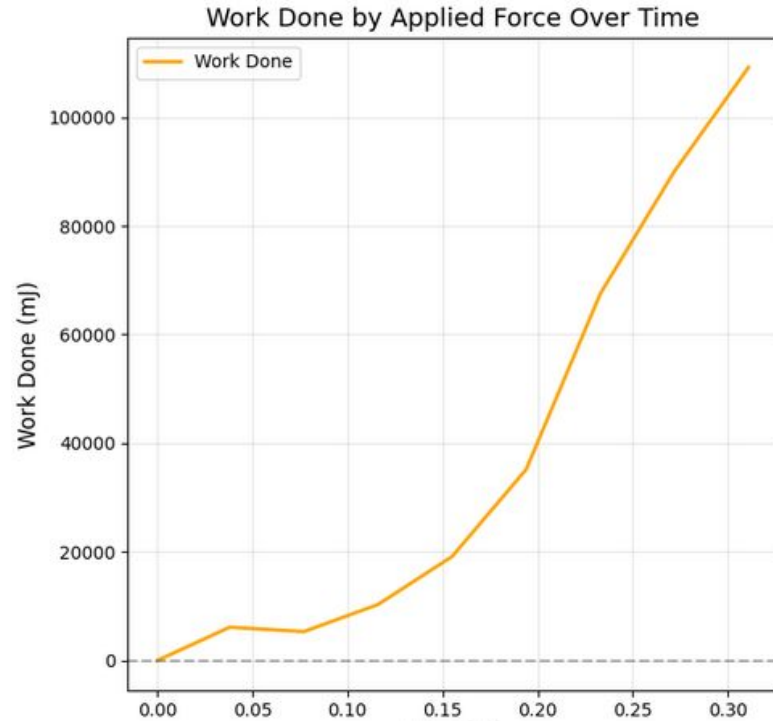
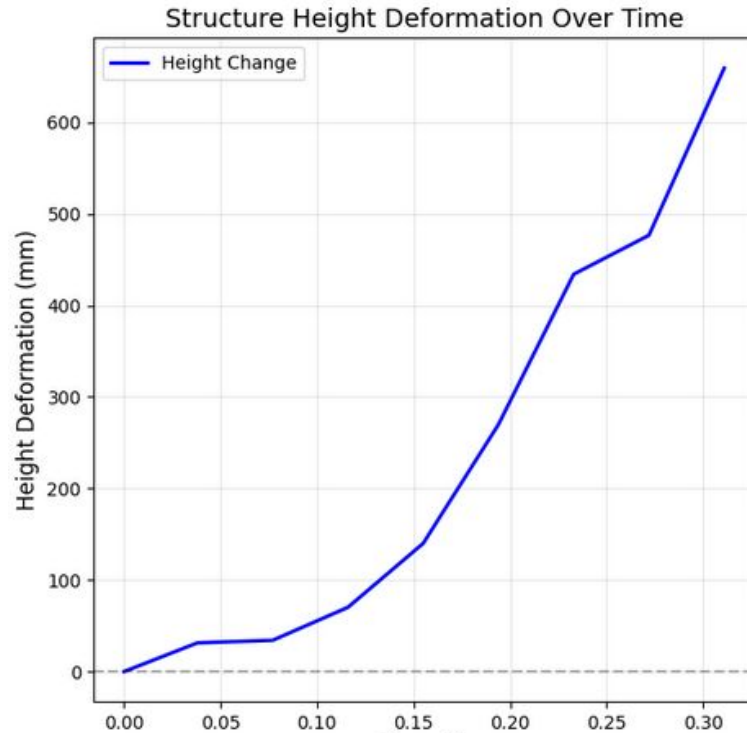


Triangular Lattice Overview

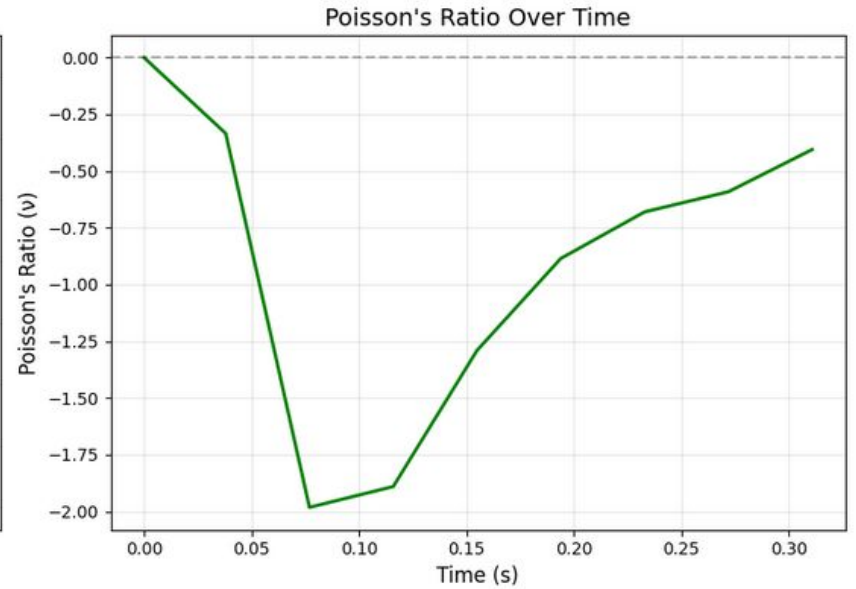
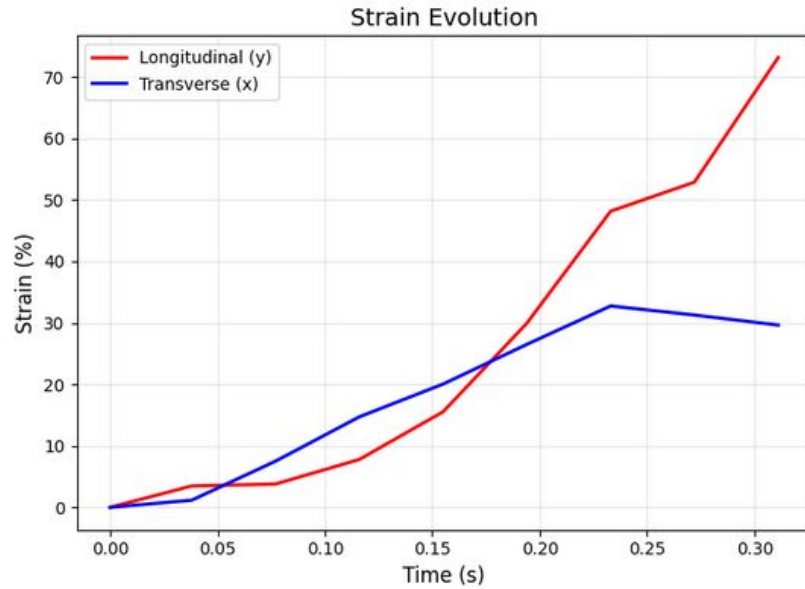
- Moderate Stiffness under the load
- Higher Negative Poisson Ratio
 - equal strain over time until passing 0.16 seconds of simulated time
- Max Work done 109.1 Joules
 - Decent Energy Absorption



Triangular Lattice Results

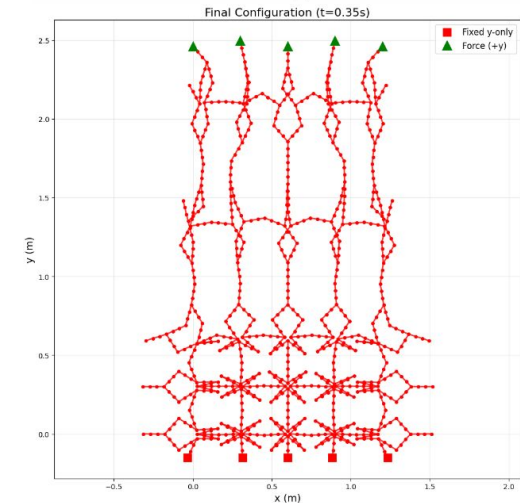
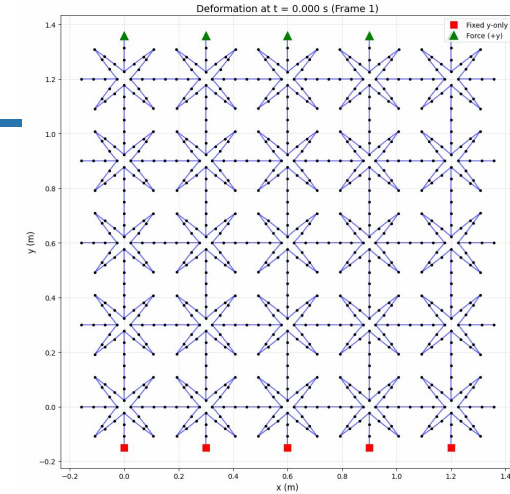


Triangular Lattice Results

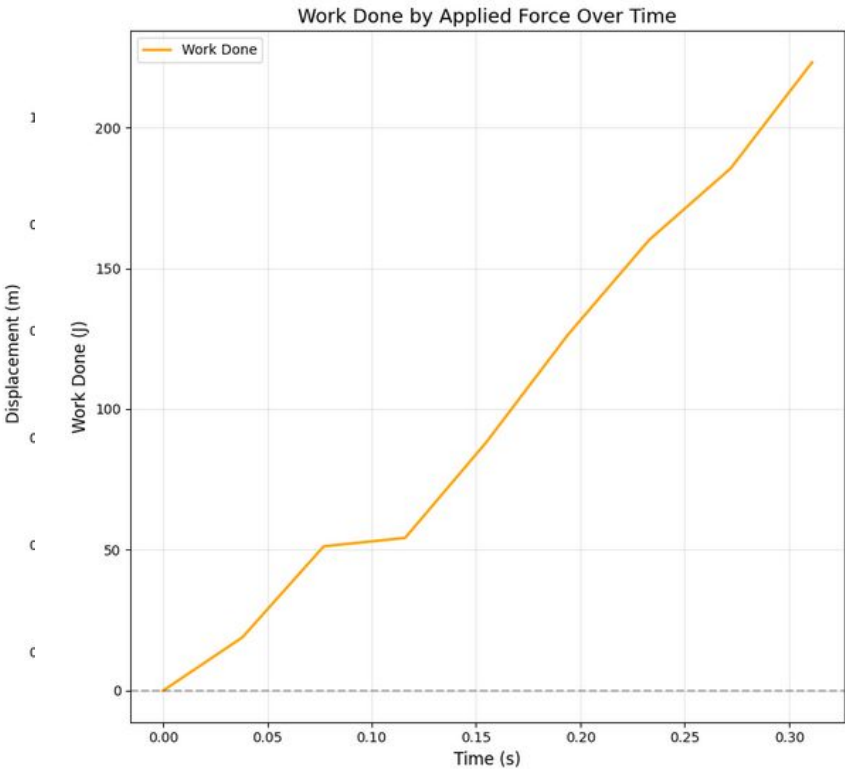
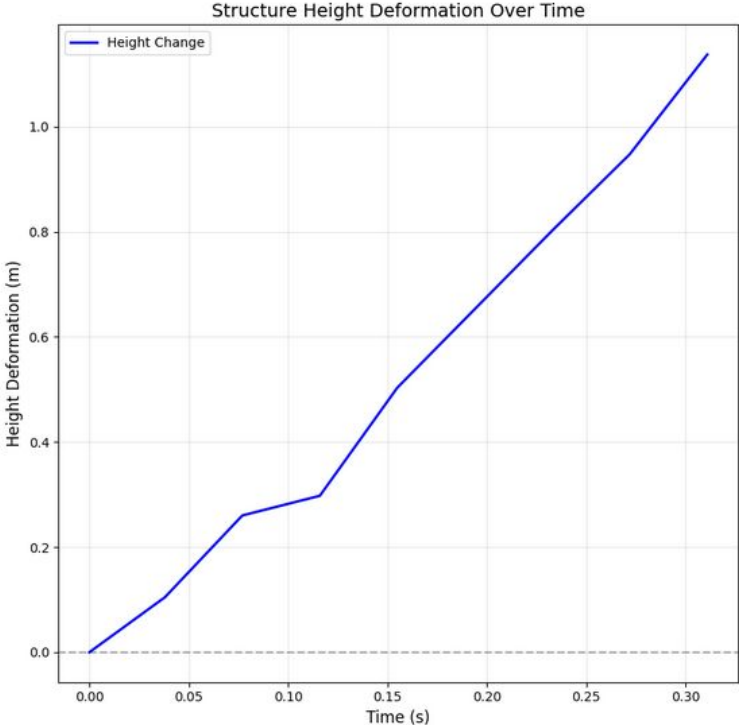


Star-Grid Lattice

- Low Stiffness
- Lower Negative Poisson Ratio
 - The width does not get influenced as much by the deformation of the
- Max Work done 223.1 Joules
 - Higher Energy Absorption

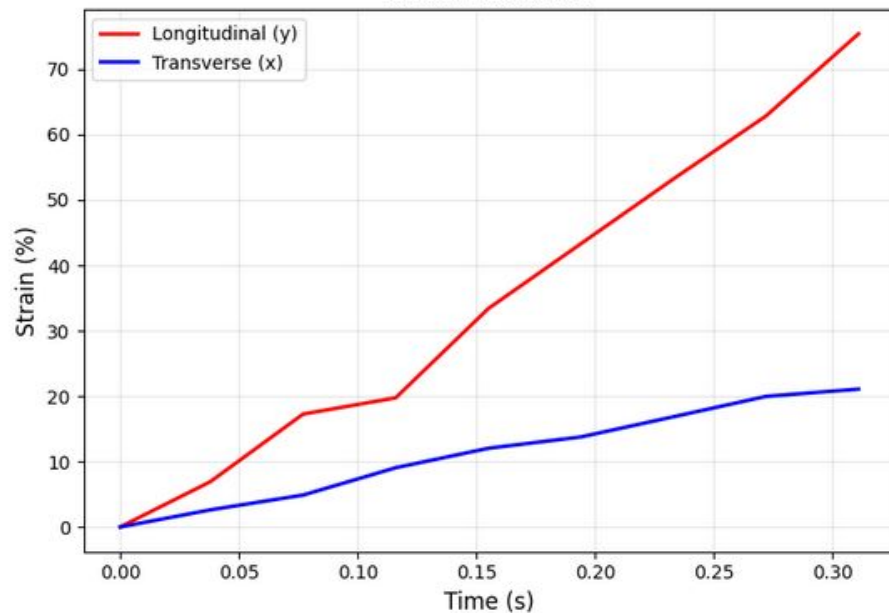


Star-Grid Lattice

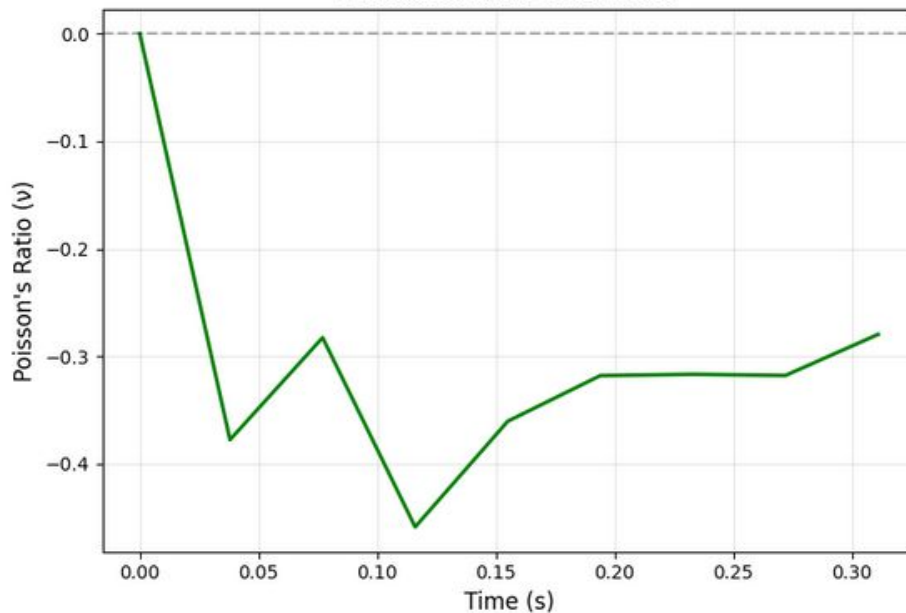


Star-Grid Lattice

Strain Evolution

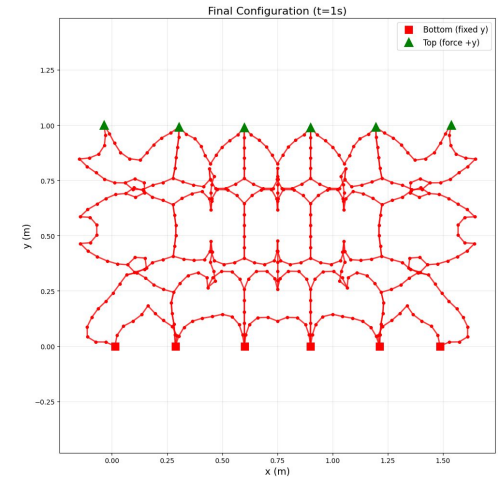
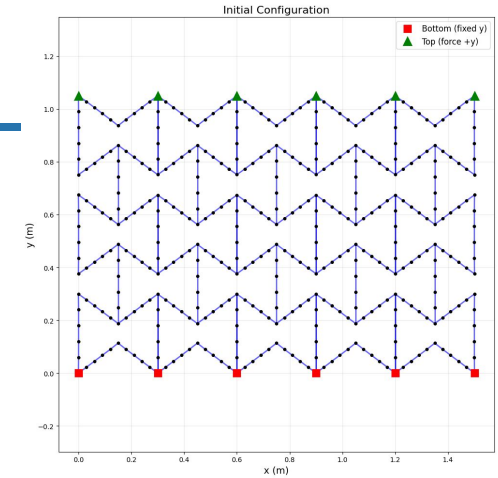


Poisson's Ratio Over Time

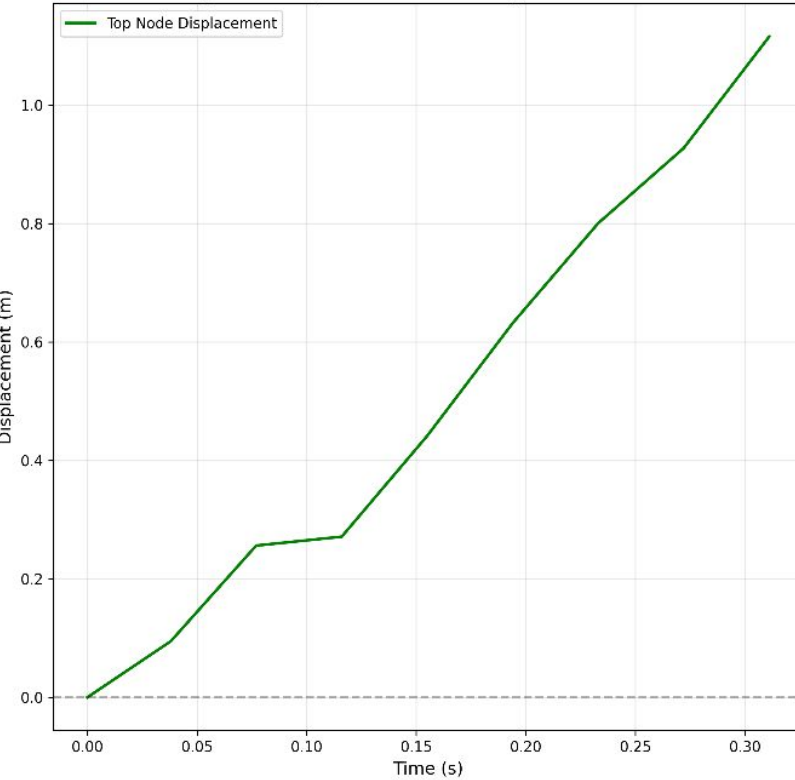


“Bow-tie” Lattice (Case 1)

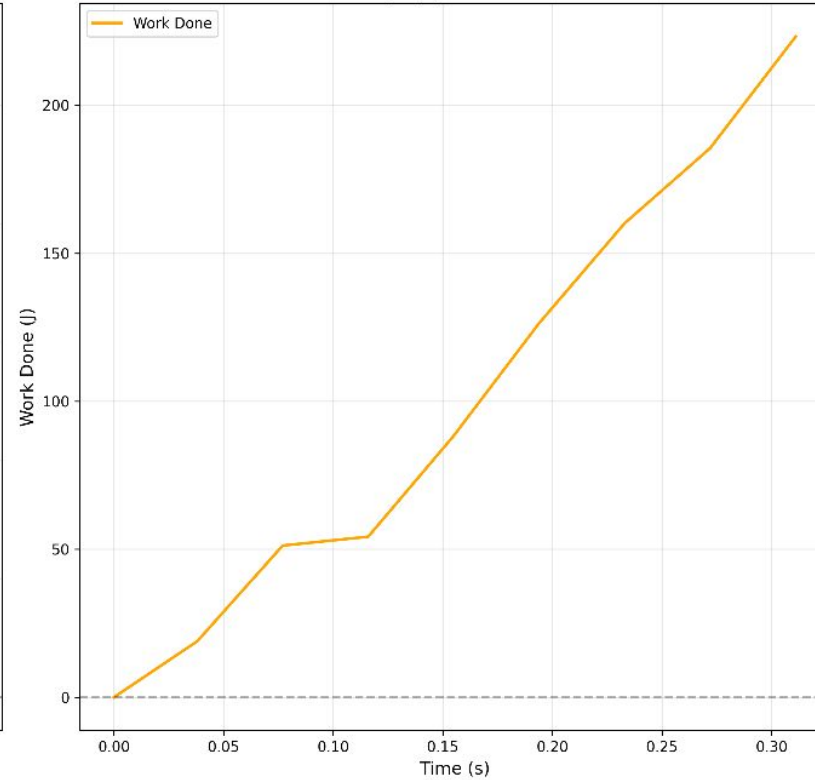
- 5x5 / Tension (+y) / Standard scale
- Positive Poisson Ratio
 - Width decreased with height
 - Max Work done -11 Joules



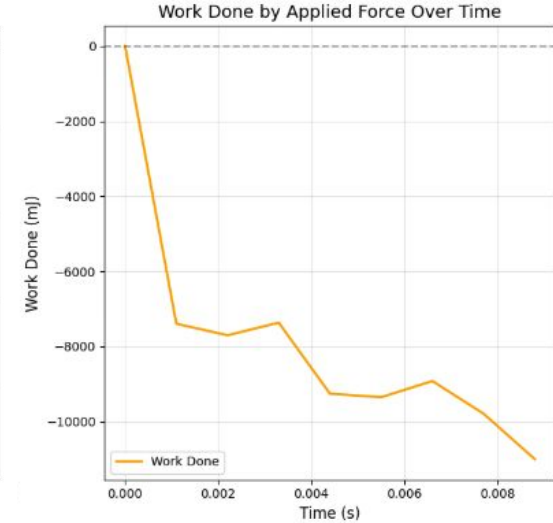
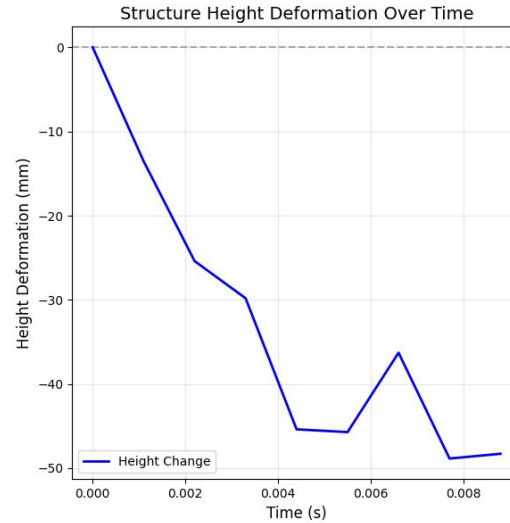
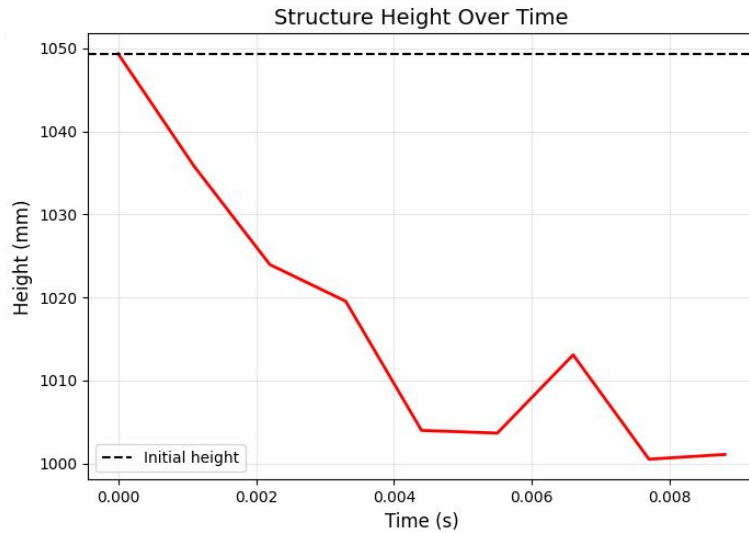
Top Node Displacement (Force Application Point)



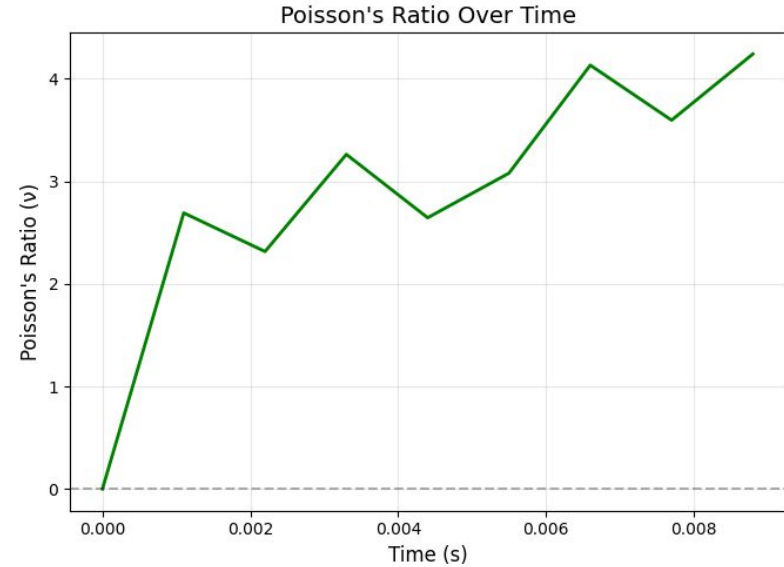
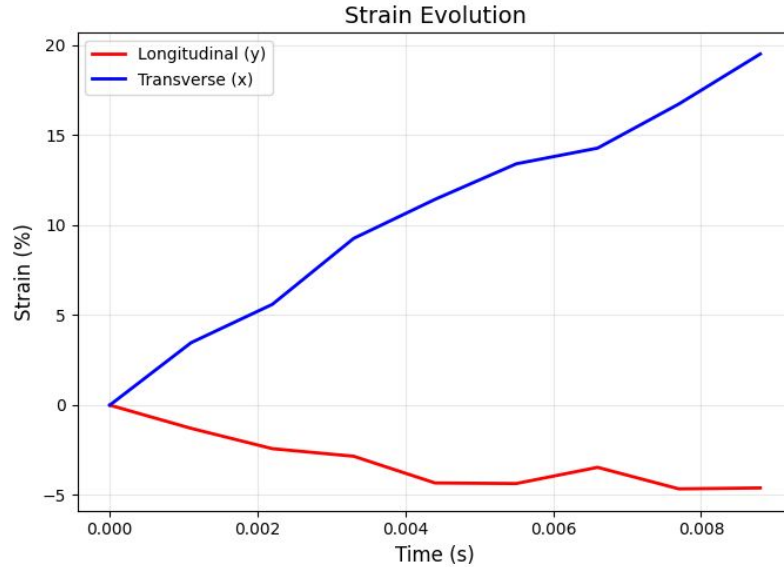
Work Done by Applied Force Over Time



“Bow-tie” Lattice (Case 1)

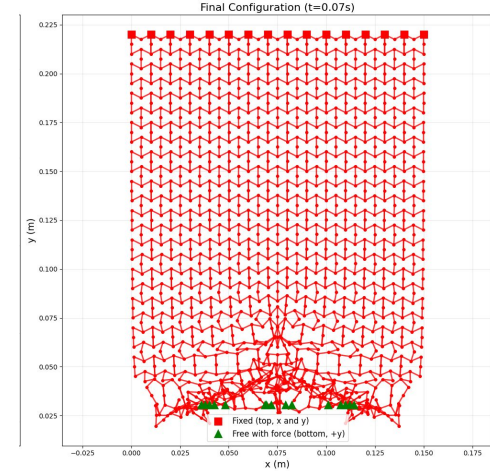
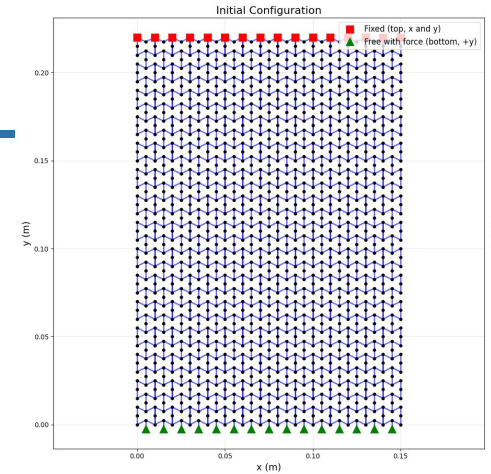


“Bow-tie” Lattice (Case 1)

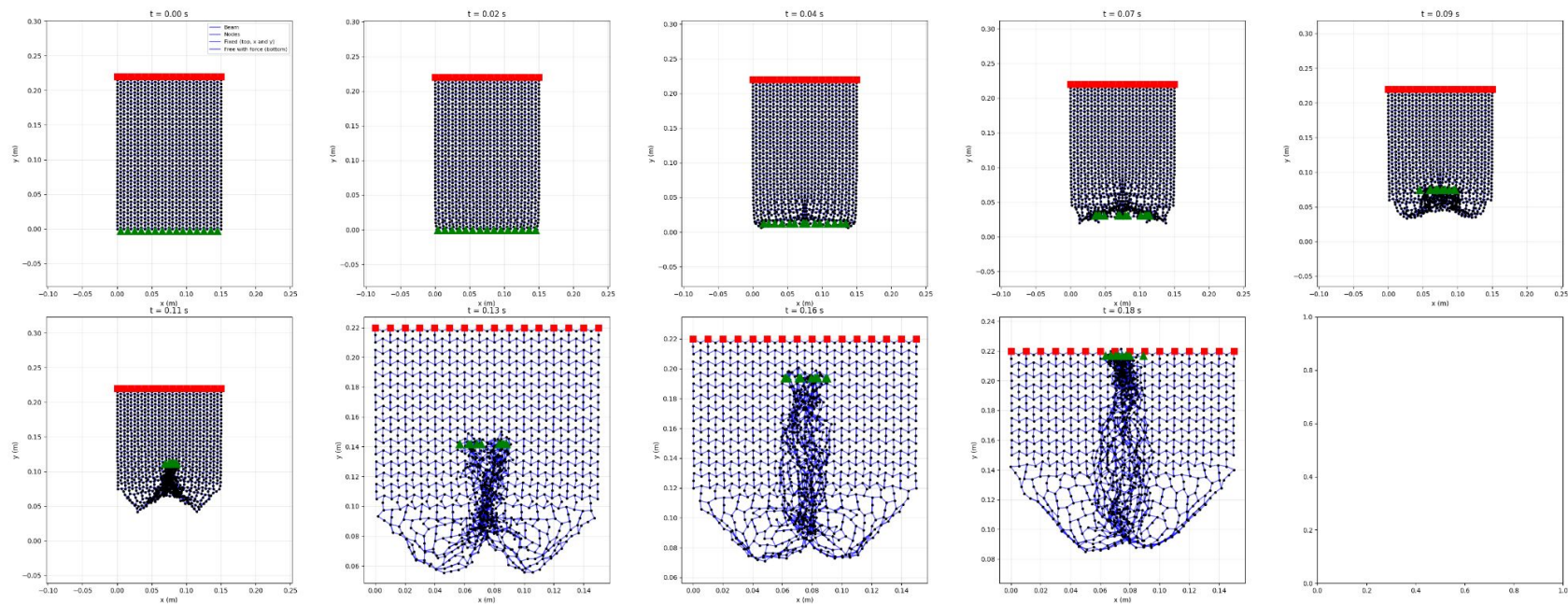


“Bow-tie” Lattice (Case 2)

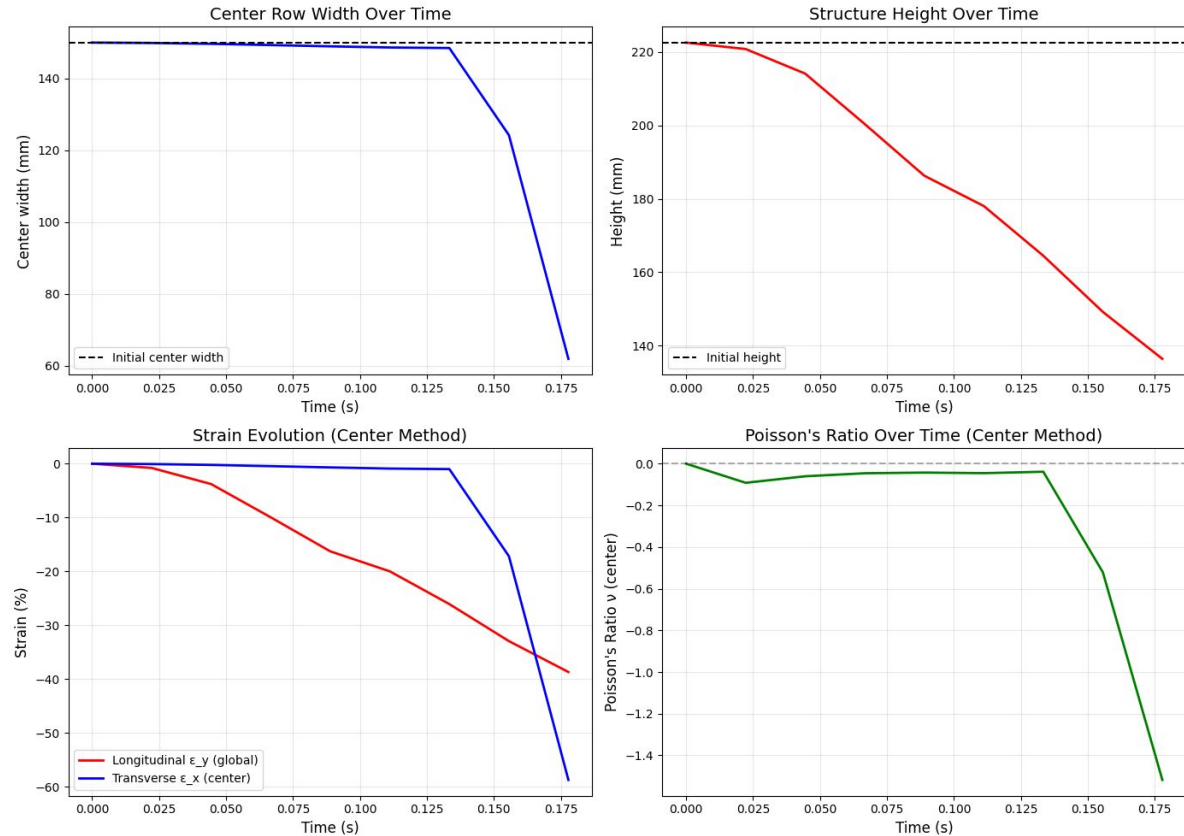
- 15 x 15 / compression (+y) / smaller scale
- Negative Poisson Ratio
 - sudden decrease in width after certain time



“Bow-tie” Lattice (Case 2)



“Bow-tie” Lattice (Case 2)



Comparison and Discussion

- **Max Poisson ratio comparison**

- **Triangular: -2.0**
- Star Grid: -0.45
- Bow-Tie: +4.0

- **Shock Absorption comparison**

- Triangular: 109.1J
- **Star Grid: 223.1J**
- Bow-Tie: -11J

- **Behavior**

- Lagging Structure
- Overlapping (Reduced)
- Bow-Tie Stiffness

- **Ideal Robotic Skin selection**

- Star Grid
 - best shock absorption and adequate negative poisson ratio

Future Work

- **Hyperelastic material model**
 - Changing Young's modulus in relative deformation
- **Contact and finite thickness**
 - Function for collision
 - better for compression
- **Joint stiffening and geometric refinement**
- **Experimental validation**
 - Experimental comparison of the model
- **3D lattice model experiment**
- **Integration with robotic hardware**

Q&A
