A study of auxetic materials for blast-resistant sandwich panels

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Introduction

Sandwich panels are an effective means of absorbing the impulsive load of a blast at a much lighter weight than comparable solid plates. They consist of a core sandwiched in between two plates which deforms plastically, absorbing energy. A class of materials called "auxetics" is a possible improvement on traditional core geometries. Due to their geometry, auxetics "densify", or draw inward when placed under load, as opposed to being pushed outward in a traditional material. We seek to identify whether this unique effect has any advantage when used in a sandwich panel core for blast resistant applications.

Theory

The auxetic effect results in a negative Poisson's ratio, which describes the relationship between transverse and axial strain. Strain is a dimensionless value which is calculated by dividing a material's initial length by the change in its length. The Poisson's ratio can be described by

$$v = -\frac{d\varepsilon_{trans}}{d\varepsilon_{axial}} \text{ ,}$$

where v is the Poisson's ratio, ε_{trans} is the transverse strain, and ε_{axial} is the axial strain.

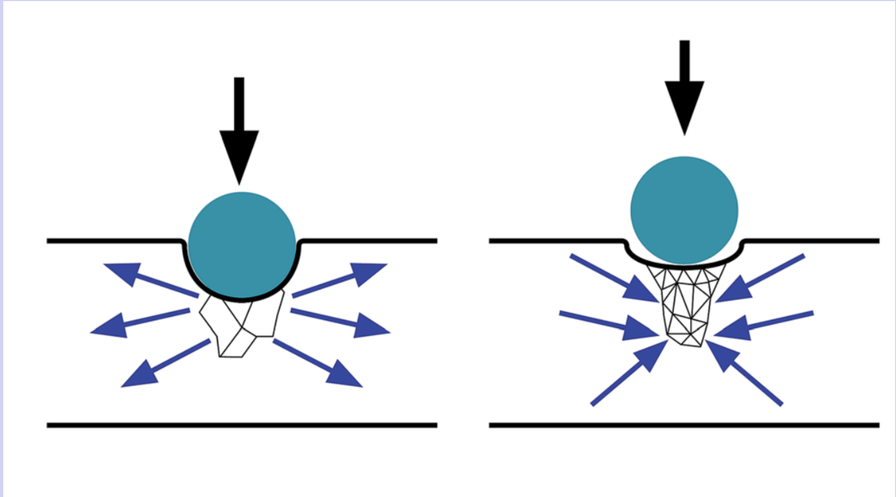

Figure 1: Typical loading effect (left) and auxetic effect (right) [1]

Most materials expand perpendicular to the direction of compression, resulting in a positive Poisson's ratio. Auxetics do the opposite, giving them a negative ratio. This is achieved through unit cells of a specific shape.

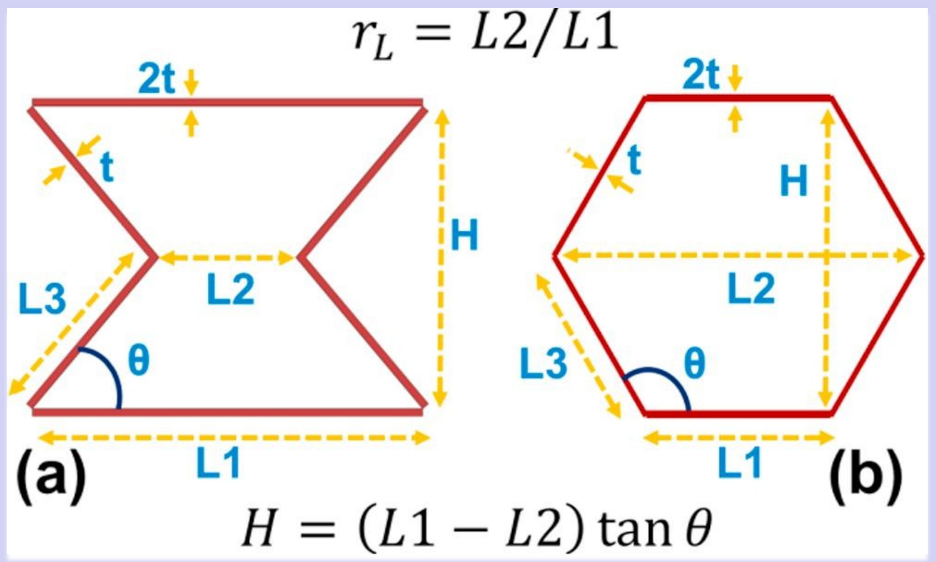

Figure 2: auxetic unit cell (a) vs. honeycomb unit cell (b) [2]

Methods

- Explicit Dynamics using Abaqus
- Three Solid models of equal core dimensions created
- Unit cells of honeycomb and auxetic have equal variables found in Figure1
- Shell elements used in core, solid elements in face plates
- CONWEP pressure curve of 1kG TNT at 100mm from face

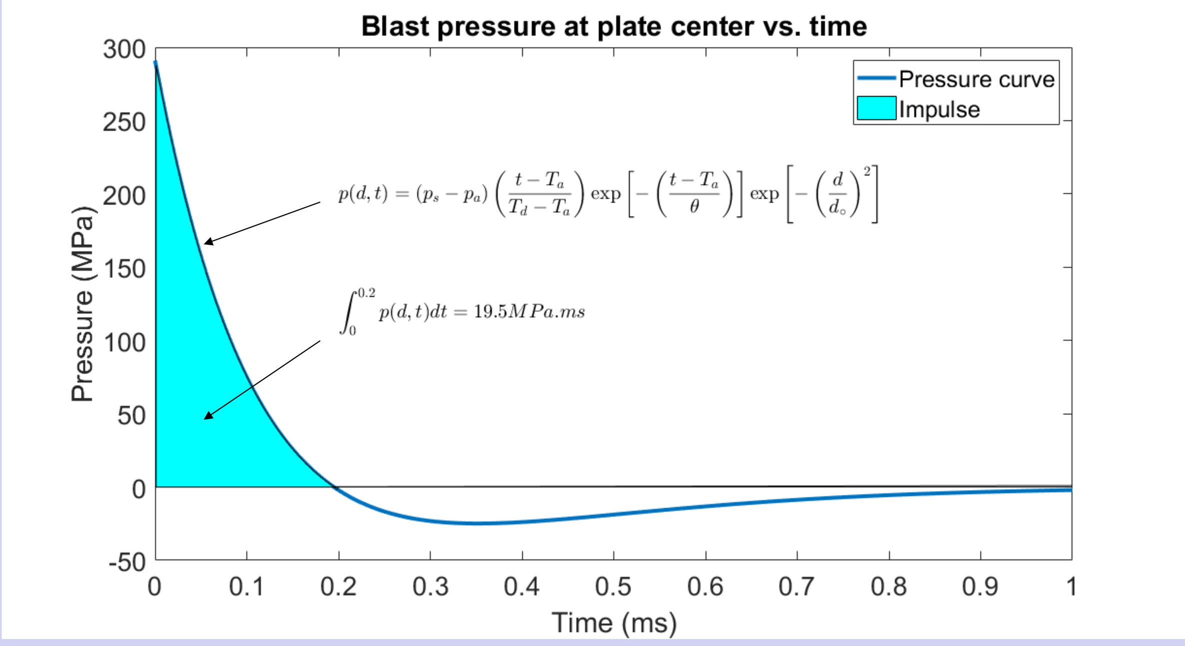

Figure 3: CONWEP pressure curve

Results

- Auxetic effect of core shown in Figure 4
- Bending modes of horizontal cells, buckling mode of vertical cells seen in Figure 5
- Auxetic has no advantage of energy dissipation over either honeycomb mode
- Vertical mode has much higher reaction force than honeycomb or auxetic
- Auxetic has advantage of smaller bottom displacement

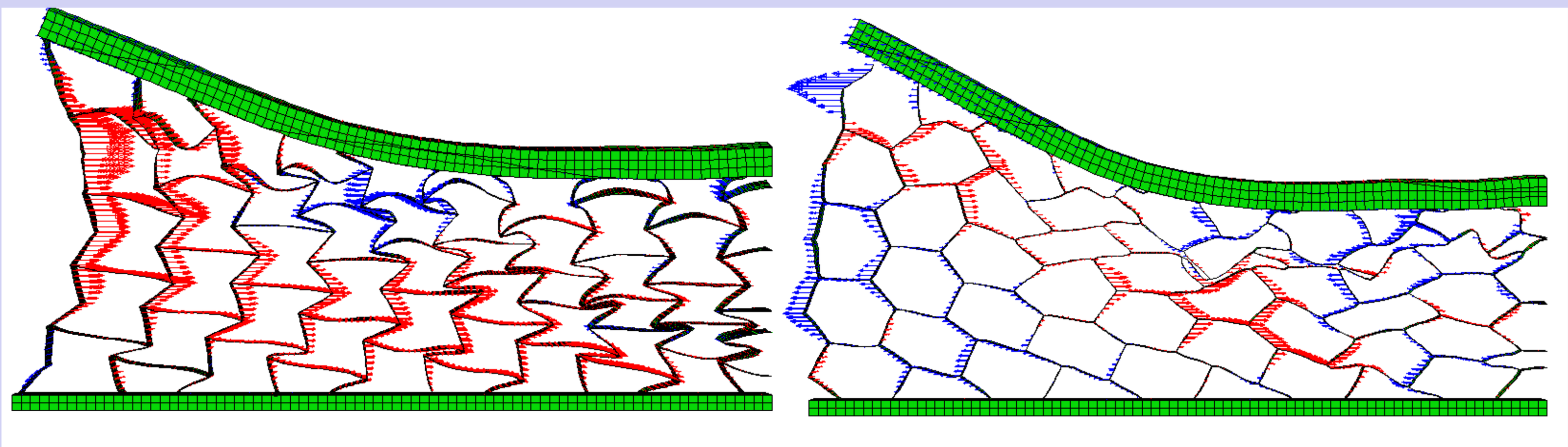

Figure 4: Auxetic effect demonstrated by velocity at t=0.75ms. Auxetic (left) is moving inward, while the honeycomb (right) is being pushed outward.

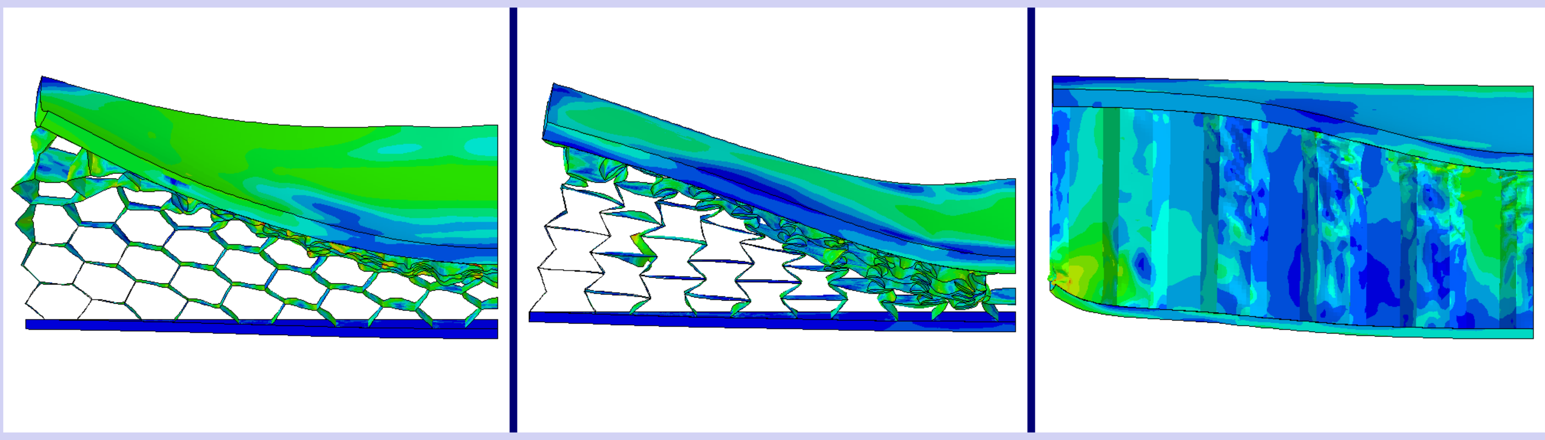

Figure 5: Deformation of horizontal honeycomb, auxetic, and vertical axis honeycomb

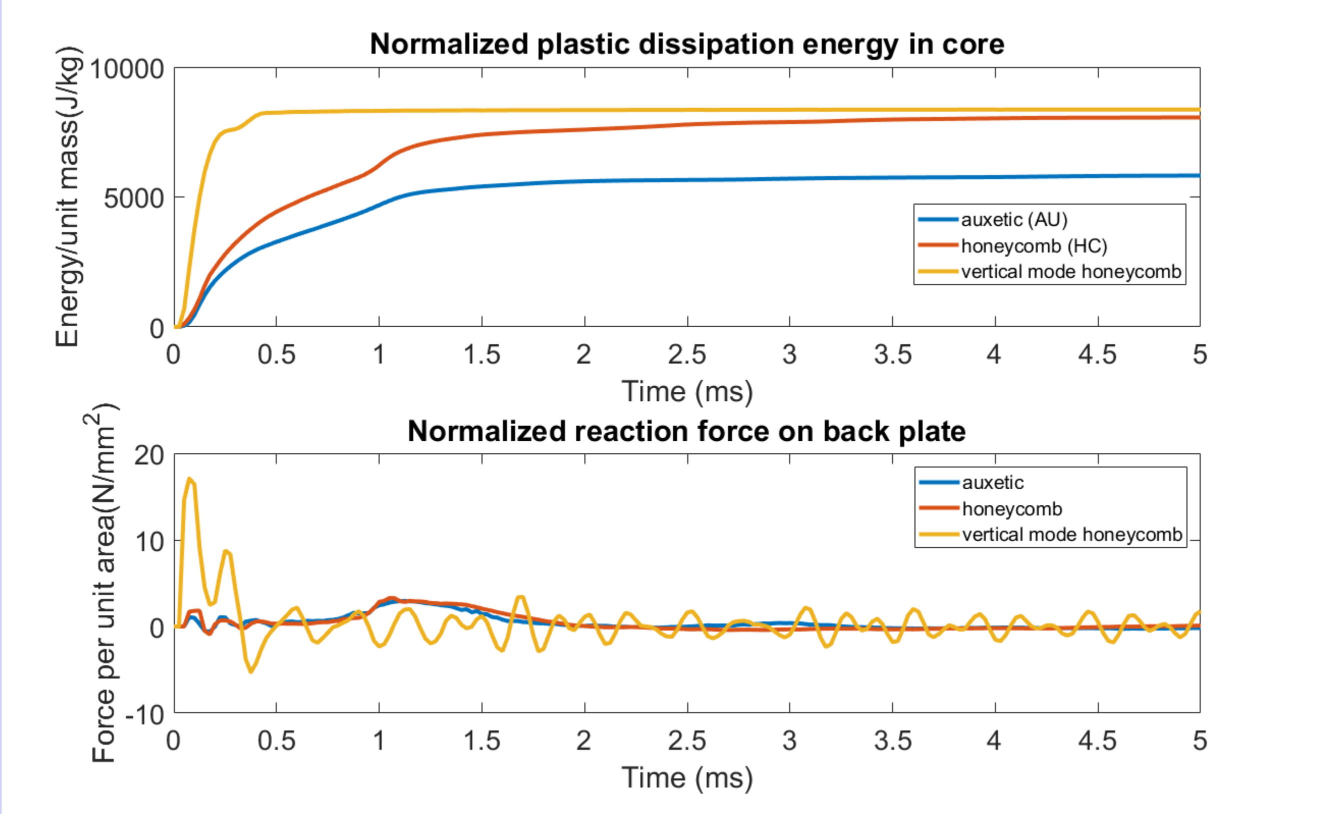

Figure 6: Normalized plastic dissipation energy and reaction force

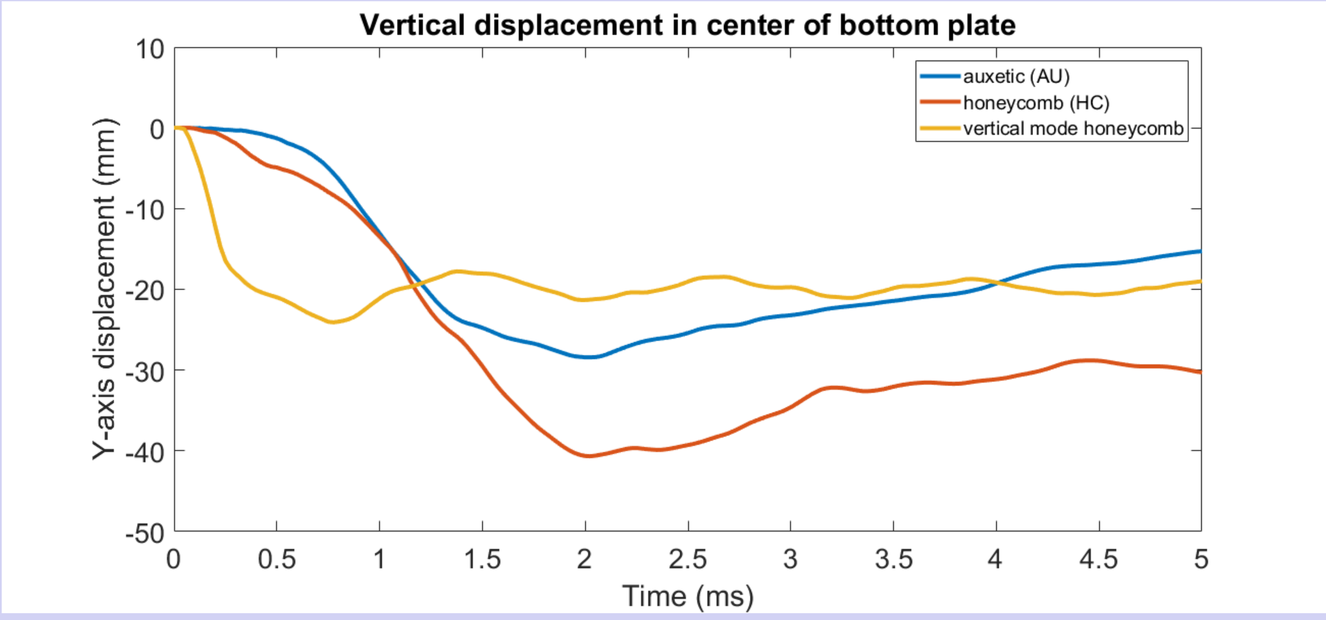

Figure 7: Bottom plate center displacement

Conclusions and Future Studies

For the geometries considered, the auxetic material had no benefit over either honeycomb structure in terms of plastic energy absorbed, but preformed well in the deflection results. Future work will experiment with a hybrid of vertical and horizontal cells, and will preform experimental tests using 3D printed specimens.

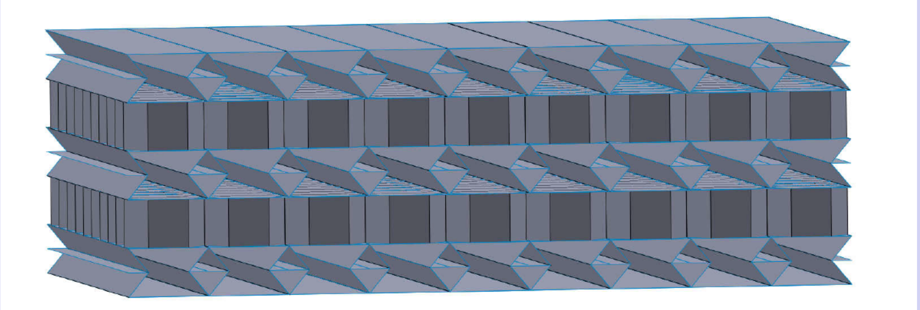

Figure 7: Hybrid honeycomb/auxetic core

Acknowledgments

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References

[1] Kolken, H. MA, and A. A. Zadpoor. "Auxetic mechanical metamaterials." *RSC Advances* 7, no. 9 (2017): 5111-5129.

[2] Imbalzano, Gabriele, Steven Linforth, Tuan Duc Ngo, Peter Vee Sin Lee, and Phuong Tran. "Blast resistance of auxetic and honeycomb sandwich panels: comparisons and parametric designs." *Composite Structures* 183 (2018): 242-261