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STEM

Phase Transforming Cellular Materials (PXCMs) Design and Assembly

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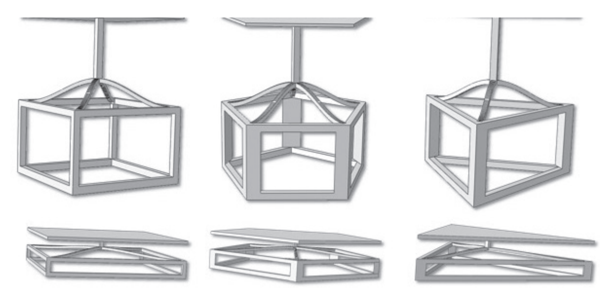
Active materials such as shape memory, ferroelectric, and magnetostrictive alloys obtain their characteristic properties of superelasticity and energy dissipation as a result of phase transformations. In these materials, phase transformations occur by changing the packing arrangement of the atoms in a process that resembles multistable mechanisms switching between stable configurations. Phase transformations can be introduced into architectured materials by considering periodic cellular solids whose unit cells have multiple stable configurations. In this case, each stable configuration of the unit cell corresponds to a stable phase, and transitions between these phases are defined as phase transformations for the material. We call these materials phase transforming cellular materials (PXCMs). The novelty and benefits of PXCMs are (1) they can absorb important amounts of energy and yet be reusable since the phase transformation is entirely reversible without inducing permanent/inelastic deformation into the base material; (2) they are very low cost, which means they potentially can be 3D printed during construction; and (3) due to their low cost, more buildings and large structures could easily incorporate a PXCM system, which translates directly into significant reductions in the number of casualties when natural disasters strike.

During this study a new fabrication approach based on the assembly of slotted stripes was studied. In this approach a 1D PXCM unit cell was disassembled into six components. CAD models of these components were designed, 3D printed, and assembled together, forming the cellular material. Additionally, we explored the geometric design space of the PXCMs that exhibit phase transformation in two or more preferential directions. For this, 2D and 3D geometric designs were proposed and a parametric study was performed using 3D-printed models to explore the behavior of each cell. Each printed model was subjected to a compression test in which a load was applied until the snap-through behavior was observed, or until the model broke. The results from this research allowed exploration into methods that increase the versatility of PXCMs, leading to designs applicable in the development of safer, multi-hazard resilient buildings.

Graduate research advisor David Restrepo writes: "PXCMs are a new type of energy-absorbing material that relies on reversible mechanical instabilities rather than plastic deformation as a main dissipation mechanism. Nadia's work allowed the initial exploration of new PXCM designs that can be used in various applications, ranging from passive dissipation dampers in high-rise buildings to human body protection."

The research was done in Pablo Zavattieri's lab in the Lyles School of Civil Engineering, in collaboration with Dr. Nilesh Mankame from GM Research and Development. The work was funded by General Motors, and more recently by the National Science Foundation.

Graduate research advisor David Restrepo (left) and Nadia Aljabi (right) retrieving 3D-printed cube model for testing.



Dimensionless design parameters used to create variations in 3D models, including cube, tetrahedron, and dodecahedron, at varying sizes.

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