Seismic metamaterials through alternating truss-plate structure design

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Abstract

Recently, a novel class of elastic metamaterials with alternating lattice and plate structures has attracted considerable attention. The attractive properties of these metamaterials are that they are lightweight, with advanced effective mechanical properties and improved energy absorbing mechanisms. These metastructures show a potential for shear-wave band gap systems, seismic wave abatement, vibration control, etc.

This study examines the mechanical and dynamic characteristics of highly deformable layered elastic metamaterials composed of pentamode lattices and stiffening plates. The metamaterial unit cell consists of a sub-lattice of the face cubic-centered unit cell confined between two elastic plates. By performing numerical finite-element simulations, we study the dependence of mechanical and dynamic characteristics of the metastructures on the design parameters: the lattice constant, the cross-section area of the rods, the solid volume fraction, and the plate thickness. We find that the geometry of the microstructure, and the macroscopic aspect ratio of the confined lattices strongly influence the effective mechanical properties and the wave attenuation performance of the metamaterials.

Additively manufactured polymeric metastructures have also been experimentally analyzed in the elastic and finitely-deformed regimes. To this purpose, an in-house experimental setup was used to apply vertical force–displacement histories under constant load on the specimens. The tests were aimed at revealing the effective shear and compression properties of the fabricated systems, and their inelastic response under cyclic and monotonic loading. Despite the preliminary nature of this study, the obtained results provide insights into possible applications of layered plate-lattice metamaterials for innovative seismic isolation devices and impact protection equipment.