
Surface waves in 2D bistable lattices

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Abstract

In this work, we study a relatively new class of metamaterials, namely architected materials with bistable building blocks. These multi-stable architected materials offer a unique set of mechanical properties and extraordinary behaviors, such as the ability to undergo large reversible deformations, the ability to provide mechanical protection and efficient shock absorption, and the ability to retain variety of geometrical configurations after loads have been removed. In addition to its relevance to metamaterials, the study of lattice-based multi-stable structures is of relevance to a range of engineering and physical phenomena, such as atomic models of shape memory materials, mechanics of protein networks, foldable structures for engineering applications, and more. Recently, the quasi-static behavior of bistable lattices has been studied for unidirectional tension and also shear. Importantly, the dynamic response of 1-D bistable lattices (chains) has been studied in a recent series of papers. Still, understanding the dynamic response of 2-D bistable lattices is still in its infancy, particularly the response to impacts. In this work, we make a step towards bridging this gap. We study, theoretically and numerically, the dynamic response to impacts of 2-D multi-stable lattices. Special emphasis is placed on energy landscape, non-linear wave phenomena like solitary waves or impact mitigation as well as the evolution of phase-transition patterns and surface waves. In addition, the influence of the lattice geometry and the properties of the bistable springs on the abovementioned features is investigated. Furthermore, we explored heterogeneous lattices involving bistable springs with different properties within the same lattice. In particular, the surface wave involves a combination of a solitary wave that propagates at the top row (surface) and a kink (transition) wave that follows the solitary wave right below the surface. We show that by clever design of the lattice properties, the propagation of the surface wave can be made stable for arbitrary long distances and that propagation is robust even in the presence of dissipation.

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