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Strength and toughness of planar ductile lattices

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ABSTRACT

The effective medium properties of planar lattices made from ductile cell-wall materials are obtained analytically for four periodic topologies: the regular triangular honeycomb, the Kagome lattice, the +45^{o} square lattice, and the regular hexagonal honeycomb, by assuming a power–law relation between cell-wall plastic stress and strain. The strength of the ductile lattice is estimated as the remote macroscopic stress leading to critical strain in a cell-wall anywhere in the lattice. The functional form of fracture toughness in terms of relative density and cell-wall material properties is estimated analytically and determined numerically from the asymptotic problem of a long crack. The results show that the stiffness, onset-of-yield stress, and strength are significantly higher for stretching topologies, i.e., the triangular honeycomb and the Kagome lattice. The presence of an elastic deformation zone surrounding the crack-tip plastic zone in Kagome and the formation of a shear lag zone along the lattice principal directions in square lattice lead to a toughness that is much higher than anticipated. Analytical and numerical predictions are also made for the transition crack length below which the lattice discreteness and crack-tip plasticity ensure un-notched strength, and beyond which the lattice is prone to brittle fracture. The dependence of transition length on the ratio of cell-wall material failure strain to yield strain is shown to be beneficial for increasing the damage tolerance of otherwise flaw-sensitive triangular and hexagonal honeycombs.