

Exploring the fracture toughness of tessellated materials with the discrete-element method

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Architected materials contain highly controlled structures and morphological features at length scales intermediate between the microscale and the size of the component. In dense architected materials, stiff building blocks of well-defined size and shape are periodically arranged and bonded by weak but deformable interfaces. The interplay between the architecture of the materials and the interfaces between the blocks can be tailored to control the propagation of cracks while maintaining high stiffness. Interestingly, natural materials such as seashells, bones, or teeth make extensive use of this strategy. While their architecture can serve as inspiration for the design of new synthetic materials, a systematic exploration of architecture-property relationships in architected materials is still lacking. In this study, we used the discrete element method (DEM) [1,2] to explore the fracture mechanics of several hundreds of 2D tessellations composed of rigid “tiles” bonded by weaker interfaces. We explored crack propagation and fracture toughness in Voronoi-based tessellations (to represent intergranular cracking in polycrystalline materials), tessellations based on regular polygons, and tessellations based on brick-and-mortar. We identified several toughening mechanisms including crack deflection, crack tortuosity, crack pinning and process zone toughening. These models show that periodic architectures can achieve higher toughness compared to random microstructures, that the toughest architectures are also the most anisotropic, and that tessellations based on brick and mortar are the toughest [3]. These findings can serve as initial guidelines in the development of new architected materials for toughness.

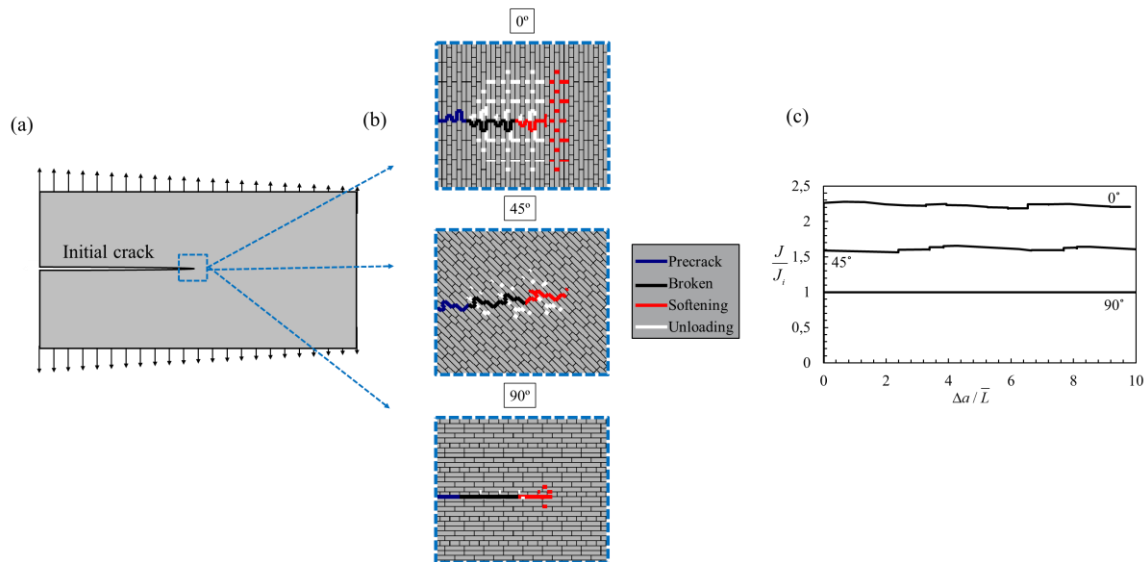


Figure 1. (a) Overview of the fracture DEM model. (b) Close-up snapshots of deformation and crack propagation for a given tessellation with crack orientations at 0°, 45° and 90° and (c) corresponding crack resistance curves.

References

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