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New Perspective of Quasibrittle Fracture Mechanics Inspired by Novel Test with Crack-Parallel Compression

Zdeněk P. Bažant

Collaborators: Hoang Nguyen, Madura Pathirage,
Masoud Rezaei, Mohsen Issa, Gianluca Cusatis

ABSTRACT: The line-crack models, including the linear elastic fracture mechanics (LEFM), cohesive crack model (CCM), and extended finite element method (XFEM), rest on the century-old hypothesis of constancy of material's fracture energy. However, a new type of fracture test presented here, named for brevity the "gap test", reveals that, in concrete and probably all quasibrittle materials, including coarse-grained ceramics, rocks, stiff foams, fiber composites, printed materials, wood and sea ice, the effective mode I (opening) fracture energy depends strongly on the crack-parallel normal stress, in-plane or out-of-plane or both. This stress can double the Mode I fracture energy or reduce it to zero. Why hasn't this been detected earlier?--Because the crack-parallel stress in all standard fracture specimens is negligible, and is anyway unaccountable by line-crack models. To simulate this phenomenon by finite elements (FE), the fracture process zone (FPZ) must have a finite width and must be characterized by a realistic tensorial softening damage model whose vectorial constitutive law captures oriented mesoscale frictional slip, microcrack opening and splitting with possible microbuckling. This is effectively accomplished by the FE crack band model. When coupled with microplane model M7, it fits the test results closely. The lattice discrete particle model (LDPM) also works. However, the line-crack models LEFM, CCM and XFEM do not, while the simple damage laws used phase-field models are inadequate. The gap test is proposed as a standard. It represents a simple modification of the three-point-bend test in which both the bending and crack-parallel compression, generated sequentially, are statically determinate. The lecture closes by offering a new perspective of various far-reaching consequences.

Reference: PNAS, in press.

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TAM Program – Northwestern University