A comparative study on characterization, stochastic realization, and fracture simulation of quasi-brittle materials

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We use a phenomenological Weibull model or a stochastic volume element (SVE) based model to represent failure strength of a quasi-brittle material as a random field. For the Weibull model, we first use the same discrete grid for finite element solution and failure strength values. At the vertices of the discrete mesh we modulate a reference Weibull model based on the area of the elements surrounding the vertex. If the effective stress at the vertex is greater than the sampled strength value a crack is nucleated (or extended if the vertex is an active crack tip). To improve this approach, we use an independent discrete grid to sample and store failure strength values prior to the solution. A consistent approach is then used to transfer information between two discrete grids during fracture simulations. For the SVE-based approaches, we first use one microstructural realization of a quasi-brittle material and use SVEs at different locations of this sample to extract homogenized, and yet macroscropically heterogenous, failure strength values. Again a consistent scheme is used to communicate between the finite element solution and the material failure strength meshes. Finally based on one- and two-point statistics obtained from the SVE homogenization, we use the Karhunen-Loeve (KL) method to realize random fields for failure strength that correspond to the microstructural distribution of the material considered. This enables us to go beyond one macroscopic failure strength field generated based on one determinstic microstructural realization of the mateiral; multiple macroscopic failure strength fields can be realized and simulated with the KL method.

We use initial and boundary conditions that correspond to a spatially uniform amd temporally increasing stress field. This loading most clearly demonstrates the effect of material inhomoegeneities on fracture patterns; unlike crack propagation from existing sources of stress concentration, e.g. crack tips, crack nucleation locations and to some extend crack proagation directions are highly affected by the underlying realized random fields. The second set of simulations correspond to dynamic crack propagation for a mid-crack specimen. It is demonstrated that the proposed model can capture some features of dynamic fracture such as crack oscillation, microcracking, and crack branching as a function of loading rate or magnitude.