Modeling fracture in quasi-brittle materials under high frequency loading using a multi-scale method

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Introduction
Macroscopic behavior of quasi-brittle materials is determined by their heterogeneous microstructure. Initiation and propagation of cracks are controlled by the randomness of the material and occur at different length scales (figure 1). Multi-scale approaches provide methodologies to obtain the mechanical behavior of a heterogeneous material from a local scale response. The present project deals with developing an objective multi-scale method to model cracking in heterogeneous materials under high frequency loading conditions.

Multi-scale model
A standard computational homogenization scheme is used until strain localization occurs in the material. When localization occurs in the RVE associated to a certain macro material point, a crack initiates and the cohesive law for the crack is determined using a discontinuous homogenization scheme (figure 2). When the macroscopic wave length is significantly larger than the meso-scale characteristic length, the meso-scale problem can be solved as a quasi-static problem [1]. In figure 3 objective results are shown. However, when the macroscopic wave length becomes comparable to the meso-scale characteristic length, meso-scale inertia forces lead to dispersion effects which are not captured in the model.

Dispersion effects
Dispersion effects can be taken into account through a so-called dispersion tensor which depends on the meso-scale model heterogeneity:

$$D_{ijkl} = \frac{\rho_s}{\Omega} \int_{\Omega} h_s^{ij} h_s^{kl} d\Omega$$  \hspace{1cm} (1)

Where $h_s^{ij}$ is a periodic tensor which depends on the material properties of the meso-scale model and can be obtained by solving a quasi-dynamic problem at the meso-scale. The dispersion tensor appears in the macro-scale formulation as an additional inertia force. Dispersion effects caused by meso-scale inertia forces are shown in figure 4.

References