A closed-form homogenization model for composites made of an elasto-damageable matrix reinforced by rigid particles and for structural computations.

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Abstract

The present study relies on the elastic damage model derived from nonlinear homogenization by Ben-El-Barguia et al in (1). By specifiying it to composites made of spherical rigid particles in an elasto-damageable matrix, we show that the effective constitutive law of such composites fully comply with the generalized standard material framework and can be described by closed-form expressions for both the macroscopic free energy and the effective dissipation potential. This allows to explicitly analyze the influence of the particles volume fraction on the macroscopic behavior of the composite.
Owing to the above results, the closed-form elasto-damageable model is implemented in a Finite-Element Fenics software in order to analyze the response of different structures made of the considered composite. In order to avoid mesh dependency of the structural responses, predicted by local damage models, a nonlocal extension of the model is proposed following a variational gradient damage approach as in (2,3) and its implementation via an alternate minimization algorithm.

We then carry out structural calculations by means of Fenics on different structures corresponding to an 1-dimensional bar submitted to a tensile stress, a traction of a plate reinforced by a circular rigid particle and a L-shape 2D structure. On the whole, the results exhibit the same following trends for the three structures. An analysis of the fracture paths shows that an increase in the volume fraction promotes both the damage and the fracture propagations, which start and end earlier in time, without changing the final geometry of the fracture path. We also performed an analysis of the influence of the volume fraction on the dissipated energies of the whole structure and found the same conclusions than those derived for the fracture paths. Moreover, the value of the final dissipated energy of the whole structure, i.e. that for which the final fracture path is reached, decreases as function of the concentration.

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