Micromechanics-based non-local damage theory: Application to the prediction of localization and precursors to failure

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ABSTRACT

Quasi-brittle solids like rocks, mortar or ceramics fail through the emergence of a localization band that results from the collective response of a large number of microcracks in interaction. Originally, this problem was tackled through the study of the response of a single representative volume element [1]. However, it fails to capture the complex behavior of quasi-brittle solids as it misses the central role played by the long-range elastic interactions between the elements constituting a quasi-brittle specimen. To circumvent this difficulty, so called non-local or gradient damage models have then been proposed [2]. They rely on the introduction ad hoc of a regularization length that smears out damage. It overcomes several limitations of local models like for example the mesh dependency encountered during the computational resolution of elasto-damageable problems. However, it introduces artificial interactions between neighboring material elements that turn out to control the model prediction.

In this work, we propose a micromechanics-based non-local model derived from the mechanism governing the interactions between material elements during the process of damage spreading. In this approach, long-range elastic interactions within the damaging specimens result from the redistribution of elastic stress following the local material softening associated with a damage event. In disordered solids, this mechanism promotes cooperativity in the process of damage spreading, as one single damage event can trigger a cascade of events. As recently illustrated through the implementation of these concepts in a unidimensional system [3], this original approach captures the main features of quasi-brittle failure, like damage localization and the strong and increasing intermittent damage activity that precedes it. It also shows that cooperativity takes place over a characteristic length scale that increases as the specimen approaches failure. In this talk, we will also show how to apply these new concepts to describe the compressive failure of 2D and 3D elasto-damageable specimens. The predictions of our approach are compared with direct simulations of compressive failure as well as with compression experiments performed on two-dimensional cellular solids made of soft hollow cylinders where damage evolution can be resolved both in space and time [4]. We show that our physics-based non-local damage theory captures not only the critical load at localization and the inclination of the localization band, but also the complex statistics of precursory damage events taking place as the material is driven towards localization. The implication of our findings for the modeling of damage spreading and failure in quasi-brittle structures is finally discussed.

REFERENCES

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