Applications of a micro-structured brittle damage model to laboratory tests on rocks

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A multiscale microstructured brittle damage model [1] is used to describe the behavior of confined rock materials.

Plane strain and triaxial tests conducted at the laboratory scale are simulated in terms of boundary value problems. Simulations reveal good predictive qualities of the model to describe the macroscopic features of specimens at failure. The microstructures, oriented in different directions, allow the localization of the macroscopic strain along straight lines, emerging at the macroscale in the form of shear bands.

The microstructured material model, characterized by recursive equidistant parallel cohesive-frictional faults, is fully defined by six elastic and inelastic material constants. The model was originally developed in a finite kinematics framework to simulate the dynamic behavior of confined brittle materials [2]. In linearized form, it has been extended and used for the simulation of in-field excavations [3]. The performance of the model in predicting the behavior of small scale rock tests in the laboratory, the object of the present study, has never been investigated.

In this study, we conduct numerical simulations of laboratory tests as boundary value problems, with the goal to show that the model is able to capture several important features observed in rocks, in particular the reduction of the overall stiffness for increasing deterioration of the material, fragile to ductile transition, strain localization, shear band formation, and more general size-effect.

The model, in all the numerical tests, has been able to describe the different responses of the sandstone, reproducing both the overall mechanical response and the failure patterns, in keeping with the typical brittle-to-ductile transition manifested by geological materials under confinement.
Remarkably, all the results have been obtained by using the same set of material parameters, with no need to tune them according to the particular loading condition examined [4].
This property is a natural outcome of the microstructured nature of the model that can be characterized by several length scales and does not suffer of mesh dependency when used in discretized domains.

We conclude that the brittle damage model in the linearized version is a very promising material model for geomechanical problems, especially considering the very small number (six) of characterizing material parameters.

References

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