A linearized microstructural model for hydraulic conductivity evolution due to brittle damage

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ABSTRACT

Fractures and discontinuities are among the most important features of geological structures and are of interest in a large number of applications, spanning from the water reservoir exploitation to deeper Earth systems. In particular, in natural rock formations, fractures and discontinuities play an important role to facilitate storage and movements of fluids, since they provide preferential pathways in low permeability or impermeable rocks. A complete understanding of the influence of these structures on fluid flows is still far from being satisfactory, in particular when the hydro-mechanical coupling is significant [1].

The influence of fractures and discontinuities on the hydraulic properties of a brittle material is studied frequently through methods proper of fracture mechanics and damage mechanics or statistical approaches [2]. Contrariwise, the point of view taken in this study is based on the presence of microstructured faults which automatically provide a link between mechanics and permeability. The approach is based on a hierarchical constitutive model of distributed damage, characterized by microstructures in the form of nested families of equi-spaced frictional-cohesive faults, bounding otherwise linear elastic matrix material [3]. A linearized version of the constitutive model has been implemented into a coupled hydro-mechanical finite element code based on the Terzaghi effective stress model [4]. Fully saturation of the fluid, incompressibility of the solid skeleton, and incompressibility of the fluid have been accounted for as simplification assumptions.

The constitutive model is validated against experimental data from hydromechanical triaxial tests performed on rocks. Although the material model is characterized by a small number of mechanical parameter, validation tests confirm the ability of the model to reproduce the experimental evidence of rock behaviour even at the constitutive level.

The coupled code is used in boundary value problems, to model extended hydraulic fracturing interventions and excavation of tunnels and boreholes.

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