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Author(s):
Lei, Qinghua; Gholizadeh Doonechaly, Nima; Wang, Xiaoguang; Tsang, Chin-Fu; Loew, Simon

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A Multiphysics Platform for Modelling Coupled Deformation, Damage, Flow and Transport in Fractured Rocks

Qinghua Lei [a], Nima Gholizadeh Doonechaly [a], Xiaoguang Wang [b], Chin-Fu Tsang [c,d], Simon Loew [a]

[a] Department of Earth Sciences, ETH Zürich, Zürich, Switzerland

[b] Laboratoire HydroSciences Montpellier, Université de Montpellier, Montpellier, France

[c] Department of Earth Sciences, Uppsala University, Uppsala, Sweden

[d] Energy Geosciences Division, Lawrence Berkeley National Laboratory, Berkeley, USA

Email Corresponding Author: qinghua.lei@erdw.ethz.ch

Abstract

We present a novel multiphysics computational platform for modelling coupled hydro-mechanical processes in fractured rocks including solid deformation, damage evolution, fluid flow and mass transport. We explicitly represent the geometrical complexities of natural fracture systems associated with various length distributions, anisotropic conditions and connectivity states based on the discrete fracture network approach. We resolve the stress and strain fields within the geological formations using a state-of-the-art finite element model with the damage of intact rocks captured by an elasto-brittle failure criterion and the displacement of natural discontinuities mimicked by a non-linear elasto-plastic constitutive law with strain-softening. We couple the solid deformation and damage processes with Darcy-type fluid flow within fully-saturated fractured porous media, such that important coupling mechanisms are simulated including stress-dependent transmissivity of natural fractures, poro-elastic deformation of intact rocks, and pore pressure-induced fracture slip and rock failure (Figures 1 and 2). We further link mass transport with the flow velocity field, permitting the capture of stress-induced anomalous transport behaviour like early arrival and late-time tailing of radionuclides. We deliver a few examples in the context of nuclear waste repository engineering to demonstrate the capabilities of our platform for hydro-mechanical modelling of fractured geological media.

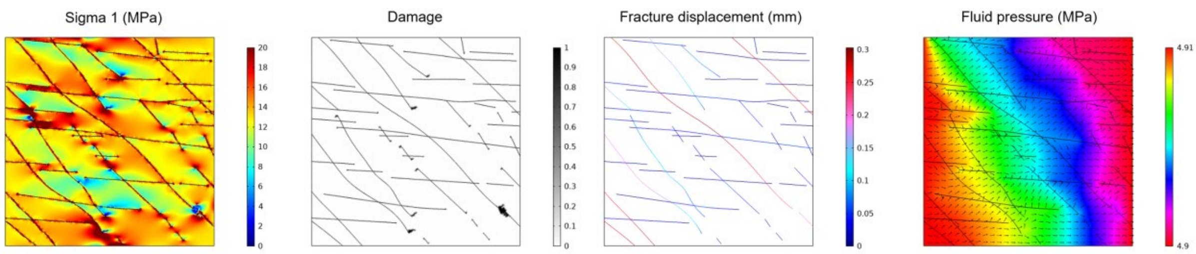

Figure 1: Simulation of stress distribution, damage evolution, fracture displacement and fluid flow in a fractured rock subjected to far-field stress loading and pore fluid pressure conditions.

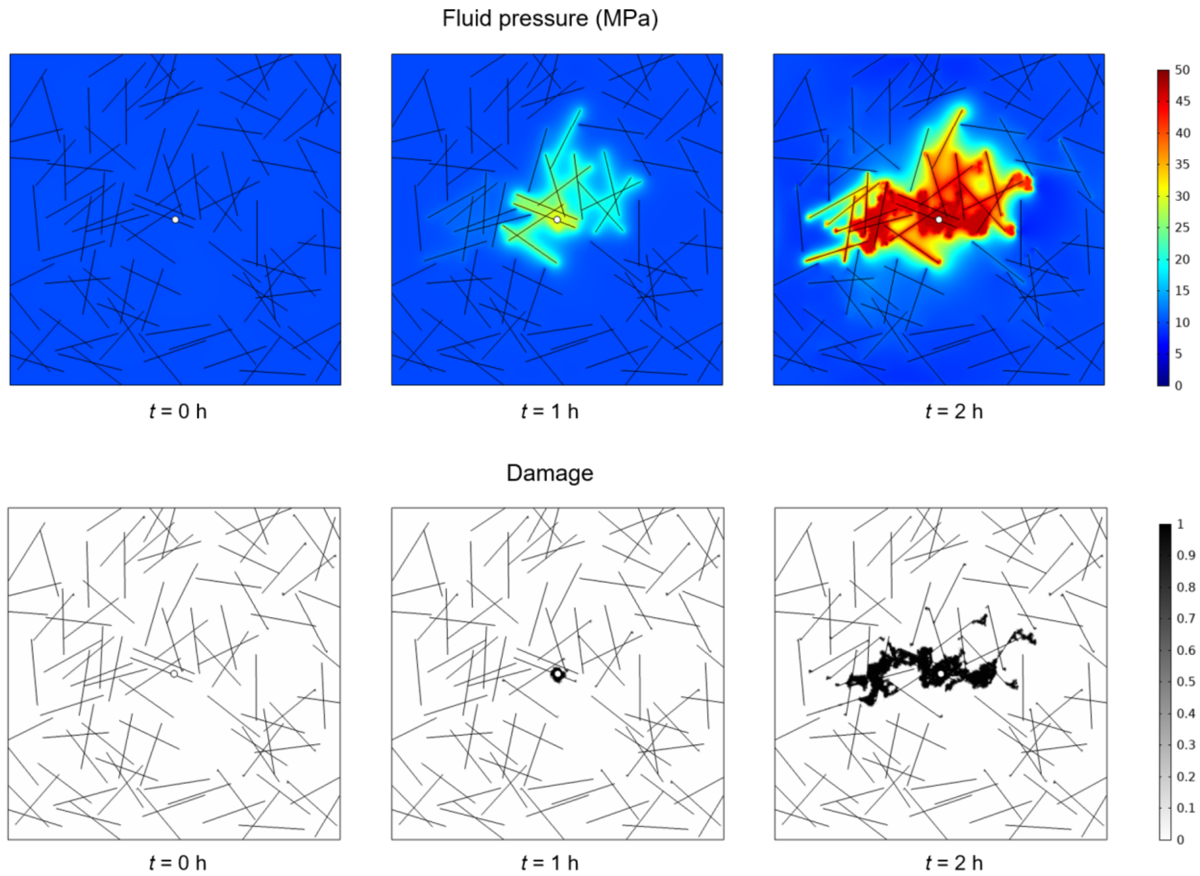

Figure 2: Simulation of fluid pressure distribution and damage evolution during the high-pressure fluid injection into a borehole through a fractured formation at a depth of 1000 m.