Supplement of

Hydro-mechanical effects of seismic events in crystalline rock barriers

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Hydro-mechanical effects of seismic events in crystalline rock barrier

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MOTIVATION

Under ideal conditions, owing to its extremely low matrix permeability, crystalline rock can constitute a suitable hydro-geological barrier. Mechanically, its high strength and stiffness provide advantages when constituting a repository and for long-term stability. However, crystalline rock usually occurs in a fractured form which can drastically alter hydro-mechanical (HM) behavior due to increased permeability and decreased strength. Seismic events have the potential to alter these HM properties by activating faults, increasing their transmissibility, creating new fractures or altering existing connectivity [1]. Therefore it is of high importance to build computational models allowing to assess the HM effects of seismic events in a Deep Geologic Repository (DGR) in crystalline rock, as illustrated in Figure 1.

The Noordbergum effect and the Mandel-Cryer effect are well-known examples of HM coupling [2] and we focus on the consequences of the time-dependent pressure and stress fluctuations after a change of the stress in the ground. Such stress changes and stress redistributions may occur after earthquakes [3]–[5] and affect even distant areas. Here, we present a coupled HM simulation, using OpenGeoSys [6], of a large-scale, three-dimensional finite-element model of the Tyasnyy Site (YS) in Russia to assess the consequences of seismically induced stress-field changes on the local stress field.

MODEL

As an example, we consider YS [8] for high-level waste in crystalline rock which is located close to a potentiometrically very high permeable aquifer, (iii) flow-induced fractures propagate generating a heterogeneous porosity-permeability field, (iv) Changing climate/permafrost impacts [7].

Geology and Hydrology

The site is located in Southern Siberia and lies on the southwestern edge of the Siberian shield. It consists of Archean and Proterozoic gneisses and is covered by Quaternary rocks. Hydrologically the region belongs to the catchment area of Yenisey river. The site itself is located on the watershed between Yenisey and another river. The borehole consists of a composite formation, the horizontal stress in average $\alpha = (\sim 500 \text{m}) = 15.5\, \text{MPa}$ higher than they would be due to gravitational only [8]. In a distance of 100 km to 1002 km9 earthquakes occurred and seismic activity has been recorded in the last 200 years [9].

Physical Properties

The physical parameters, listed in Table 1, are estimated from borehole logs, geophysical measurements and laboratory experiments. Figure 2(b) shows the estimated distribution of hydraulic conductivity.

RESULTS AND OUTLOOK

For the first load case stress increase we observe in Figure 5 the effective deviatoric stresses, collected in the von-Mises stress $\sigma_{\text{m}}$ increase as the total stresses do. Whereas the fluid (pressure) $\sigma_{\text{p}}$ carries the added total mean stress first and shifts it slowly to the solid (effective mean stress $\sigma'_{\text{m}}$).

A rotation of the horizontal stress, as in the second load case, does not change the total mean stress and so it changes neither the fluid pressure nor the effective mean stress. Still, there is a change in the deviatoric stresses.

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