Institute for Nuclear Waste Disposal (INE)

Modelling the impact of fracture geometry on bentonite erosion

F.M. Huber[1*], D. Leone[1], M. Trumm[1], A. Wenka[2], I. Neretnieks[3], L. Moreno[3] and T. Schäfer[1]

[1]Karlsruhe Institute of Technology (KIT), Institute for Nuclear Waste Disposal (INE), P.O. Box 3640, D-76021 Karlsruhe, Germany.
[2]Karlsruhe Institute of Technology (KIT), Institute of Micro Processing Engineering (IMVT), P.O. Box 3640, D-76021 Karlsruhe, Germany.
[3]Department of Chemical Engineering and Technology, Royal Institute of Technology, Stockholm, Sweden
*florian.huber@kit.edu

Background

Natural fractures are characterized by complex geometries [1]. Numerous laboratory and numerical studies carried out in the last decades have shown the importance of fracture geometry and aperture distributions on the fracture flow field. One of the most pronounced features is flow channeling arising from heterogeneity in fracture hydraulic conductivities as function of fracture apertures and geometries. These flow gradients lead to complex patterns of hydrodynamic dispersion of e.g. solute and particle/colloids present in the seeping water.

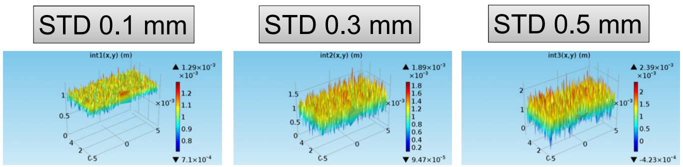
Objectives

The "KTH" model [2] on bentonite erosion was used by Moreno et al. [3] to calculate bentonite erosion rates in a parallel plate fracture geometry (constant fracture aperture of 1mm). The aim of this study is to investigate the impact of fracture aperture on bentonite erosion behavior and bentonite erosion rates. For this, the KTH model was modified to incorporate normal distributions of fracture apertures to obtain more complex fracture flow fields. Simulations cover a range of standard deviations (STDs) (0.1mm, 0.3mm and 0.5mm) and mean fracture flow velocities (315 – 0.315m/yr).

Conceptual model

Fracture aperture distributions

Since detailed natural aperture (and/or hydraulic conductivity) distributions of field scale fractures are not available, synthetic random fracture aperture distributions were generated and used in the model. From µ-computed x-ray tomography (µCT) characterizations (resolution of 80µm and 32µm) of cm scale drill cores from Äspö, Sweden by e.g. [4] information on natural fracture aperture distributions are known. These measured aperture distributions follow normal/log-normal distributions with standard deviations in the range of ~30% of the mean aperture.

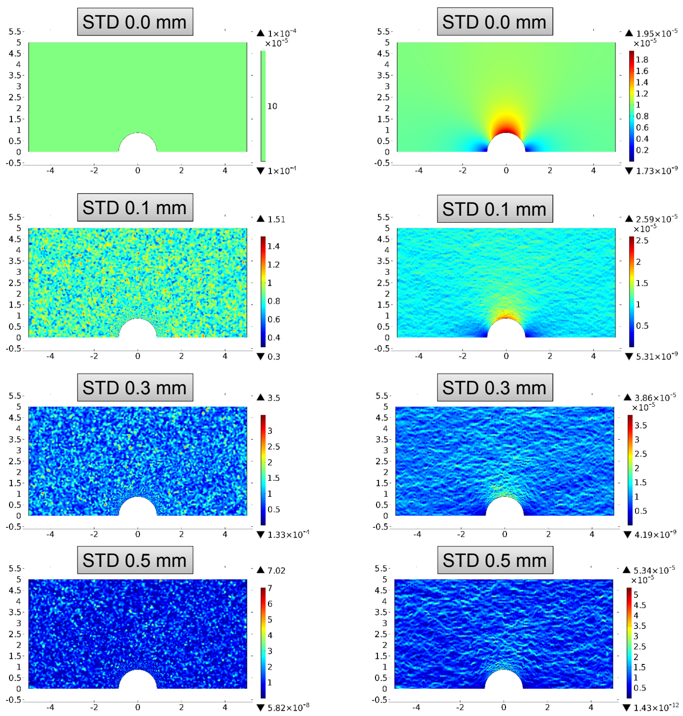


Hydraulic conductivities and Darcy flow fields

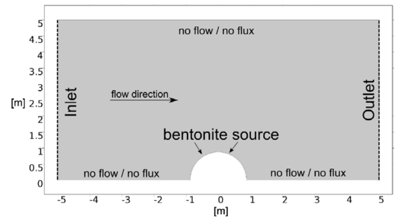
Based on the synthetic aperture distributions, hydraulic conductivity fields were calculated using the cubic law [5]:

$$K_f = \frac{\rho g}{12\mu}\delta^2$$

where K_f is the hydraulic conductivity [m/s], ρ is the density of water [kg/m³], g is the gravitational constant [m/s²], μ is the dynamic viscosity [Pa ·s] and δ is the aperture [m].

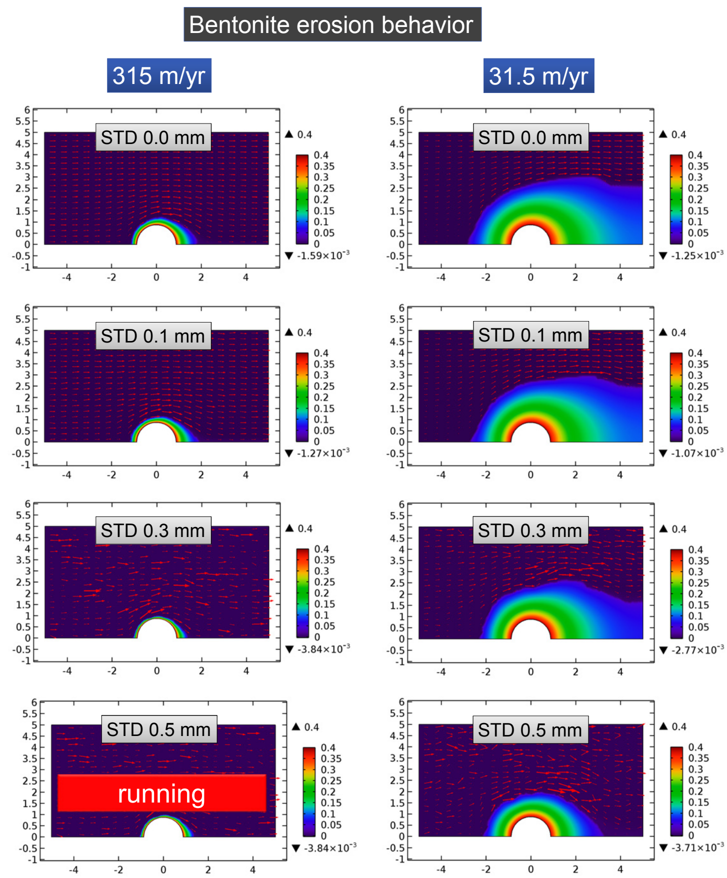


Model setup



- COMSOL Multiphysics V5.1
- Model setup as in [3]
- Pressure inlet and outlet
- No flow and no flux boundaries at model bottom and top
- Flow field coupled to bentonite transport
- 10m x 5m model size and bentonite deposition hole of 1.75m

Preliminary qualitative model results



"Conclusions" and Outlook

- Use of random aperture fields introduce complex flow velocity distributions
- Complex flow fields impact bentonite extrusion behavior into fracture
  - "Distance to gel/water interface" decreases
  - Bentonite "tail" is reduced
- Simulations for 3.15m/yr and 0.315m/yr still running and calculation of rates pending

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