EROSION OF BENTONITE BY FLOW AND COLLOID DIFFUSION

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Bentonite intrusion into a fracture intersecting the canister deposition hole is modelled. The model describes the expansion of the bentonite within the fracture (Liu *et al.*, 2009a). It accounts for the repulsive electrostatic double-layer forces, the attractive van der Waals forces and friction forces between the particles and the water. The model also takes into account the diffusion of the colloid particles in the smectite sol. The buffer contains sodium in the pore water in much higher concentrations than the approaching seeping groundwater in the fracture has. Diffusion of sodium outward in the expanding gel is accounted for as this strongly influences the double layer force and the viscosity of the gel/sol. The gel/sol is considered to be a fluid with a varying viscosity that is strongly dependent on the bentonite volume fraction in the gel and the sodium concentration in the water.

Two different geometries were modelled; a rectangular and a cylindrical showing the flow in a fracture intersecting the deposition hole with the canister. The rectangular geometry was used to gain experience with the processes and mechanisms and how they interact since the cylindrical geometry was somewhat less stable numerically and more time consuming. In the rectangular geometry a fracture 1 metre long in the flow direction was modelled. In both geometries the fracture depth (extent from the deposition hole) was selected sufficiently large to ensure that the water velocity, near this border was nearly the same as the approaching water velocity and that the smectite concentration there was vanishingly small.

It was found that the velocity of the fluid drops considerably where the bentonite volume fraction is larger than 1-2%. This is due to the strong increase in viscosity with increasing bentonite volume fraction. Figure 1 shows as the viscosity varies with the smectite volume fraction for different sodium concentrations.

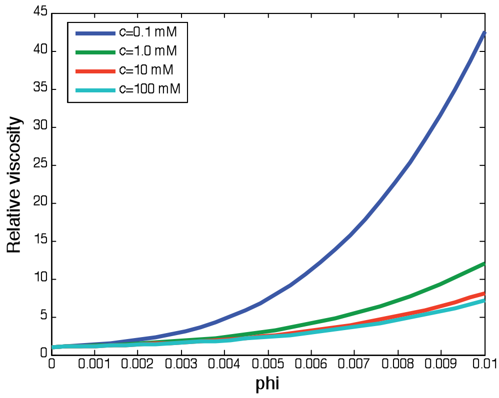

Figure 1: Relative viscosity as function of the smectite volume fraction for different sodium concentrations.

The loss of smectite as it is carried away by the slowly flowing fluid was found to be proportional to the square root of the seeping water velocity for the rectangular geometry. For the cylindrical geometry, the dependence is somewhat lower (exponent about 0.4) since the length of the gel/water interface decreases with increasing water flow rate. The penetration depth of the gel/water interface decreases with increasing water flow rate. For water velocity of the order of a metre per year the gel may penetrate several metres into the fracture at steady state.

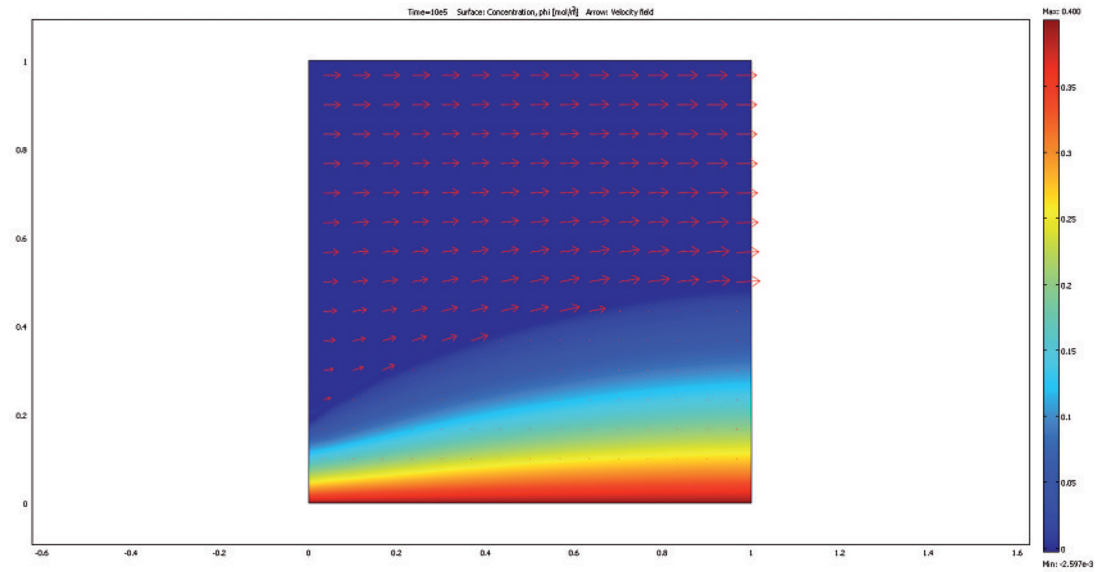

Figure 2: Smectite volume fraction distribution and water velocity field in the fracture.

Figure 2 shows the penetration of smectite into the fracture and the water velocity for the rectangular geometry. The dimensions of the fracture are 1m x 1m.

The simulations were made with only sodium as counterion. Most simulations had sodium concentrations below the critical coagulation concentration, CCC. In the compacted bentonite at the fracture mouth it was 10 mM and 0.1 mM in the approaching water. At these concentrations the gel is expansive and can turn into a sol releasing colloidal particles. The low ion concentration has a strong impact on the fluid viscosity, which increases with decreasing ionic strength. At the same time, however the repulsion forces between the smectite particles increase causing a quicker expansion and sol formation. Simulations with higher sodium concentrations in the seeping water had a marginal influence on the erosion rate.

For the highest water flow rates the smectite loss could be up to 0.3 kg per year for one canister. This is more than one order of magnitude more than what would result by smectite particle diffusion alone if gel flow was neglected and account was only taken of particle diffusion out into the seeping water.