Modeling of Bentonite Hydration Process in a High Level Waste Repository

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Abstract

Introduction
We deal with a problem of bentonite behavior during the saturation process in a high level waste repository of KBS-3V conception, SKB (2010). (Swedish conception which considers radioactive waste stored in copper canisters deeply in boreholes in compact crystalline rock, sealed with bentonite, Figure 1). Bentonite is a type of clay with specific nonlinear behavior caused by water adsorption and swelling ability in contact with water. It leads to nontrivial problems for a numerical solution.

Solved models
We solve problems of bentonite saturation (flow of water in partly saturated conditions) with simple 2D axisymmetric models which includes borehole filled with bentonite, deposition tunnel and surrounding rock with the fracture as a main path for transport of water to bentonite. In the next step models are extended with the process of diffusion of water vapor in model. Vapor diffusion is another way for bentonite hydration and it affects the process especially at higher temperatures, which are expected inside the repository.

Use of COMSOL Multiphysics® and model results
Referred process is possible to describe with Darcy's law in partly saturated conditions - so called Richards' equation and related models were implemented in COMSOL Multiphysics® using Richards' equation interface. Governing equations for process considering additional vapor diffusion are more general mass balance equations for non-isothermal multiphase flow of water and gas through porous media according to Olivella et al. (1996). Models with additional vapor diffusion was not possible to solve using built-in interface in COMSOL Multiphysics®, thus they are defined in General form PDE interface.

Described problems were also compared with previously developed models described in Skarydova (2013) solved with FE computing system Ansys, Ansys (2010). Models with an identical axisymmetric geometry were solved using slightly differently defined physical model - diffusion equation with nonlinear diffusivities, Börgesson (1985). Nevertheless this concept corresponds with Richards' equation concept (because it is derived from it using specific relation for material permeabilities and retention curves). COMSOL Multiphysics® problems were more easily defined and diffusion of water vapor was included in contrast to Ansys problems. Models show small differences in distributions of saturation over time but they are probably caused by

different type of finite elements.

Our modeling is based on the work which was done during author's stay in Clay Technology AB in Sweeden. Model concept in COMSOL Multiphysics® was developed on another simple benchmark model of bentonite hydration. Model reproduced analogical Clay Technology's computation defined by software Code_Bright in the past (specialized FEM program that allows for thermo-hydro-mechanical analysis in geological media, which is based on mass balance equations in general form, Olivella et al. (1996)).

The reffered model geometry (for Ansys and COMSOL Multiphysics® simulations), input data are connected with international Task Force on Engineered Barrier Systems project (TF EBS), Bockgård et al. (2010), and ongoing experiment called BRIE (Bentonite Rock Interaction Experiment) in the Äspö hard rock laboratory, SKB (2011), designed for predictions of bentonite hydration and better understanding of processes during the saturation.

Reference

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Figures used in the abstract

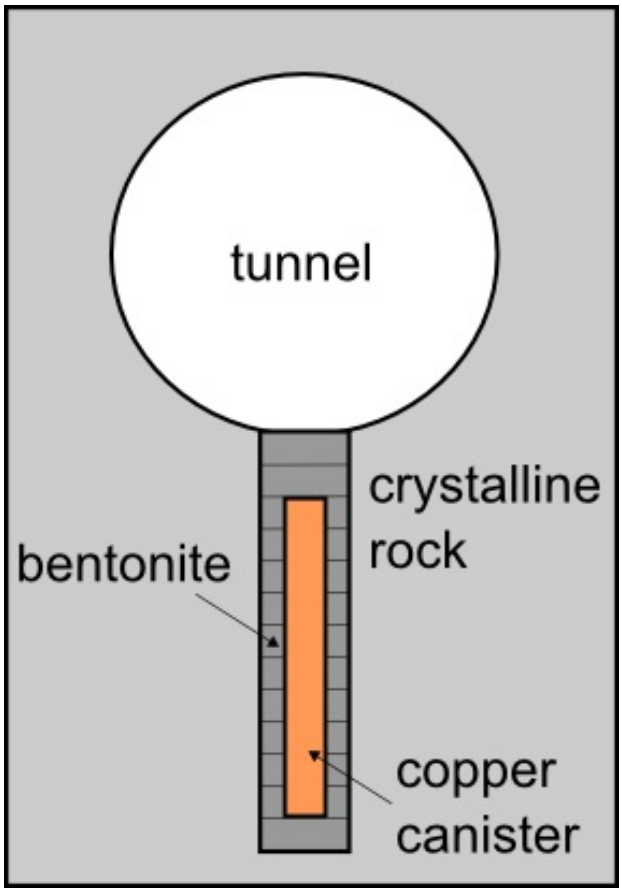

Figure 1: Schematic representation of KBS-3V conception