COMPARING FLOWS TO A TUNNEL FOR SINGLE POROSITY, DOUBLE POROSITY AND DISCRETE FRACTURE REPRESENTATIONS OF THE EDZ

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INTRODUCTION

Andra is studying the Callovo-Oxfordien mudstones, located at a depth of approximately 500 m beneath the borders of the Meuse and the Haute-Marne *Départements*, in order to assess the feasibility of constructing a repository for radioactive waste in this low-permeability geological formation.

The construction of a repository will lead to the formation of a zone adjacent to the repository (the Excavation Damaged Zone, or EDZ) in which the rock suffers mechanical damage. In the EDZ, fractures and cracks will develop, and therefore the hydraulic properties (including the permeability) will be different from those of the undamaged rock. There are some experimental data which, despite significant uncertainties, allow a conceptual model of the fractures to be defined.

The objectives of this study were:

- To develop a Discrete Fracture Network (DFN) model of the EDZ;
- To derive effective properties for both single continuum and Multiple Interacting Continua (MINC) models from the DFN model; and
- To use the various models to simulate desaturation of the rock during the operational phase of the repository, and subsequent resaturation of a tunnel post-closure (a period of thousands of years).

MODELLING FRACTURED SYSTEMS

The approaches to modelling flow and transport in fractured systems fall into two rough classes: DFN models; and continuum models.

DFN models account explicitly for the effects of individual fractures on fluid flow and solute transport, and usually do not consider the interaction between the fractures and the rock matrix.

Continuum models may be single continuum, double continuum or MINC. Single continuum models are applicable when the interaction between the fractures and the rock matrix is sufficient to establish a local equilibrium. Double continuum models account for the two interacting systems (i.e. fractures and rock matrix) by conceptualising each as a continuum occupying the entire domain. An exchange function describes mass transfer between the continua. The MINC model (Pruess 1983, Pruess 1992) is an extension of double continuum models. Double continuum models assume that the flow between the fractures and matrix blocks is "quasi-steady" (i.e. proportional to the local difference in average pressure between the fractures and matrix blocks). In contrast, the MINC model treats this flow in a fully transient way; it resolves the gradients that drive the flow by discretising the matrix blocks into a nested sequence of volume elements.

SOFTWARE TOOLS

DFN models were implemented using the computer program NAPSAC (Serco 2009). The program uses an efficient finite-element method that allows the flow through many thousands of fractures to be calculated accurately. Amongst its capabilities, NAPSAC is able to: calculate the effective continuum permeability tensor; calculate the porosity and the inter-fracture matrix block size; simulate steady-state and transient inflows to tunnels; and simulate unsaturated flow in fractured rocks.

Continuum models were implemented using the computer program TOUGH2v2 (Pruess 1987, Pruess 1991, Pruess *et al.* 1999). TOUGH2v2 can be used to simulate multiphase flows in single continuum, double continuum or MINC models.

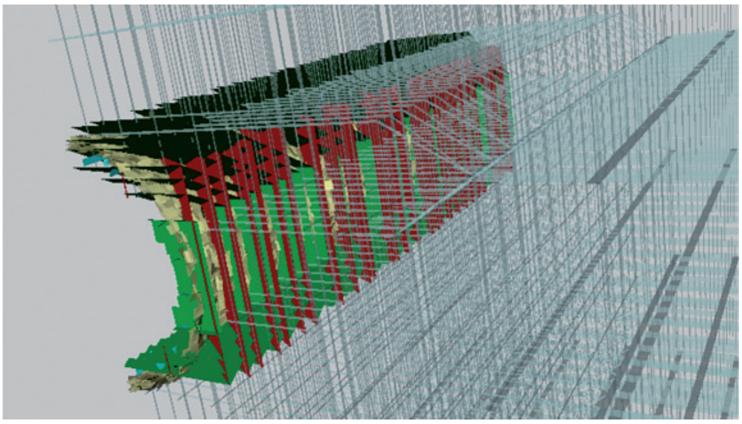

Figure 1: DFN model of the EDZ (chevron fractures are coloured green; oblique fractures are coloured red; and random fractures are coloured yellow).

MODELS OF THE EDZ

A DFN model of the EDZ was developed. The model includes three classes of fractures.

- Chevron fractures are curved, flowing surfaces, which cut perpendicular to the tunnel axis and have a variable spacing.
- Oblique fractures are planar, and cut into the side of the tunnel at a defined angle.
- Random fractures are small, planar features, which lie in a narrow region close to the tunnel wall.
- Additionally, lattices of fractures were included in the DFN model to represent the undamaged clay and the concrete lining of the tunnel.

NAPSAC was used to calculate effective continuum permeability tensors and porosities for sub-regions of the DFN model. These permeability tensors and porosities were used to parameterise both single continuum and MINC models of the EDZ.

RESULTS

For each of the models (i.e. DFN, single continuum and MINC), desaturation of the rock during the operational phase of the repository and subsequent resaturation of a tunnel post-closure is simulated. The different results (e.g. flows to the tunnel) are compared.

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