3D modelling of the Excavation Damaged Zone around HLW/ILW tunnels and shafts using a Marked Point Process technique

Andrés Alcolea [1], Uli Kuhlmann[1] and Paul Marschall[2]

(1) TK Consult AG; Mainaustrasse 30, 8008 Zürich; andres.alcolea@tkconsult.ch; +41 44 310 14 76.

(2) Nagra (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle); Hardstrasse 73, 5430 Wettingen.

Target topic: CHARACTERISATION AND MODELLING OF REPOSITORY INTERACTION PROCESSES; Topic 6: Hydromechanical and gas transport processes during the excavation, operational and post-closure phases.

Preference: Oral Presentation (Andrés Alcolea), eligible for publication in Journal

The evaluation of the impact of repository induced effects has been identified as a key aspect in the assessment of engineering feasibility and long-term safety of deep geological repositories for radioactive waste. In the Swiss disposal concept the key effects addressed are the pH-plume associated with the cement backfill of the L/ILW caverns, the accumulation and release of repository gases, the heat emission of the SF/HLW canisters and the Excavation Damage Zone (EDZ hereinafter) around the backfilled underground structures. The EDZ represents a possible release path for radionuclides and corrosion and degradation gases which needs to be addressed quantitatively in Safety Assessment (SA).

In hard rocks and indurated claystones the EDZ is often represented by a discrete fracture network (Geomechanica, 2013, Lisjak et al. 2015). The complexity of a dense fracture network precludes its implementation in conventional SA models. To overcome the implementation problem, Alcolea et al. (2014) elaborated a traceable and versatile heuristic modelling workflow for the conversion of the discrete fracture network into a hydraulically equivalent two-dimensional porous medium model that allows the simulation of hybrid processes, accounting simultaneously for both fracture flow in the excavation induced fractures and porous medium flow in the intact rock matrix. Alcolea et al. (2014) also included mechanical processes like fracture mechanical closure and matrix swelling in response to variations of effective stress. This allows the simulation of the self-sealing processes in the EDZ in response to pore pressure recovery and swelling pressures caused by resaturation of the bentonite buffer.

The aforementioned methodology was benchmarked using data from the HG-A experiment in Mont Terri (Alcolea et al., 2015). One main result of that exercise is that simplified 2-D axial symmetric models are insufficient to fit to available pore pressure measurements along the EDZ. The physical phenomena associated with the re-saturation of the system are clearly three-dimensional, which needs to be addressed in an adequate manner.

In this presentation, we show the extension of the 2D approach to render 3D continuum models of the EDZ. To that end, we use a Marked Point Process technique (Illian et al., 2008) including Monte Carlo analysis. The 2D geomechanical simulations of the discrete fracture network are "training" data sets, whose characteristics are borrowed by the derived stochastic models. Fractures are modelled as a point process in the fracture plane. Fracture location is modelled as a Poisson point process in which the points are the midpoints of line representations of fractures. Since just points do not provide any information about fracture characteristics, such as length, aperture or orientation, the so-called marks are assigned to the representative points to represent these characteristics. The inclusion of marks provides a marked point data set that can be modelled as a Marked Point Process. Once the models for points and marks are established they can be used to simulate points and associated marks for other regions that are assumed to have the same, or similar, characteristics as the training dataset from which models are derived. Fracture networks are stochastically simulated by replacing the simulated marks with the properties they represent (Figure 1; white lines).

Once a 3D simulation of the discrete fracture network has been obtained, the upscaling methodology of Alcolea et al (2014) can be applied to convert it into a hydraulically equivalent porous medium model. Such models can then be the subject of further modelling exercises, e.g. flow and transport simulations.

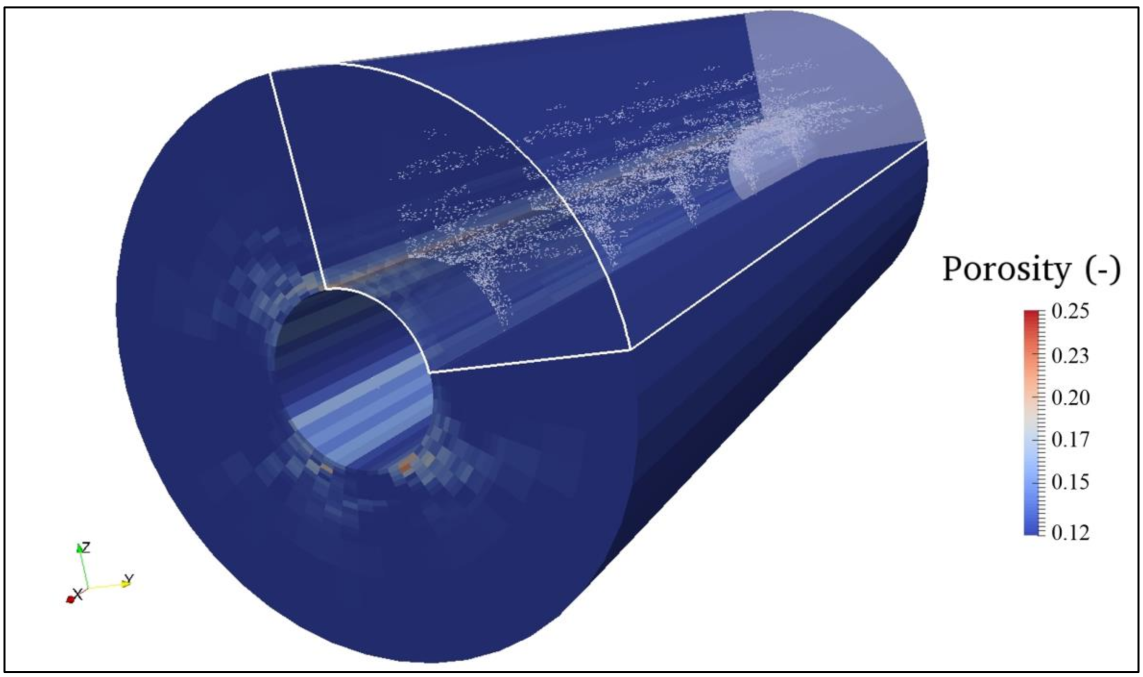

Figure 1: Simulated 3D equivalent porous model generated with the 50x50 super-blocks grid. The fracture network is partly visible and depicted by gray lines (quadrant 12 o'clock to 3 o'clock, encompassed by white lines; the opacity of the porosity distribution has been reduced to 50%).

References

Alcolea, A., Kuhlmann, U., Lanyon, G.W. & Marschall, P. (2014): Hydraulic conductance of the EDZ around underground structures of a geological repository for radioactive waste – A sensitivity study for the candidate host rocks in the proposed siting regions in Northern Switzerland. Nagra Arbeitsbericht NAB 13-94, Nagra, Wettingen, Switzerland.

Alcolea, A., Kuhlmann, U., Lanyon, G.W. & Marschall, P. (2015): Hydraulic conductance of the EDZ around underground structures of a geological repository for radioactive waste – Application to the HG-A experiment in Mont Terri. Nagra Arbeitsbericht NAB 15-42, Nagra, Wettingen, Switzerland.

Alcolea A., Marschall P. (2016): 3D modelling of the Excavation Damaged Zone around HLW/ILW tunnels and shafts using a Marked Point Process technique. Nagra Arbeitsbericht NAB 16-64; Nagra, Wettingen, Switzerland.

Geomechanica (2013): Extent and shape of the EDZ around underground structures of a geological repository for radioactive waste – A sensitivity study for the candidate host rocks in the proposed siting regions in Northern Switzerland. Nagra Arbeitsbericht NAB 13-78, Nagra, Wettingen, Schweiz.

Illian J., Penttinen A., Stoyan H., Stoyan D. (2008): Statistical analysis and Modelling of Spatial Point Patterns. John Wiley and Sons, England, ISBN: 978-0-470-01491-2, pp.560.

Lisjak, A., Tatone, B.S.A., Mahabadi, O.K., Grasselli, G., Marschall, P., Lanyon, G.W., de la Vaissiere, R., Shao, H., Leung, H., Nussbaum, C. (2015). Hybrid finite-discrete element simulation of the EDZ formation and mechanical sealing process around a microtunnel in Opalinus Clay. Rock Mechanics and Rock Engineering. Doi:18 10.1007/s00603-015-0847-2