Change of Fractured Rock Permeability due to Thermo-Mechanical Loading of a Deep Geological Repository for Nuclear Waste - a Study on a Candidate Site in Forsmark, Sweden

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Opening of fractures induced by shear dilation or normal deformation can be a significant source of fracture permeability change in fractured rock, which is important for the performance assessment of geological repositories for spent nuclear fuel. As the repository generates heat and later cools the fluid-carrying ability of the rocks becomes a dynamic variable during the lifespan of the repository. Heating causes expansion of the rock close to the repository and, at the same time, contraction close to the surface. During the cooling phase of the repository, the opposite takes place. Heating and cooling together with the virgin stress can induce shear dilation of fractures and deformation zones and change the flow field around the repository.

The objectives of this work are to examine the contribution of thermal stress to the shear slip of fracture in mid- and far-field around a KBS-3 type of repository and to investigate the effect of evolution of stress on the rock mass permeability. In the first part of this study, zones of fracture shear slip were examined by conducting a three-dimensional, thermo-mechanical analysis of a spent fuel repository model in the size of 2 km x 2 km x 800 m. Stress evolutions of importance for fracture shear slip are: (1) comparatively high horizontal compressive thermal stress at the repository level, (2) generation of vertical tensile thermal stress right above the repository, (3) horizontal tensile stress near the surface, which can induce tensile failure, and generation of shear stresses at the corners of the repository. In the second part of the study, fracture data from Forsmark, Sweden is used to establish fracture network models (DFN). Stress paths obtained from the thermo-mechanical analysis were used as boundary conditions in DFN-DEM (Discrete Element Method) analysis of six DFN models at the repository level. Increases of permeability up to a factor of four were observed during thermal loading history and shear dilation of fractures was not recovered after cooling of the repository.

An understanding of the stress path and potential areas of slip induced shear dilation and related permeability changes during the lifetime of a repository for spent nuclear fuel is of utmost importance for analysing long-term safety. The result of this study will assist in identifying critical areas around a repository where fracture shear slip is likely to develop.

The presentation also includes a brief introduction to the ongoing site investigation on two candidate sites for geological repository in Sweden.