DRIFT SCALE THERMOMECHANICAL ANALYSIS FOR THERMAL LOADING AND RETRIEVABILITY STUDIES

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SUMMARY

Currently, the repository portion of the Mined Geologic Disposal System for the disposal of spent nuclear fuel and high level radioactive waste is in the advanced conceptual design (ACD) stage. A number of systems studies have been undertaken to support the development of ACD options for the repository design. As a part of the Thermal Loading Systems Study and the Retrievability Period Systems Study, a numerical method was used to estimate the stability of emplacement drifts. Drift stability is an important performance issue, particularly for the concept of a waste package (WP) in an open drift. Drift stability is both a preclosure and postclosure issue. Specifically, preclosure worker safety and WP retrievability can be affected by drift stability. Important postclosure drift stability issues are the potential for rockfall which might damage a WP or the potential formation of cracks and upheaval of rock masses which may alter the hydrologic performance of the repository.

When a drift is excavated in a rock mass, the introduction of the boundary surfaces (drift walls) reduces the traction on the surfaces from the natural state of stress to zero. Such traction reduction induces change in the stress state within the host rock around the drift causing displacements in the vicinity of the excavation. Fractures in the rock mass may be extended or initiated, and existing fractures can be opened or closed by the change of the stress state. Thermally-induced stresses in rock can exacerbate the responses described above. Upon the rapid cooling of a repository (possibly performed for the retrieval of the WPs) the volume of rock blocks decreases with the decreasing temperature. Because the specified displacement boundary condition of the system does not change, and the movement of rock blocks is not reversible for thermal changes, the fracture size in the rock mass may increase further during a temperature drop.

In the current study, thermomechanical analyses, using the Discontinuous Deformation Analysis (DDA) numerical code, were performed to support the thermal loading study and the retrievability study. The coupled effects between thermal and mechanical behavior induced by the excavation, thermal loading and rapid cooling were analyzed using rock-mass models shown in Figure 1. The theoretical detail and the formulations of the DDA code can be found in Shi[1] and Tsai[2]. Four simulations were conducted using the DDA method to investigate the effects of drift size and the thermal load on the stability of an unsupported emplacement drift.

Input data for the jointed-rock pattern, in situ stress condition, and the material properties of intact rock and rock joints were adopted from the Yucca Mountain Site Characterization Project Reference Information Base, DOE,[3] and a Yucca Mountain Site Characterization Project report, Lin et al.[4] Nonlinear thermal expansion coefficients for the rock blocks were adopted from the preliminary results of a laboratory test performed by Sandia National Laboratories, Chocas.[5] In the deformed mesh resulting from simulation of drift excavation, the 100-year post-emplacement temperature at the center of each rock block is computed using Lingineni's model for each simulation, Lingineni.[6] To retrieve waste canisters, it will be necessary to cool the air temperature in the drift by ventilation (rapid cooling) to perform the operation. The temperature di boundary condition of 43°C at the drift wall and then calculating the temperature decay profile as a function of time using Lingineni's model.

The opening and closing of fracture apertures in the immediate area of a waste emplacement drift, together with the induced stress state, were used to provide information for assessing the stability of an unsupported drift. To evaluate the stability of the rock mass a few meters away from the drift (i.e., in the near field), the computed stresses in the rock mass were compared with the established criterion for the rock mass strength. The analysis found that the stresses produced in the rock at thermal loads of 27.4 kgU/m^2 (111 MTU/acre) would exceed stability criteria and could result in tunnel instability. At thermal loads between 20.5 kgU/m^2 (83 MTU/acre), the drift is predicted to be stable and its structural integrity remains after thermal loading. In this case, the emplacement drift with the smaller diameter appears to have better stability due to the smaller free surface allowing less rigid body motion of rock blocks separated by joints. However, local rock spalling may occur which would require tunnel support such as rock bolts and/or liners. According to the numerical prediction, more rock fall may occur during the retrieval period due to the stress relaxation caused by the rapid cooling in the area immediately around the drift.
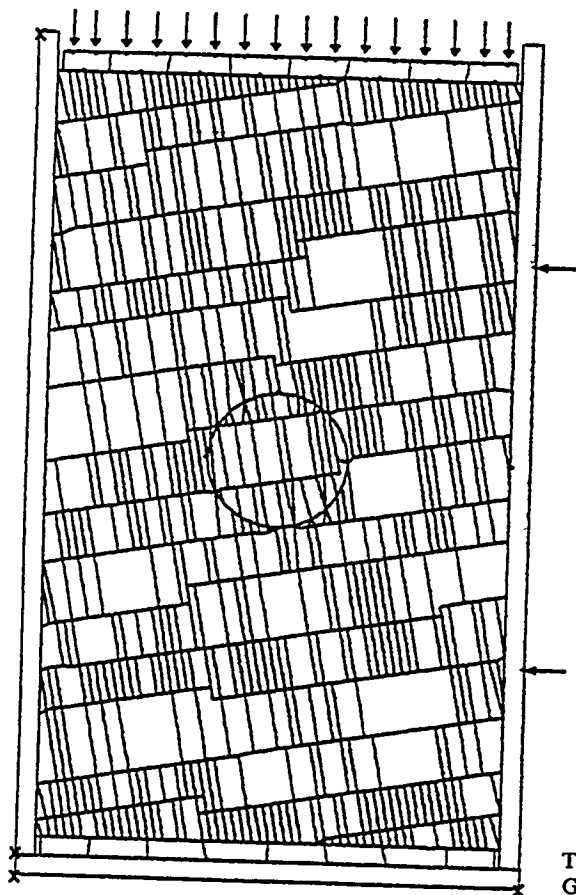

Figure 1. DDA Mesh for a 7m Drift

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