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Consulting Group, Inc.

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U.S. Nuclear Regulatory Commission
Division of Waste Management
Mail Stop 4H3
Washington, D.C. 20555

"NRC Technical Assistance
for Design Reviews"
Contract No. NRC-02-85-002
FIN D1016

Dear Mr. Tanious:

Enclosed please find an outline of the report entitled "Sensitivity of the Stability of a Waste Emplacement Drift to Variation in Assummed Rock Joint Parameters in Welded Tuff". This report is to be completed under NRC Contract 02-85-002, Task Order No. 005.

Please review the outline and contact me regarding your comments.

Sincerely,

Mark Christianson

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Project Engineer

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SENSITIVITY OF THE STABILITY OF A WASTE EMPLACEMENT DRIFT TO VARIATION IN ASSUMED ROCK JOINT PARAMETERS IN WELDED TUFF

1. INTRODUCTION

1.1 Background

In jointed rock masses such as the welded tuffs of the Topopah Spring member, behavior is likely to be controlled in large part by existing discontinuities or joints. Key to jointed rock mass behavior, therefore, are the joint strength parameters of cohesion and friction angle, the joint deformation parameters of dilation, normal and shear stiffness, and the geometric parameters of joint orientation, spacing, and persistence. With the exception of dilation and persistence, average values and variability of the parameters are reported in the SCP-CDR. The dilation of the joints are not reported, however representative values for other rock joints are known and can be used as a basis for assuming values here. The joints persistence is also not reported but is thought to play an important role in governing rock mass behavior. Extreme values of persistence will be studied to determine the importance of persistence on room stability.

There is some concern as to the ability of current test procedures to properly determine the properties needed to predict insitu joint behavior. Inability to control normal stiffness and sample rotation during shear testing may result in apparent friction angles which are too high. In addition some parameters appear to be load path dependent. The final report will elaborate further on this issue.

1.2 Objectives

Determine the relative effects of variation in joint parameters on room stability in a thermally loaded waste emplacement drift.

2. APPROACH

2.1 Assumptions and Idealizations

The emplacement drift being modelled is in the center of an emplacement panel. This assumption allows symmetry to be imposed reducing the computation time. The emplacement of waste in the panel is assumed to be instantaneous.

The analyses ignore any effects of the joint on the thermal conductivity of the rock mass. Based on the results of the G-Tunnel Heated Block Test and other tests involving thermal conductivity of rock masses, this assumption appears reasonable. The analyses also ignore the effects of fluid (i.e. air and water) convection in the rock mass and emplacement room. The analyses ignore effects of boiling of pore water which could affect heat transfer rates. The thermal properties used assume fully saturated conditions.

A linear stiffness Mohr-Coulomb joint model will be used for all analyses involving explicit representation of joints. While more complex models exist such as the continuously yielding model (Cundall, 1988) and the Barton-Bandis model (Barton, 1982), these models vary in detail of the behavior, but the fundamental effects are similar.

2.2 Numerical Models

The two computer codes, FLAC (ITASCA, 1987) and UDEC (ITASCA, 1988), are used to simulate the thermal/mechanical response of the rock from the time of initial waste emplacement. Both codes consider a two-dimensional section of a disposal room perpendicular to the room axis at the center of an emplacement panel (i.e. plane strain conditions are assumed).

The rock mass is modeled in FLAC using an ubiquitous joint model with a single orientation of jointing. The ubiquitous joint model is analogous to a model in which joints are continuous (i.e. persistent) and very closely spaced. Ubiquitous joint models are therefore often compared to a 'deck of cards'. In UDEC each joint is explicitly modeled with variable spacing and persistence. The matrix in UDEC is assumed to behave elastically. This means that inelastic behavior is allowed to occur in the rock mass in FLAC but only in the joints in UDEC. It is acknowledged that Mohr-Coulomb failure of the rock mass could also occur but is not included in the analysis so that the effects of joints alone may be determined.

2.3 Conceptual Considerations

Only emplacement of waste in vertical boreholes is being considered in these analyses. It is assumed that the general conclusions will also apply to the horizontal placement alternative.

Using two-dimensional models requires that the discrete location of the waste containers be distributed uniformly along the disposal room. In the case of vertical emplacement, this means the location of a vertical heat-generating trench at the center of the floor along the axis of the room. Because of the transient nature of the problem as well as the geometric layout of the waste, the "trench" concept is expected to be an adequate idealization of the emplacement. The thermal loading is based on the current layout of commingled spent fuel and defense high level waste as given in the SCP-CDR.

3.0 Modelling sequence

- EXCAVATION OF THE DISPOSAL ROOM AT TIME = 0

  (Deformations and stresses are determined throughout the rock.)

- INITIAL WASTE EMPLACEMENT AT TIME = 0

  (Heat transfer calculations start.)

- WASTE ISOLATION AT 50 YEARS

  (The thermal/mechanical response of the rock is predicted, and compared for times of 0 and 50 years. The disposal room is not ventilated during this period. Most of the heat transfer in the room during this period is by convection and thermal radiation. The codes used do not allow for the simulation of radiation explicitly.

4. MATERIAL PROPERTIES

The base thermal and mechanical properties used are consistent with the 'design' rock mass properties reported in the SCP-CDR. The range in properties analyzed will include the variation reported for the 'recommended' properties in the SCP-CDR.

TABLE 1

'Design' values as reported in chapter 2 SCP-CDR

Property	AVG	MIN	MAX	Units	Comments
Rock Mass property					
Bulk Density	2.34			g/cc	
E	15.1			GPa	
Poisson's ratio	0.20				
Comp Str	75.4			MPa	
Cohesion	22.1			MPa	
Friction	29.2			Degrees	
K (sat)	2.07				
Cp (sat)	2.25			j/cm^3 K	
Therm Exp.	1.07E-05			1/K	
Joint property					
Kn	1E+07	1E+05	1E+07	MPa/m	
Ks	1E+05	1E+05	1E+07	MPa/m	
Cohesion	1.0	0.0	1.0	MPa	
Friction	0.8	0.2	0.8	Coef	
Dilation	2.0	0.0	5.0	Degrees	(assumed)

5. DISCUSSION OF RESULTS

The mechanical results will compare the data in 5.1 and 5.2. Of primarily interest are the predicted displacements along the joints in UDEC and inelastic behavior of the rock (ubiquitous joints) in FLAC. The inelastic rock behavior is the parameter that indicates the potential for rock instability. The amount of inelastic rock behavior is what may determine the structural integrity of the disposal rooms.

5.1 FLAC

Displacements of crown, rib and floor.

Area of plastic yield

5.2 UDEC

Displacements of crown, rib, and floor

Normal and shear displacements along joints

6. SUMMARY AND CONCLUSIONS

Provide a brief summary of the analyses. Relate any predicted inelastic rock behavior to room stability. Give suggestions as to any ground support that may be required. Point out important assumptions and limitations, and in what way the results may change given the current parameter uncertainties.

7. REFERENCES

Cundall, Peter, 1988

Barton, Nick, 1982. Modelling Rock Joint Behavior from In Situ Block Tests: Implications for Nuclear Waste Repository Design, ONWI-308, Prepared by Terra Tek, Inc. for Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

APPENDIX A

Listing of the computer input files. Identification of the computer input and output files and their physical location.

Fig. 2-7 Illustration of the Movement of the Resultant Contact Force Due to Rotation of the Surfaces in Contact (overlaps are exaggerated)

K_T, as defined above, has the dimension of length, but it should probably be normalized by the length of the contact plane in the direction of movement of C_i. However, more data is needed from laboratory tests before K_T can be defined properly.

(3) limit to movement of reference-point

Because the reference-point is the point at which contact forces act, it must lie on the surface of both blocks. After applying Eqs. (11) and (12), the reference-point is tested against each face of the two blocks comprising the contact. If it is found to lie outside any one, it is brought back toward the face as follows:

$$C_i := C_i + [n_i n_k n_k(f) - n_i(f)].d \qquad (2\text{-}13)$$

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