SCIENTIFIC NOTEBOOK

612-21E

by

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Southwest Research Institute Center for Nuclear Waste Regulatory Analyses San Antonio, Texas **Date:** 18 April 2006 **Title:** Drift Degradation implementation in driftfail.f for TPA 5.0.

References: Drip Shield – Waste Package Mechanical Interaction prepared by L. Ibarra, T. Wilt, G. Ofoegbu, R. Kazban, F. Ferrante, and A. Chowdhury January 2006.

MECHFAIL: A Total-System Performance Assessment Code Module for Evaluation Engineered Barrier Performance Under Mechanical Loading Conditions, prepared by G. Douglas Gute et al.

Drift Degradation Analysis prepared by the DOE document number (ANL-EBS-MD-000027 REV 03 September 2004)

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Objectives : Document the Development of a computational model to represent the degradation process of the repository drifts in the Yucca Mountain waste facility for the TPA assessment.

Work Plan:

- 1) Establish a mathematical description of the drift geometry
- 2) Establish a reasonable description of the drift degradation process
- 3) calculate a vertical pressure as a result of rubble accumulation

Discussion: The geometry of a drift is relatively simple: The drip shield with a width (D_w) and height (D_h) sits on top of an invert (height = IH) inside a circular drift (radius= R).

As time proceeds it is proposed that the drift will collapse. The collapsed matter will rubblize and begin to fill up the unoccupied areas within the drift. The volume of the rubble will be slightly larger than the rock volume from which it degraded from. The amount of increase in volume is defined as the bulking factor,

$$V_f = V_o \Big(1 + B_f \Big)$$

where V_f and V_o are the final and initial rock volumes and B_f is the bulking factor. This collapse will continue until the rubble completely fills the available void spaces.

Two shapes of drift degradation are proposed to represent the majority of drift degradation cases. The first is a simple chimney type degradation (see Drift Degradation Figure 1) and the second is a trapezoidal type degradation (see Drift Degradation Figure 2).



Drift Degradation Figure 1. A simplified diagram of the drift. The drift has a radius of R, with an invert of height IH. During chimney (piping) type drift degradation the drift height increases to height H above the original drift ceiling, and maintains a constant width equal to the diameter of the drift (2R).

During chimney drift degradation the maximum height of the drift is determined by the bulking factor of the rubble and the size of the void space within the drift. Returning to the definition of the bulking factor the final and initial volumes can be evaluated in two dimensions as the initial area of the rock which degrades and the final area of the rubble.

$$A_f = A_o \Big(1 + B_f \Big)$$

The initial area of the rock in this shape is the rectangular area and the small semi-circular region above the initial drift that lies below the rectangular region.

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$$A_o = 2RH + 2R^2 \left(1 - \frac{\pi}{4}\right)$$

The final area is the initial area plus the void space within the drift, which is the area of the drift minus the excluded areas of the drip shield and invert,

$$A_f = A_o + (\pi R^2 - D_w D_h - IA)$$

where IA is the area of the invert,

$$IA = R^2 \operatorname{arccos}\left(\frac{R-IH}{R}\right) - (R-IH)\sqrt{(2RIH-IH^2)}.$$

Substituting and solving for H, the maximum height increase for chimney degradation is

The second shape for degradation is a trapezoidal degradation, see Degradation Figure 2. In this method the width of the degraded area above the drift widens to a width larger than the original drift, with the width of the chimney area being mathematically determined by the angle at the trapezoidal base (θ). As in the simple chimney degradation the maximum height of the drift degradation can be determined by

$$H_{\max} = \frac{1}{2R} \left[\left(\frac{\pi R^2 - D_h D_w - IA}{B_f} \right) - 2R^2 \left(1 - \frac{\pi}{4} \right) \right]$$

evaluating using the area of the void space within the drift, the bulking factor of the rock and the area of rock which will degrade.

The initial area for the trapezoid method is

$$A_o = H(2R)(1+\cot(\theta)) + 2R^2\left(1-\frac{\pi}{4}\right) + R^2\cot(\theta).$$



And the final area is the initial area plus the size of the void space within the drift,



Drift Degradation Figure 2. A simplified diagram of the drift. The drift has a radius of R and the invert has a height of IH.

During Trapezoidal degradation, degradation above the drift spreads out and then begins to move upwards. The width of the degraded drift is a function of the angle theta.

Using the definitions of initial and finial areas the maximum increase in the drift height can be evaluated as,

$$A_f = A_o + (\pi R^2 - D_w D_h - IA)$$

In both descriptions of drift degradation the maximum height can then be used readily to calculate the maximum area of rock rubble.

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The degradation of the drift is approximated using a linear estimation in the change in degraded rubble area with respect to the time. The rate of degradation is the maximum rubble area divided by the time of degradation.



Drift Degradation Figure 3. Plot of Area vs. Time with no seismic events.

During seismic events which occur prior to complete drift degradation the damage to the drift is proportional the magnitude of the seismic event peak ground acceleration and the remaining portion of the drift left to degrade. In reference (2) this equation (4-12) was in reference to the heights of the drift. If it is assumed that the majority of the drift area is derived from within the rectangle above the drift then the essence of the equation should be maintained when area is substituted.

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$$\Delta Area = \frac{\left(Area_{\max} - Area_{i+1}\right)}{\left(g_{\max} - g_{o}\right)}\left(pga - g_{o}\right)$$

The area of rubble for seismic events is the sum of the basecase rubble area and the change in rubble area because of the seismic event until the maximum rubble area is reached. Once this value is reached the area of the rubble is at its maximum. As described in the Mechfail abstraction the Bulking factor changes for seismic events. The bulking factor after the seismic event is a function of a compression factor (C)

$$B_f^{i} = 1 + (B_f^{i-1} - 1)C_i$$

A minimum value of 1.15 has been outlined in the Mechfail abstraction, if the bulking factor is initially less than 1.15 then it will remain unaffected by the seismic events.

If the bulking factor decreases for a seismic event then the maximum drift height and amount of rubble area will increase. The drift failure time is defined to be the time at which the drift height reaches the maximum drift height for the initial value of the bulking factor. After that time the total change in drift height (and rubble area) due to seismic events are applied immediately after the seismic event, see Drift Degradation Figure 4.

The vertical pressure exerted by the rubble on the drip shield is determined by evaluating the rubble height above the drip shield. In each of the degradation shapes this height is a function of the geometry of the drift degradation. The vertical pressure is evaluated using the following equation

$$P = \frac{Hg\rho}{B_f^{\ i}}$$

where H is the rubble height above the drip shield, g is the gravitational acceleration constant, ρ is the rock density and B_f is the bulking factor at that time.

The vertical pressures can be separated into two categories; static and seismic. The static pressure is the pressure that is determined on regular TPA time intervals using the height of the rubble at that time step. Seismic pressures are the vertical pressures at the time of the seismic event. These again are the result of rubble height above the drip shields. However, if degradation has not yet reach the initial maximum height of the drift, the drift height is interpolated between the two standard TPA time steps bracketing the seismic event. In addition, during a seismic event the drift height may increase resulting in an increased height of rubble above the drip shield. In all seismic events the seismic pressure does not include the increased rubble which occurs because of the seismic event. This is justified by the assumption that the seismic event will occur very quickly, and that the rubble accumulation will take some time to occur.

Degradation of Drift



Drift Degradation Figure 4. Plot of Area vs. Time with seismic events.



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Entries into Scientific Notebook #612-21E for pages 1-8 have been made by James Mancillas.

No original text entered into this Scientific Notebook has been removed.

I have reviewed this scientific notebook and find it in compliance with QAP-001. There is sufficient information regarding methods used for conducting tests, acquiring and analyzing data so that another qualified individual could repeat the activity.

No Further entries