SAND2008-7189C

Estimating the Extent of the Disturbed Rock Zone around a WIPP Disposal Room

Courtney G. Herrick
Sandia National Laboratories
Performance Assessment Decision Analysis Department
4100 National Parks Highway
Carlsbad, NM 88220, USA
email: cgherri@sandia.gov

Byoung Yoon Park
Sandia National Laboratories
Performance Assessment Decision Analysis Department
4100 National Parks Highway
Carlsbad, NM 88220, USA
email: bypark@sandia.gov

David J. Holcomb
Sandia National Laboratories
Geomechanics
P.O. Box 5800
Albuquerque, NM 87185, USA
Email: djholco@sandia.gov

Moo Y. Lee
Sandia National Laboratories
Performance Assessment Decision Analysis Department
4100 National Parks Highway
Carlsbad, NM 88220, USA
email: mylee@sandia.gov

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, is operated by the U.S. Department of Energy (DOE) as the underground disposal facility for defense generated transuranic (TRU) nuclear waste. It is located in a bedded salt formation at a depth of about 655 m. At this depth the salt behaves as a viscous material having an initially lithostatic stress condition. Mining of an opening disturbs the static equilibrium to a degree where fracturing of the rock surrounding a room occurs, changing its mechanical and hydrologic properties. This disturbed rock zone (DRZ) is an important geomechanical feature used to predict future repository conditions. Based on ongoing scientific investigations and evaluation of published data since the original certification in 1998, our understanding of the DRZ has continued to progress.

Three deformation processes occur as deviatoric stresses are induced upon excavation of a room in salt: (1) an elastic deformation, (2) inelastic viscoplastic flow, and (3) inelastic-damage induced flow. Damage, which is manifested by the time-dependent initiation, growth, coalescence, and healing of microfractures, depends on the continuously changing stress conditions and is the least understood of the three deformation processes. Over the years various means to measure the spatial and temporal changes in salt damage have been undertaken. For this study, we used sonic velocity measurements obtained over a 12 year period as the principal field data to describe the extent of the DRZ. Predictions of the DRZ extent based on these experimental results are compared with other data sets, such as permeability measurements, microfracture density analyses, and borehole observations obtained from other places in the repository.

Laboratory salt creep experiments have demonstrated that damage can be assessed in terms of volumetric strain and principal stresses. Stress states that cause dilatant damage can be defined in terms of the ratio of stress invariants, which can be use to model the DRZ evolution with time. The change in the DRZ extent is calculated based on a dilatant damage potential criterion defined as:

$$D = \frac{C \cdot I_1}{\sqrt{J_2}}$$

where D is the damage potential, I_1 is the first invariant of the stress tensor, and J_2 is the second invariant of the deviatoric stress tensor. The calibration constant C in the damage criterion is assumed to not vary with time and was determined in this study by comparing finite element method results with the in situ sonic velocity field data. When $D \leq 1$, the shear stresses in the salt (J_2) are large compared to the mean stress (I_1) and dilatant damage is expected.

The creep closure process in the WIPP is a complex and interdependent series of events starting after a region within the repository is excavated. Creep closure of a room begins immediately upon excavation and causes the volume of the cavity to decrease. In a waste-filled room, the rock will contact the waste and the rate of closure will decrease as the waste compacts, stiffens, and strengthens; eventually, closure will cease when the compressed waste is strong enough to maintain the full overburden load without further deformation. In addition, the presence of gas in the room can retard the creep closure process. Pressure in the completely sealed repository will be increased by creep closure of the salt and degradation of TRU waste contents arising from interactions with the underground chemical environment and microbial activity. An increased pressure in the repository will reduce the extent and permeability of the DRZ (by providing sufficient back pressure). The reduced DRZ extent and permeability will decrease the amount of brine that is available to interact with the waste which affects the underground chemical environment and microbial activity. Furthermore, the potential for radionuclide release from the repository is dependent on the amount of available brine in the repository. As a result of these coupled phenomena, the extent and permeability of the DRZ can have a significant impact on the potential for radionuclide release from the repository.

Our numerical modeling analyses calibrated by the in situ sonic velocity field data suggest that the most extensive DRZ exists at early times, within the first ten years after a room is mined. The maximum extents calculated below and above a room reach approximately 2.25 m and 4.75 m, respectively, and 2 m in the side. Predictions of the calculated DRZ extents are generally in good agreement with various field measurements, such as permeability measurements, microfracture density analyses, and borehole observations, in the WIPP.

Sandia is a multi program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000. This research is funded by WIPP programs administered by the Office of Environmental Management (EM) of the U.S. Department of Energy.