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U.S. Nuclear Regulatory Commission
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TWF Mail Stop 7 C6
Washington, DC 20555

Subject: Submittal of Abstract: Simulation of Earthquake Effects on Underground Excavations Using Discontinuous Deformation Analysis (DDA)

Dear Mrs. DeMarco:

Attached is an abstract authored by Sui-Min Hsiung (Simon Hsiung) and Gen-hua Shi for presentation at the 38th U.S. Rock Mechanics Symposium to be held in Washington, DC on July 7–10th, 2001. Discontinuous Deformation Analysis (DDA) computer code is being used to investigate the effects of earthquake ground motions on inducing rockfalls in emplacement drifts during pre-and postclosure periods of the proposed repository at Yucca Mountain under heated conditions. The goal of the study is to relate the magnitude of ground motion with the extent of rockfall. The result of the study will be used as input for the SEISMO module in the NRC Total-System Performance Assessment Code.

This abstract documents some aspects of the rockfall potential when an emplacement drift is subjected to earthquake ground motion. This abstract is also intended to evaluate performance of rock supports under seismic ground motion.

Please advise me of the result of your programmatic review. If you have any questions, please contact Dr. S. Hsiung at (210) 522-5209 or me at (210) 522-5252.

Sincerely,

Budhi Sagar
Technical Director

Attachment

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Simulation of Earthquake Effects on Underground Excavations Using Discontinuous Deformation Analysis (DDA)

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Abstract

In seismic prone regions, consideration of earthquake effects is an important aspect in designing underground civil structures, underground storage, and underground power stations. Also, potential earthquake effects on stability of underground openings that will be used for disposal of high level waste in a geologic repository may have both preclosure and postclosure performance implications. Both continuum and discontinuum approaches are used in analyzing rock-mass responses to earthquake ground motions. Continuum approach provides some understanding of stresses and displacements of excavations subjected to earthquake ground motion for rock media with relatively little discontinuities or for excessively fractured rock media. Whereas the discontinuum approach would be more appropriate for excavations in moderately jointed rock media where a system of rock blocks is formed. The presence of joints reduceS modulus and strength of rock media, and provides planes of weakness on which slip, separation and rigid body translation of blocks can occur preferentially (Kana et al., 1989). Excessive slippage along joints may have serious consequences on the stability of excavations. Observations indicated that damage to underground excavations due to oscillatory motions or shaking in jointed rock media is manifested as displacements along joint surfaces, perhaps involving rockfalls, and cracking and spalling of the rock media (Kana et al., 1989). Two discontinuum methods are currently available for analyzing responses of rock media surrounding underground excavations: distinct element method and discontinuous deformation analysis (DDA). In this paper, earthquake effects on underground excavations in jointed rock media using DDA are reported.

DDA (Shi, 1996) is the block system version of the finite element method. It involves a finite element (block) type of mesh where each element represents a real isolated block, bounded by pre-existing discontinuities. An implicit solution algorithm is adopted in the DDA. A first-order polynomial displacement function was used to approximate displacements of element nodes. This displacement function has been recently made a special case for DDA. In the new version of DDA, polynomial displacement function of any order can be selected to approximate displacements at block nodes (Hsiung, 2000). The simulation of earthquake ground motions in DDA was introduced by Shi (1999) to study stability of blocky rock slopes. The same concept is being used to investigate rockfall and stability of underground excavations. The investigation was conducted using a joint pattern which contains three sets of joints. The joint information considered in the analysis included joint spacing, joint length, and bridge (gap) length. A series of DDA models were generated by introducing perturbations to joint spacing and length, and bridge length based on a uniform distribution. The ground acceleration signal used in the analysis was the 3-dimensional acceleration time history developed by the California Department of Transportation for the Yerba Buena Island Tunnel seismic retrofit program (Shi, 1999; Law and Lam, 1999). The effects of earthquake magnitudes were investigated by scaling the ground acceleration time history to various levels. Excavations with and without supports were studied to assess their effectiveness. The analysis results indicate that DDA

can be used for assessing performance of underground excavations subjected to earthquake ground motions and it may be an useful tool in assisting design of underground excavations in earthquake-prone regions. Specific findings of the study thus far include that:

- Under a seismic signal, the extent of rockfall depends highly on block geometries surrounding excavations.
- Seismic frequency has an effect on extent of rockfall.
- More severe rockfall and collapse of sidewalls are predicted for an underground excavation if the second-order polynomial displacement function (Figure 1) is used instead of the first-order polynomial displacement function (Figure 2). In general, the second-order polynomial displacement will produce a little more accurate results. The colors in the figures are intended to distinguish individual blocks only.
- Adding thermal stress by increasing temperature to the system appears to make excavations more stable under seismic loading (e.g., emplacement drifts in a repository for high-level nuclear waste disposal). After cooling down, the excavations appear to be relatively more stable compared to those that had not experienced thermal stress at all.

ACKNOWLEDGMENT

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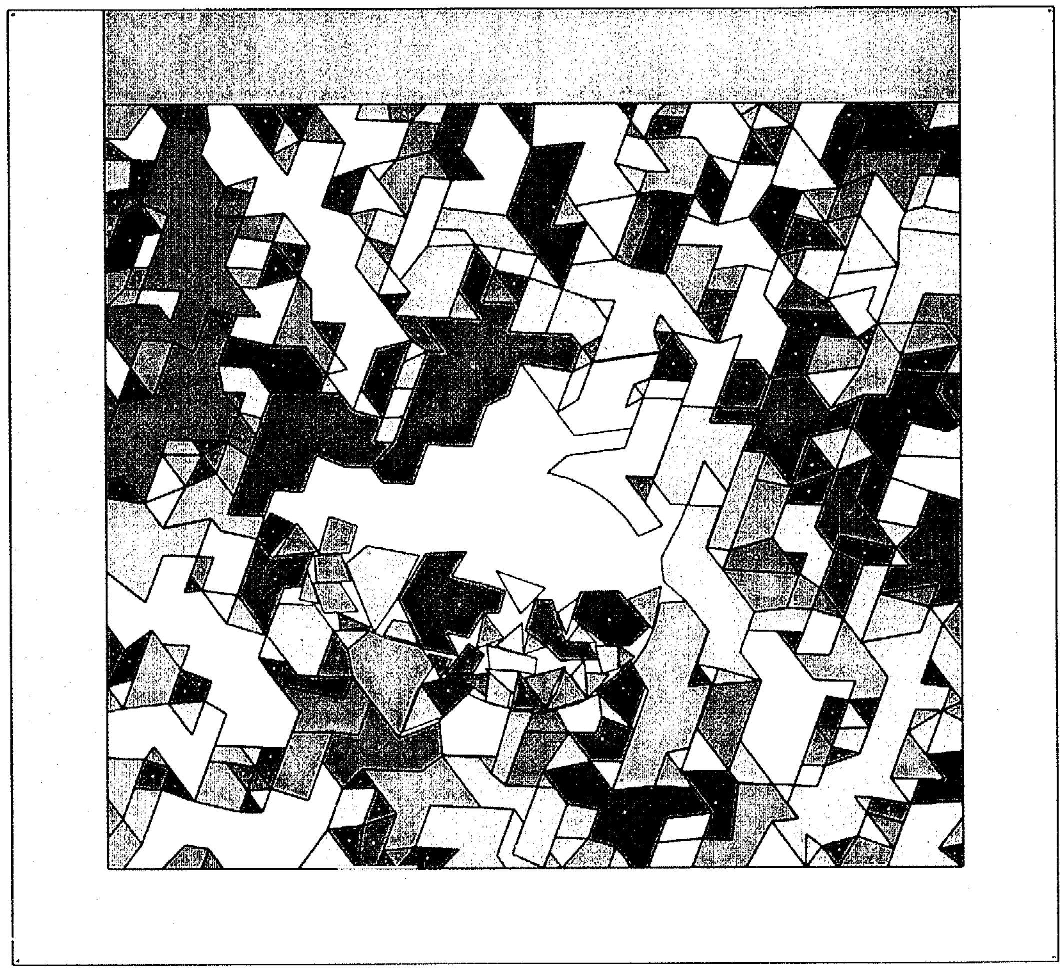

Figure 1 Response of an excavation to earthquake ground motion using the second-order polynomial displacement function

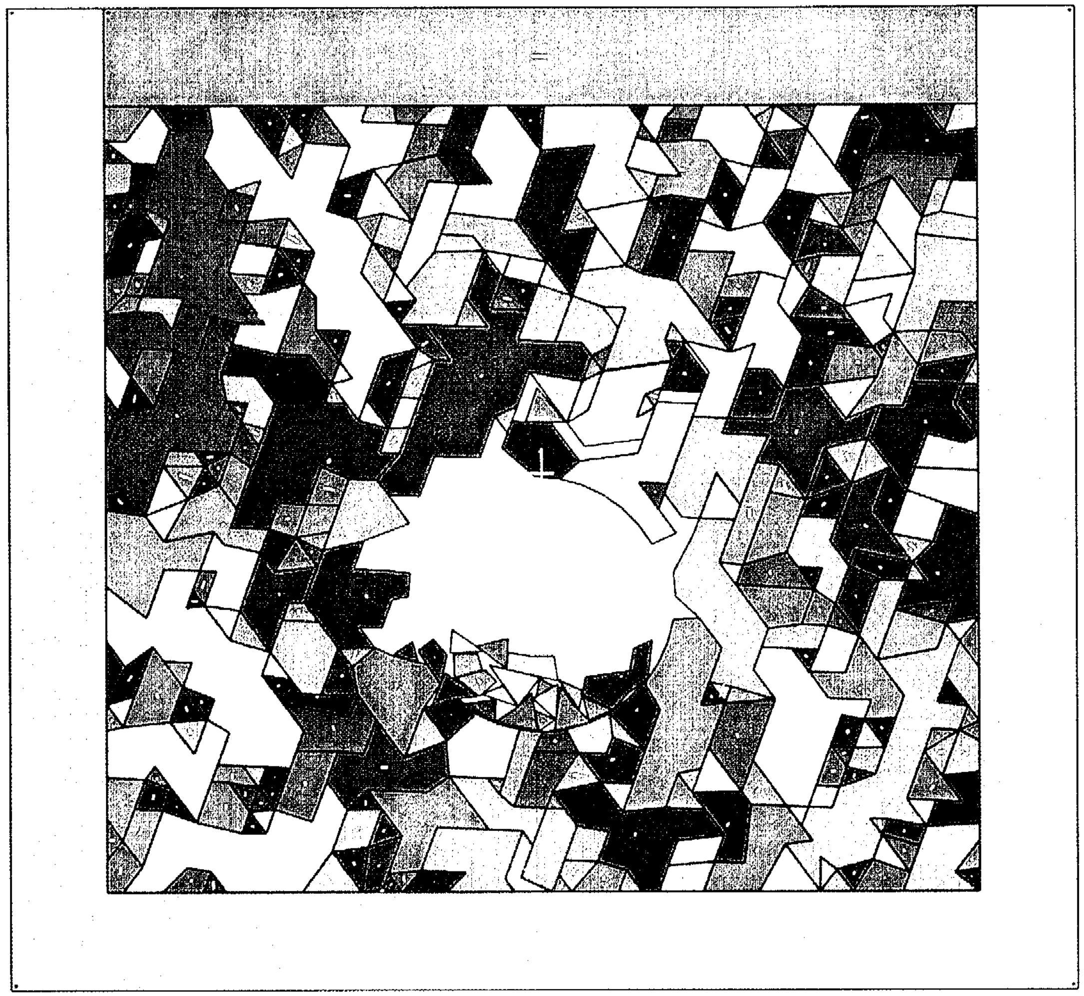

Figure 2 Response of an excavation to an earthquake ground motion using the first-order polynomial displacement function