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Geomechanical Observations During the Large Block Test

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GEOMECHANICAL OBSERVATIONS DURING THE LARGE BLOCK TEST.

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ABSTRACT

This paper presents an overview of the geomechanical studies conducted at the Large Block Test at Fran Ridge, near Yucca Mountain, Nevada. The 3-dimensional geomechanical response of the rock to heating is being monitored using instrumentation mounted in boreholes and on the surface of the block. Results show that thermal expansion of the block began a few hours after the start of heating, and is closely correlated with the thermal history. Horizontal expansion increases as a linear function of height. Comparison of observed deformations with continuum simulations shows that below the heater plane deformation is smaller than predicted, while above the heater plane, observed deformation is larger than predicted, and is consistent with opening of vertical fractures. Fracture monitors indicate that movement on a large horizontal fracture is associated with hydrothermal behavior.

1. INTRODUCTION

Efforts to understand and characterize coupled processes in the Near Field Environment of a potential high-level waste repository include the Large Block Test (LBT) currently underway at Fran Ridge, near Yucca Mountain, Nevada. The LBT is being conducted on a rectangular prism of rock that is 3m x 3m in cross-section and 4.5m high. It is a fractured rock mass that was exposed from an outcrop by excavating the surrounding rock, leaving the rectangular prism (see Figure 1). Two sub-vertical sets of fractures and one set of sub-horizontal fractures intersect the block. The sub-vertical fracture sets are approximately orthogonal, with spacing of 0.25 to 1 m and are oriented generally in the NE-SW and NW-SE directions. Moreover, a major sub-horizontal fracture is located approximately 0.5m below the top surface. This fracture is visible in Figure 1.

The objective of the LBT is to create, maintain and observe a planar, horizontal region of boiling in the block, so as to observe coupled thermal-hydrologic-mechanical-chemical (THMC) behavior in a fractured rock mass [1]. To this end heaters have been placed in the rock to simulate a plane heat source at a height of 1.75m from the base of the block, and a steel plate fitted with heating/cooling coils has been mounted on the top of the block. This plate is

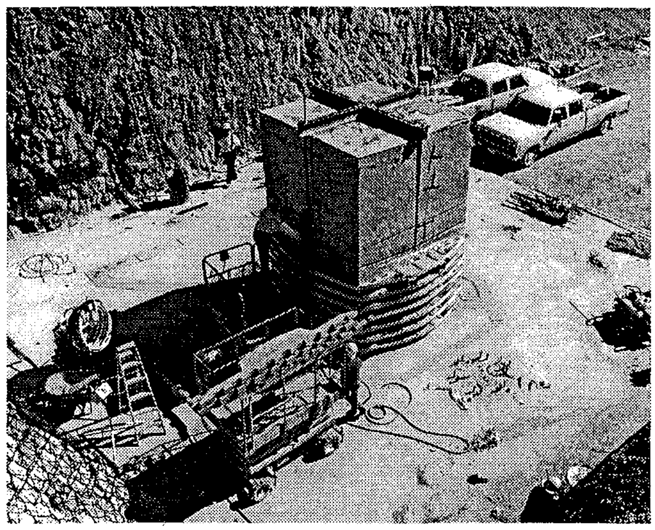

Figure 1: Photograph of large block site. In this photo the upper portion of the block is exposed to allow mapping of fractures. The lower portion is supported with bracing. T shaped grooves on face are locations of fracture monitors.

connected to a heat exchanger to allow thermal control of the top surface.

II. INSTRUMENTATION

The overall 3-dimensional geomechanical response of the rock to the heating is being monitored using six multi-point borehole extensometers (MPBX). Three are oriented in the North-South direction, two are oriented in the East-West direction, and one is oriented vertically. In addition, deformation of several major fractures that intersect the surface is being monitored using 3-component fracture monitors. These have been installed at 17 locations on the surface of the block. A few of the fracture monitor locations are visible as T-shaped grooves in Figure 1. The fracture monitors measure movement in directions across the fracture, and along the trace of the fracture both parallel and perpendicular to the face. Temperature, moisture level and electrical resistivity in the block are also being monitored, and the geomechanical data are being interpreted in conjunction with these other data sets.

III. RESULTS

Heating of the block was started on Feb. 27, 1997, and temperature vs. time measured near the center of the heater plane is shown in Figure 2. This figure shows temperature increased from ambient to 90 °C in the first few hundred hours of heating. A power outage caused a drop in temperature at approximately 600 hours. When power was restored temperatures quickly rose back to pre-outage levels, and near the heater temperature reached approximately 98 °C after 750 hours of heating. The overall temperature profile is consistent with conduction dominated heat flow in the block, except for the temperature excursions at 2520 and 4475 hours. These excursions are thought to be breakdowns in the metastable hydrothermal regime and formation of transient heat-pipes. Currently the exact mechanism causing this behavior is poorly understood.

Preliminary analysis of data from the MPBX systems show that within a few hours of the heater start-up the block started expanding. A time history for a typical MPBX anchor is shown along with the temperature in Figure 2, which shows that the overall deformation is directly correlated with the heating history. Note that the MPBX data do not indicate contraction during the thermal perturbations at 2500 and 4475 hours, indicating that these temperature perturbations are local events within the block.

Overall horizontal deformation of the block after 40 and 58 days of heating is listed in Table 1. This table shows similar amounts of expansion in both the E-W and N-S directions. These data are plotted in Figure 3, which shows that horizontal expansion is a linear function of height above the base. Also shown in Figure 3 is a profile of horizontal deformation predicted using a 3-D continuum model of the block [2].

Comparison of the observed and predicted profiles shows them to be similar below the heater plane. The similarity in slope indicates that the deformation in this region can be described by a continuum model. However, the simulation over predicts the thermal deformation, indicating that the coefficient of thermal expansion for the rock mass forming the block is smaller than that used in the model. The slight difference in slope of the two profiles below the heater plane may also indicate that the model over predicts the temperature at the heater plane.

Above the heater plane the predicted and observed profiles diverge dramatically. The decrease in deformation with height shown in the predicted profile is associated with the vertical thermal gradient imposed on the block. However, the observed horizontal deformation continues to

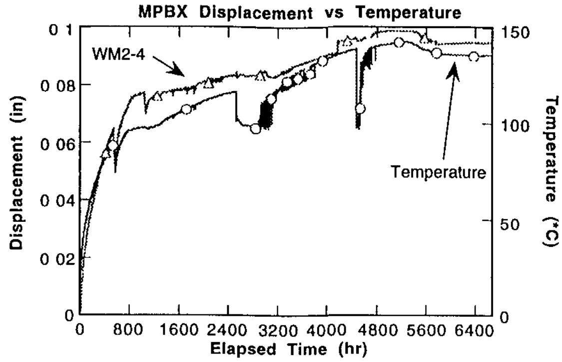

Figure 2. Temperature vs. time for thermocouple located slightly above the heater plane for the Large Block Test. Displacement of one of the MPBX anchors (relative to the borehole collar) is also shown.

increase with height and is independent of the thermal profile above the heater plane. Moreover, MPBX data from boreholes in the upper third show that most of the deformation occurs in discrete vertically oriented zones. This may be caused by opening of vertical fractures in this upper region.

Data also indicate that strain in the vertical direction is less than that observed in the horizontal direction, and that the region of the block above the heaters is moving upward as a unit.

Results from the fracture monitors are consistent with those from the MPBX in that the fractures are generally opening. The overall change in aperture measured at each location is shown in Figures 4 and 5. Figure 4 shows that several of the fractures opened between 0.05 and 0.015 in., and that closure of some fractures was observed. Figure 5 shows overall shear movement on the fractures. This figure shows that shear displacements are generally larger than normal displacements across the fractures, and that at three locations fractures have moved at least 0.02 in.

Table 1. Overall deformation at 40 and 58 days measured using MPBX systems.

Direction	Hole	Height (m)	Displ. 40 days (m)	Displ. 58 days (m)
E-W	WM-1	0.45	0.00029	0.00033
N-S	NM-1	0.58	0.00029	0.00035
N-S	NM-2	1.95	0.00062	---
E-W	WM-2	3.20	0.00097	0.00098
N-S	NM-3	3.50	0.00109	0.00112

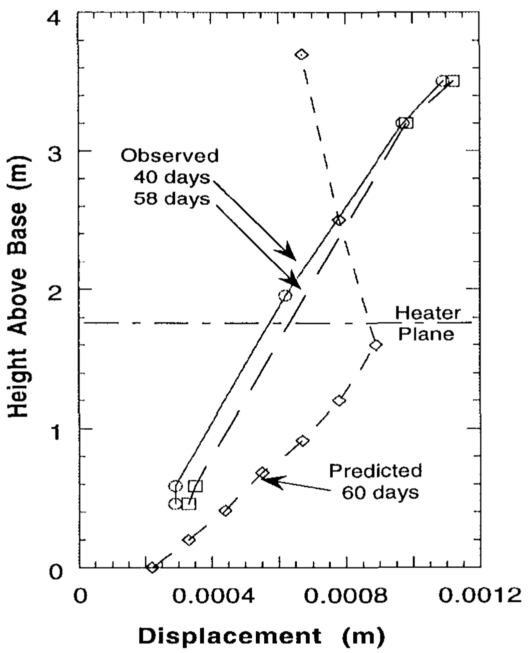

Figure 3. Comparison of observed and predicted deformations for the Large Block Test, half section.

Finally, while the hydrothermal response of the block is expected to be dominated by flow in vertical fractures, it is important to note that a few hours prior to the thermal excursion at 2500 hours, significant movement was recorded on the large horizontal fracture near the top of the block. It is also important to note that a rainstorm occurred at the site several hours prior to this thermal excursion, and it is possible that the horizontal fracture served as a primary conduit for focusing water flow within the block.

IV. CONCLUSIONS AND SUMMARY

In summary, the thermomechanical response of the Large Block has been monitored using MPBX and surface mounted fracture monitors. Thermal expansion of the block was evident a few hours after the start of heating. This is verified by data recorded on the fracture monitors and MPBX systems. MPBX data indicate that the block has expanded in the horizontal direction, and that this expansion is a linear function of the height above the base of the block. Much of the deformation has taken place in discrete zones which is consistent with opening of vertical fractures. Some correlation has been observed between movement on fractures and changes in hydrothermal behavior.

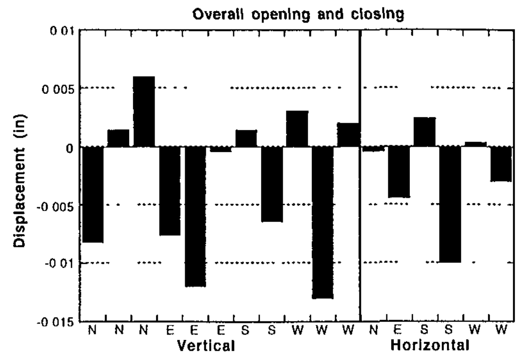

Figure 4. Normal displacements after 300 days of heating observed on selected fractures at LBT

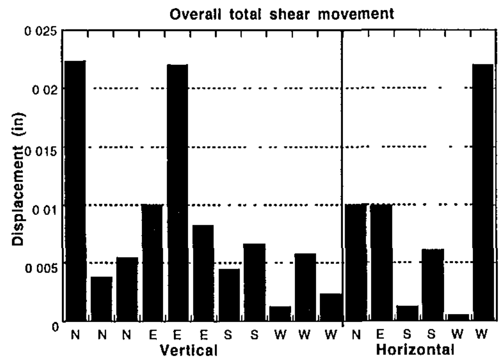

Figure 5. Shear displacements after 300 days of heating observed on selected fractures at LBT

REFERENCES

1. Lin, W. D.G. Wilder, J. A. Blink, S. C. Blair, T. A. Buscheck, W. E. Glassley, K. Lee, M. W. Owens, & J.J. Roberts (1995) "A heated large block test for high level nuclear waste management", in *Proceedings of the Second International Conference on the Mechanics of Jointed and Faulted Rock*, Vienna, Austria.
2. Blair, S. C., P. A. Berge & H. F. Wang (1996) "Geomechanical analysis of the Large Block Test", UCRL-ID 122898, Lawrence Livermore National Laboratory.

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