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# ROCK MASS DEFORMATIONAL PROPERTIES FROM A LARGE SCALE BLOCK TEST

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## ABSTRACT

### *INTRODUCTION*

*A large scale Block Test is currently being conducted by the Basalt Waste Isolation Project (BWIP) as an integral part of the thermal-mechanical field testing program investigating the suitability of the Columbia River Basalts as a potential site of a high level nuclear waste repository. The Block Test was designed to evaluate the deformational response, as a function of mechanical and thermal loading, of a specimen of basalt with sufficient volume to contain the number of structural discontinuities which would make it reasonably representative of the entire rock mass. The material properties to be evaluated include the Deformation Moduli, Poisson's Ratio, the Coefficient of Thermal Expansion and the Thermal Conductivity. Due to the highly anisotropic nature of the jointed and fractured rock mass, all of the above properties were determined as a function of orientation, as well as confining pressure, to completely characterize the block response.*

### *DESCRIPTION OF TEST ARRANGEMENT*

*The four slots which define the test block were cut to a depth of 4.5 meters by the percussion drilling of a series of overlapping boreholes. The test section around which the flatjacks are located, begin at a depth of 1.5 meters from the face of the tunnel wall to avoid blast damage and extended 2 meters. The remaining 1 meter of the slot depth was intended to eliminate end effects from influencing the response of the test block. The grout boxes, which are the steel forms which contain the flatjacks and allow their removal and replacement, are grouted into the slots and the flatjacks installed.*

*The stress in the third orthogonal direction was provided by a cable anchor system developed specifically for this project. This system consists of eight cable tendons, extending through the block, which are tensioned by hydraulic jacks mounted against the tunnel wall. Each tendon jack has a capacity of 275 tons.*

*Several types of instrumentation are installed in the Block Test to monitor the stress field and deformations within the test sections as well as to evaluate the performance of the instrumentation under controlled conditions. The borehole instrumentation includes five Borehole Deformation*

Gages (BDG), eight Vibrating Wire Stressmeters (VWS) and a four anchor Multiple Position Borehole Extensometer (MPBX). Twelve deformeters installed within two of the flatjacks are also used to monitor the displacement within the jacks.

The primary measurement system for the determination of the deformational properties is the electro-optical Basalt Deformation Measurement System (BDMS). This device was developed to allow measurement of the rock mass displacement at the depth of 2.5 meters from the surface, to a precision of less than ±30 microns ($3.0 \times 10^{-5}$ meters). The BDMS uses four targets anchored within the test block as reference light sources and a remote optical system to determine changes in their relative positions. All modulus values were determined from the BDMS output. Values of Poisson's ratio were evaluated from both the BDMS and MPBX data. Data acquisition is performed by a computer based data logger system which automatically scanned and recorded at regular intervals the output from all the instrumentation including the flatjack pressure, and numerous thermocouples throughout the test block. A backup system of magnetic tapes was also used to prevent any loss of data. During actual loading cycles, the data acquisition system was user controlled to scan at the desired load increments.

## TEST OPERATIONS

The ability to control the stress level in three orthogonal directions allowed the testing to be conducted similar to a conventional triaxial test. During a typical loading cycle, the stress level in two directions was raised to the designated confining stress and then the load in the third direction was increased incrementally to the desired maximum level. A total of seven loading cycles were performed at the ambient rock temperature. Four of the cycles had the deviatoric loading in the horizontal direction while in the other three cycles the principal loading was vertically orientated. The confining stress was increased in each succeeding loading cycle within the respective direction, beginning at 1.5 MPa and increasing to 2.5 MPa and 5.0 MPa. The fourth loading cycle in the horizontal direction was a repeat of the 5.0 MPa cycle to investigate the consistency of the rock mass response and instrument performance.

## RESULTS OF AMBIENT ROCK TEMPERATURE

The stress-strain curves from all seven loading cycles demonstrated a linear response regardless of the direction of loading. However, in those cycles in which loading was in the horizontal direction, a significant amount of hysteresis was observed, with the permanent deformation as much as 25 percent of the maximum strain level. The results of loading in the vertical direction showed a significantly different response with very little hysteresis or permanent set. This directional anisotropy was also quite evident in the values of the Moduli of Deformation determined. The modulus results, given in Table 1, from the vertical direction were as much as 77 percent greater than those from the horizontal orientation.

A parameter which was not influenced by the direction of applied stress was the sensitivity of the modulus values to the confining pressure. In both directions, the increase in confinement from 1.5 MPa to 5.0 MPa produced an increase in the deformation modulus of almost 60 percent. The Poisson's Ratio values were fairly consistent in all three directions although there was some scatter, probably due to the strain levels approaching the resolution of the instrumentation.

## CONCLUSIONS

*The Block Test ambient temperature testing series has made a major contribution to the characterization of the mechanical properties of the Columbia River Basalts. These results indicate that the rock mass deformational response is strongly anisotropic with a significant level of directionally dependent inelasticity. The sensitivity to the level of confining stress was quite unexpected and demonstrated that the two major joint sets generally control the deformational response. The actual parametric values will be invaluable in improving the quality of the predictive modeling presently being developed for the repository design effort,*

*Future Block Test efforts will evaluate the effect of elevated temperatures, up to 200°C, on the deformational response and determine the rock mass Coefficient of Thermal Expansion as a function of temperature and confining stress.*