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Publication Date

1981-05-01

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

EARTH SCIENCES DIVISION

To be published in a special issue of Geophysical
Research Letters, Vol. 8, 1981

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UNDERGROUND LARGE SCALE TEST FACILITY FOR ROCKS

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This work is to be published in a special issue of Geophysical Research Letters, Vol. 8, 1981, published by the American Geophysical Union. The work was supported by the Assistant Secretary for Nuclear Energy, Office of Waste Isolation of the U.S. Department of Energy under Contract No. W-7405-ENG-48. Funding for this project is administered by the Office of Nuclear Waste Isolation at Battelle Memorial Institute.

Abstract: This brief note discusses two advantages of locating the facility for testing rock specimens of large dimensions in an underground space. Such an environment can be made to contribute part of the enormous axial load and stiffness requirements needed to get complete stress-strain behavior. The high pressure vessel may also be located below the floor level since the lateral confinement afforded by the rock mass may help to reduce the thickness of the vessel.

Introduction

A large scale test facility for geological materials, particularly rocks serves as a via media between the conventional small scale testing and the in-situ testing. Small scale tests suffer from lack of clear cut approach for translating the data to actual rock behavior, while in the in-situ tests, the boundary conditions are not always clearly defined. It may also be difficult to eliminate some of the parameters inherent in an in-situ environment which could complicate data interpretation. Tests on large sized samples of rock may help to bridge the gap between these two extreme forms of testing.

Tests on large sized specimens of rock to failure demand very high deviatoric loads, on the order of hundreds of megaNewtons. Also, most of the brittle rocks tend to fail in an explosive manner, if tested in loading system with comparatively low axial stiffness. Confining pressures of the order of 200MPa may require very special mechanical design requirements. This brings in a number of questions regarding the structural requirements of the loading frame and the pressure vessel as well as maintenance and safety of the facility and the personnel.

This note offers certain suggestions regarding the location of such a large scale test facility in an underground environment.

Stiffness of the Roof of an Underground Opening

The axial loading stiffness of the loading frame is an important criterion which controls the post-peak behavior of most of the brittle rocks. By making the test frame an integral part of the roof of an underground opening in a competent rock, the overall stiffness of the loading system may be considerably increased.

By a simple analysis using elastic solutions (Appendix A) it is estimated that for a typical loading frame of cross-sectional dimensions 5 m x 5 m, the axial stiffness contributed by the roof-rock of an opening located at a depth of 40 meters may be of the order of 300 GN/m. It is assumed the roof-rock is not unduly loosened due to blasting and other excavation procedures. However, the presence of hydraulic systems which are normally used to apply axial loads on the rock reduces the combined stiffness of roof-rock and the loading frame. If k_r is the stiffness of the roof-rock and k_f is that of the hydraulic system, then the combined stiffness k is related to k_r and k_f as

$$1/k = 1/k_r + 1/k_f \quad (1)$$

Thus, the combined stiffness may be reduced because of the softness of the hydraulic system. If the stiffness of the rock specimen is less than the combined stiffness of the axial loading system, explosive failure may be avoided. Also, special precautions should be taken to integrate the reaction block of the loading frame with the roof of the underground opening.

Stiffness of Rock Specimen

The axial stiffness of a regular rock specimen may be expressed as (Jaeger and Cook, 1976)

$$k_s = AE/l \quad (2)$$

where A is the cross-sectional area of the specimen, E is the elastic modulus of the rock and l is the length of the specimen. The modulus of elasticity of rock is a widely variable quantity. Bieniawski (1978) has compiled results from several large scale tests and a maximum value of 60GPa is possible for granitic rock masses. Taking a maximum value of 60 GPa for the elastic modulus and the dimensions of the specimen as 1 meter in diameter and 3 meters in length, k_s works out to 15 GN/m. Even if the combined stiffness of the roof-rock and the loading system were reduced to 10% of the roof-rock stiffness, i.e., 30 GN/m, the chances of an explosive failure of a brittle rock are largely eliminated.

Location of the Pressure Vessel

For triaxial compression tests on rock specimens with confining pressures up to 140 MPa, the vessel wall should be of sufficient thickness to limit the hoop stresses to an acceptable level. Locating the vessel below the floor of the underground opening may help to reduce the thickness of the vessel. For example, the annular space between the vessel and the wall of the excavated pit may be filled with high strength reinforced concrete which could reduce the tensile tangential stresses and strains on the vessel wall. Also, if the vessel pressure increases beyond control or any crack in the vessel develops,

any resulting explosion of the vessel will be contained. However, there may be other practical problems in locating the vessel below the floor level, such as specimen handling before and after the test. The discussion of these factors is beyond the scope of this paper.

There are other advantages in locating the facility below the ground. For example, the ambient temperature at depths of meters below the ground remains fairly constant at 18-20 deg. Celsius.

Conclusions

By integrating the axial load frame with the roof rock of an underground opening, the axial stiffness may be considerably increased. This may enable obtaining complete stress-strain behavior of most of the brittle rocks. The pressure vessel may be located below the floor level, provided there are no practical problems in handling the specimens of large dimensions.

Acknowledgments. This work was supported by the Assistant Secretary for Nuclear Energy, Office of Waste Isolation of the U.S. Department of Energy under Contract No. W-7405-ENG-48. Funding of this project is administered by the Office of Nuclear Waste Isolation at Battelle Memorial Institute.

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APPENDIX A

Let us assume the location of the underground opening 'h' from the ground level.

Let the dimensions of the roof being loaded be $2b \times 2b$.

Assume the load to be uniformly distributed over the area of contact between the load-frame and the roof. For a stress of σ , the vertical displacement at the center of the loaded area is given as (Groth and Chapman, 1969)

$$\rho = 4 (bI/E) \sigma \quad (2)$$

where $2b$ = the side dimension of the load frame

E = Elastic modulus of the rock above the roof

I = Influence factor and is a function of b, h, E and ν

ν = Poisson Ratio for Rock

Rearranging equation (2)

$$\sigma/\rho = E/4bI \quad (3)$$

Since axial stiffness may be expressed as

$$k = N/\rho \quad (4)$$

where N is the axial load and is equal to

$$N = \sigma (2b)^2 \quad (5)$$

we can write for axial stiffness of roof as

$$k_r = Eb/I \quad (6)$$

If we assume $E = 30 \text{ GPa}$, $b = 2.5 \text{ m}$,

$$k_r = 75/I \quad (7)$$

The influence value of I for $h = 40 \text{ m}$ is estimated (Poulos and Davis, 1974) to be 0.25. After substituting this value for I in equation (7) we get

$$k_r = 300 \text{ GN/m} \quad (8)$$

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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