RTH-361-89

SUGGESTED METHOD FOR DETERMINING ROCK MASS DEFORMABILITY USING A PRESSURE CHAMBER

Scope

1. (a) This test determines the deformability of a rock mass by subjecting the cylindrical wall of a tunnel or chamber to hydraulic pressure and measuring the resultant rock displacements. Elastic or deformation moduli are calculated in turn.

(b) The test loads a large volume of rock so that the results may be used to represent the true properties of the rock mass, taking into account the influence of joints and fissures. The anisotropic deformability of the rock can also be measured.

(c) The results are usually employed in the design of dam foundations and for the proportioning of pressure shaft and tunnel linings.

(d) Two other methods are available for tunnel-scale deformability. See RTH-366 and RTH-367 to compare details. Potentially large impacts, especially in terms of cost, of variations at this scale justify the separation of methods.

(e) This method reflects practice described in the references listed at the end.

Apparatus

2. Equipment for excavating and lining the test chamber including:

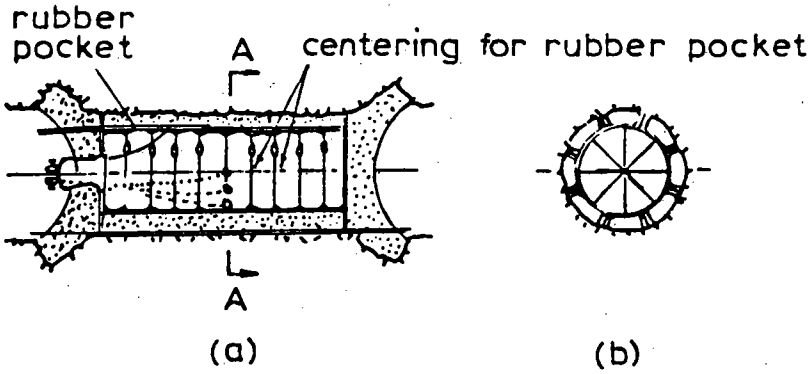
(a) Drilling and blasting materials or mechanical excavation equipment.[1*]

(b) Materials and equipment for lining the tunnel with concrete or flexible membrane.

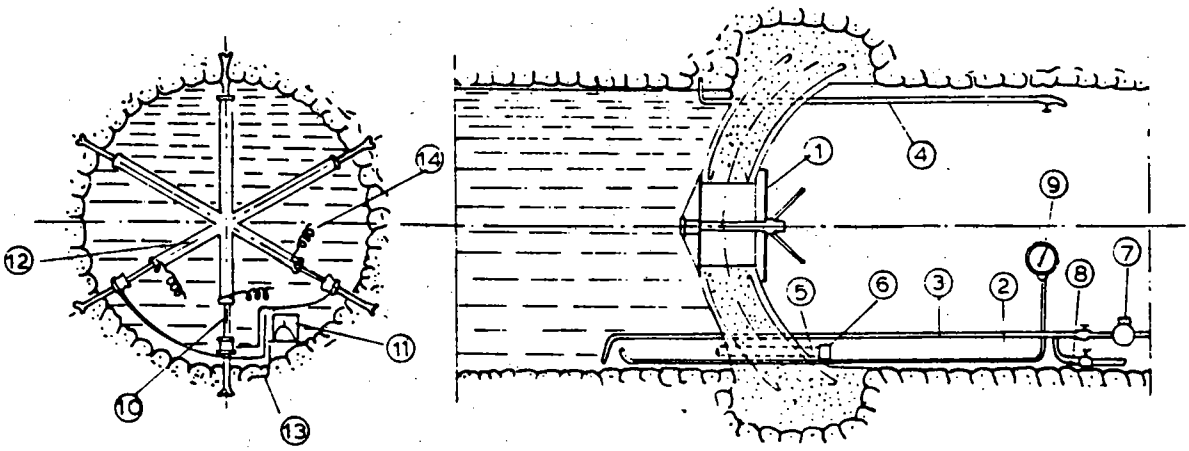
3. A reaction block (Figure 1) usually comprising a tunnel bulkhead of sufficient strength and rigidity to resist the force applied by the pressurizing fluid. The bulkhead must also be waterproof. Reusable bulkheads are possible where several sites are to be investigated.

4. Loading equipment to apply the hydraulic pressure to the inner face of the lining including:

*Numbers refer to NOTES at end of the text.



(A)



1. manhole
2. pressure gauge tube.
3. water inlet.
4. air outlet.
5. cable admission tube.
6. cable tube seal.
7. water meter.
8. water outlet.
9. pressure gauge.
10. vibrating meter.
11. air pressure equalising chamber.
12. invar rods
13. air pressure equalising tube.
14. cable.

(B)

Figure 1. Example Pressure Chamber.

(a) A hydraulic pump capable of applying the required pressure and of holding this pressure constant within 5% over a period of at least 24 hr. together with all necessary hoses, connectors and fluid.[2]

(b) Water seals to contain the pressurized water behind the bulkhead and along any vulnerable seams and boundaries of the membrane. Special water seals are also required to allow the passage of extensometer rods through the lining and instrumentation lines through the bulkhead. Pressurized water should not be allowed to escape into the rock since this may greatly affect the test results.

5. Load measuring equipment comprising one or more hydraulic pressure gages or transducers of suitable range and capable of measuring the applied pressure with an accuracy better than ±2%.

6. (a) Displacement measuring equipment to monitor rock movements radial to the tunnel with a precision better than 0.01 mm. Equipment may be extensometers, vibrating wire deflectometers, joint meters, or multipurpose strain meters. Changes in tunnel diameter have been measured with spring-loaded invar wires using LVDT's to sense. All measuring systems must be waterproof and designed to stand the pressure to which they are to be subjected.

Procedure

7. Preparation

(a) The test chamber location is selected taking into account the rock conditions, particularly the orientation of the rock fabric elements such as joints, bedding, and foliation in relation to the orientation of the proposed tunnel or opening for which results are required.

(b) The test chamber is excavated to the required dimensions.[1,3] Where possible, the dead end of the tunnel serves as one end of the test chamber, thus eliminating the need for a second bulkhead.

(c) The geology of the chamber is recorded and specimens taken for index testing as required.

(d) Extensometer holes are accurately marked and drilled, ensuring no interference between loading and measuring systems. Directions of measurement should be chosen with regard to the rock fabric and any other anisotropy.

(e) The bulkhead is installed.

(f) The chamber is lined with flexible, impermeable membrane. To protect this lining from sharp irregularities, the wallrock is first covered with thin reinforced concrete walling, gypsum board, or plaster. Rubber membrane may be stapled and vacuumed into place and the whole sprayed with rubber.

(g) Measuring equipment is installed and the equipment is checked. For multiple position extensometers the deepest anchor may be used as a reference provided it is situated at least 2 chamber diameters from the lining. Alternatively the measurements may be related to a rigid reference beam passing along the axis of the chamber and anchored of not less than 1 chamber diameter from either end of the chamber.

(h) Check water seals for leakage, if necessary by filling and pressurizing the chamber. Leaks are manifested as anomalous pressure decay and visible seepage through the bulkhead.

8. Testing

(a) The test is carried out in at least three loading and unloading cycles, a higher maximum pressure being applied at each cycle.[2]

(b) For each cycle the pressure is increased at an average rate of 0.05 MPa/min to the maximum for the cycle, taking not less than 3 intermediate sets of load-displacement readings in order to define a set of pressure-displacement curves.

(c) On reaching the maximum pressure for the cycle the pressure is held constant (±2% of maximum test pressure) recording displacements as a function of time until approximately 80% of the estimated long-term displacement has been recorded. Each cycle is completed by reducing the pressure to near-zero at the same average rate, taking a further three sets of pressure-displacement readings.

(d) For the final cycle the maximum pressure is held constant until no further displacements are observed. The cycle is completed by unloading in stages taking readings of pressure and corresponding displacements.

(e) The test equipment is then dismantled.[3]

Calculations

9. (a) The value of E is calculated from

$$E = \frac{p_i a^2}{r(U_r)} (1 + \nu)$$

where:

E = modulus of elasticity,

P_i = internal pressure,

a = radius to rock face - assuming circular chamber,

r = radius to point here deflection is measured,

U_r = change in radius due to pressure, and

ν = Poisson's ratio

and rock is regarded as linearly elastic.

(b) Where only surface deflections are measured, the equation is reduced to:

$$E = \frac{P_i a}{U_r} (1 + \nu)$$

Reporting

10. The report should include the following:

(a) Drawings, photographs, and detailed description of the test equipment, chamber preparation, lining, and testing.

(b) Geological plans and section of the test chamber showing features that may affect the test results.

(c) Tabulated test observations together with graphs of displacement versus applied pressure and displacement versus time at constant pressure for each of the displacement measuring locations.

(d) Transverse section of the test chamber showing the total and plastic displacements resulting from the maximum pressure. The orientations of significant geological fabrics should be shown on this figure for comparison with any anisotropy of test results. Calculated moduli should be shown also.

NOTES

[1]The recommended diameter is 2 m., with a loaded length about 5 m. The chamber should be excavated with as little disturbance as possible. Material disturbed by blasting may need to be removed since it tends to produce moduli lower than found at depth. However, blast effects are representative if the test results are applied directly as a "model" test to the case of a blasted full-scale tunnel.

[2]Maximum test pressure varies from 1.5 to 4.0 MPa.

[3]To assess the effectiveness of grouting, a second, adjacent chamber may be prepared. Grouting is carried out after completion of testing in the ungrouted chamber, and the equipment is then transferred to the grout chamber.

References

1. Clark. G. B., "Deformation Moduli of Rocks," in Testing Techniques for Rock Mechanics, Special Technical Publication 402, American Society for Testing and Materials, 1966, pp. 133-172.

2. Stagg, K. G., "In Situ Tests on the Rock Mass," in Rock Mechanics in Engineering Practice, John Wiley & Sons, New York, 1968, pp. 125-156.

3. Lama, R. D., and Vutukuri, V. S., Handbook on Mechanical Properties of Rock Vol. III, Trans Tech Publications, 1978, 406 pp.

4. International Society for Rock Mechanics, "Suggested Method for Measuring Rock Mass Deformability Using a Radial Jacking Test," International Journal of Rock Mechanics and Mining Sciences, V. 16, 1979, pp. 208-214.