SUGGESTED METHOD FOR DETERMINING ROCK MASS DEFORMABILITY USING A MODIFIED 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 displacements. Elastic moduli 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-361 and RTH-367 to compare details. Potentially large impacts, especially in terms of cost, of variations at this scale, justify the detailing of each method separately.

(e) This method reflects practice described in the reference 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.[2]

3. A reaction frame (Figure 1) composed of a set of steel rings of sufficient strength and rigidity to resist the force applied by pressurizing fluid must also act as a waterproof membrane.

4. Loading equipment to apply a uniformly distributed radial pressure to the lining including:

(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.[3]

*Numbers refer to NOTES at the end of the text.

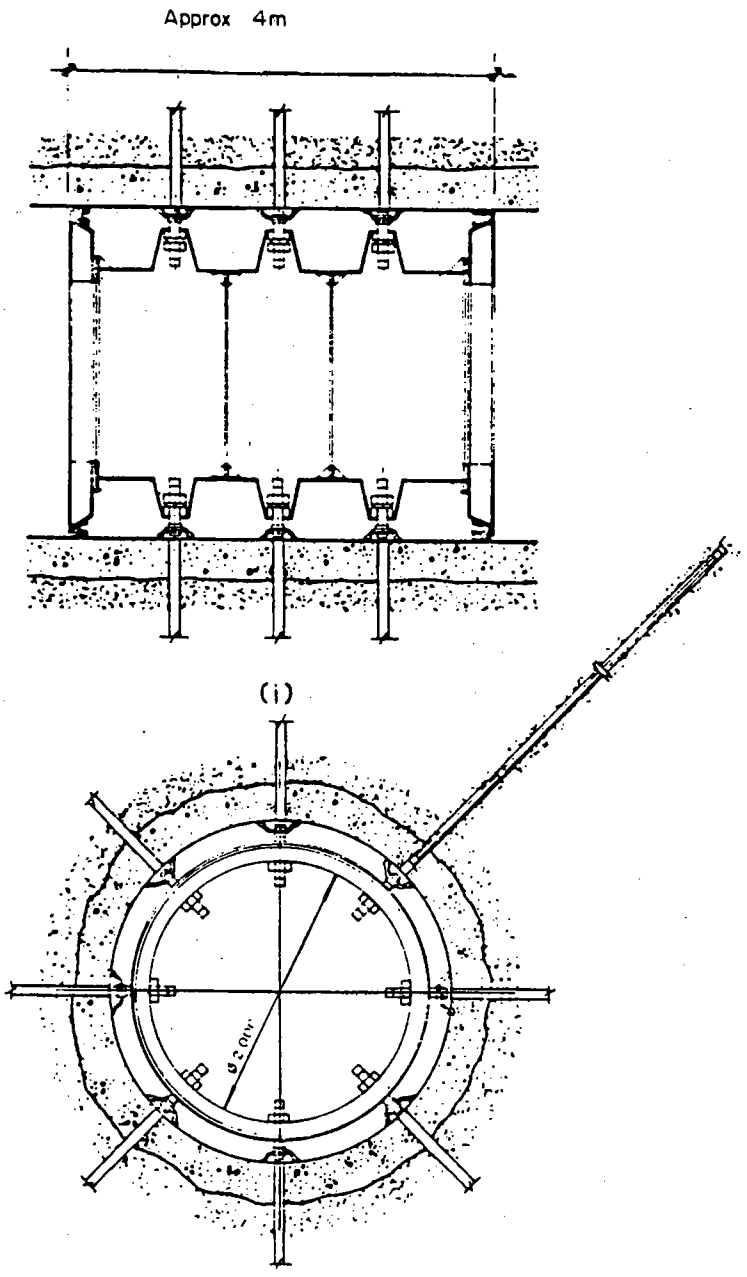

Figure 1. Example partial pressure chamber loading system.

(b) Water seals to contain the pressurized water between the lining and the reaction frame. Special water seals are also required for extensometer rods passing through the lining and reaction frame: pressurized water should not be allowed to escape into the rock since this will 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. Single or multiple position extensometers are suggested but joint meters and other measuring devices are also available.

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]

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

(d) The test section is lined with concrete.[2]

(e) The reaction frame and loading equipment are assembled.

(f) Holes for extensometers or other measuring devices 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.

(g) Measuring equipment is installed and 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 not less than 1 diameter from either end of the test section.

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

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.

(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.

Calculations

9. (a) The value of deformation modulus is calculated as follows

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

where:

E = modulus of deformation

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.

(b) The elastic modulus is sometimes represented by using only the portion of U_r which is recovered upon unloading.

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 2.5 m, with a loaded length equal to this diameter. 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]When testing only the rock, the lining should be segmented so that it has negligible resistance to radial expansion; in this case the composition of the lining is relatively unimportant, and it may be of either shotcrete or concrete. Alternatively when it is required to test the lining together with the rock, the lining should not be segmented and its properties should be modeled according to those of the prototype.

[3]Maximum hydraulic pressure varies from 5 to 10 MPa.

Reference

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.