Designation: D4971 – 16

Standard Test Method for Determining In Situ Modulus of Deformation of Rock Using Diametrically Loaded 76-mm (3-in.) Borehole Jack[1]

This standard is issued under the fixed designation D4971; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the estimation of in situ modulus of a rock mass at various depths and orientations. Information on time-dependent deformation may also be obtained.

1.2 This test method covers testing in an N size drill hole and is more relevant to a borehole jack device designed for "hard rock" than for soft rock.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.3.1 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

D6032 Test Method for Determining Rock Quality Designation (RQD) of Rock Core

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *deformation, n*—change in shape or size, (see Terminology D653). In this test method deformation is the change in the diameter of the borehole.

3.2.2 *modulus of deformation, n*—ratio of stress to strain for a material under given loading conditions; numerically equal to the slope of the tangent or the secant of the stress-strain curve.

3.2.2.1 *Discussion*—The use of the term modulus of elasticity is recommended for materials that deform in accordance with Hooke's law, and the term modulus of deformation is recommended for materials that deform otherwise, (see Terminology D653). In this test method, the modulus of deformation is calculated from the applied fluid pressure, the relative change in hole diameter, a function of Poisson's ratio, and a constant.

3.2.3 *jack efficiency, n*—ratio of the jack plate pressure to the applied hydraulic pressure.

3.2.4 *hard rock borehole jack, n*—this refers to a specific borehole jack by the manufacture that has platens designed for harder rocks, goes to higher pressures than a soft rock borehole jack and whose displacement range is not exceeded at the maximum allowable pressure for the borehole jack.

4. Summary of Test Method

4.1 The drill logs for a drill hole hole to be tested are examined. Specific depths and orientations in the drill hole are selected based upon the objectives of the test program.

4.2 The borehole jack in the fully retracted position is positioned at each location selected in the drill hole for the test program. The 76 mm (3 in.) jacks, (see Fig. 1 and Fig. 2), induce unidirectional pressure to the walls of a borehole by means of two opposed curved steel platens each covering a 90°

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

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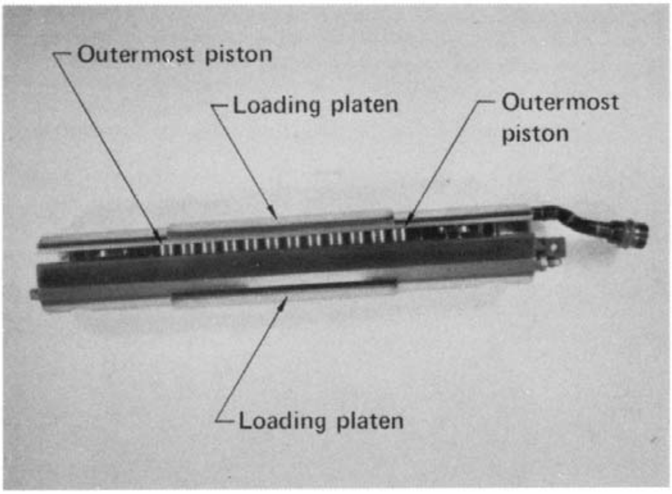
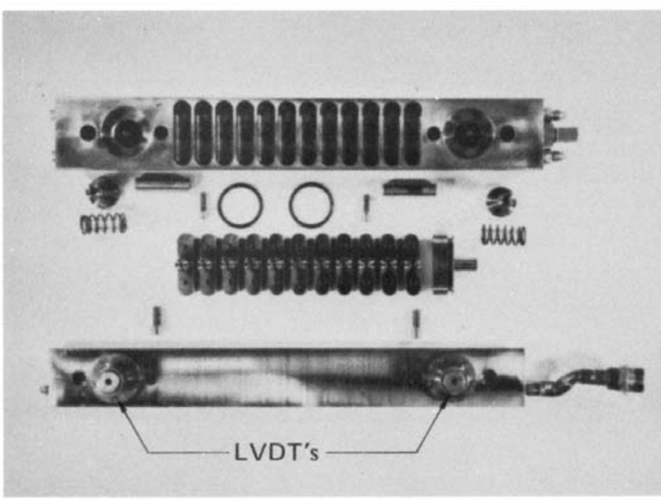
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**



a) Assembled



b) Disassembled

FIG. 1 The 76-mm (3-in.) Borehole Jack: Assemble (a) and Disassembled (b)

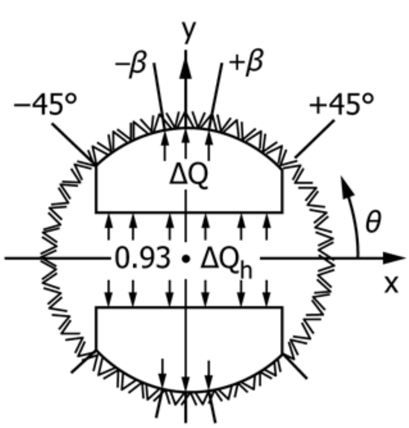


FIG. 2 Schematic of Diametrical Loading of the Borehole Wall by the Borehole Jack Platens

sector, over a length of 20 cm (8 in.) and pressure versus deformation data is collected. Testing is usually done from the deepest test zone in the drill hole and then tested at subsequent shallower test intervals to minimize risks to the borehole jack.

4.3 Raw data from a test consist of hydraulic-line pressure, Q_h, versus readout from linear variable differential transformers (LVDT's) measuring platen movement. Knowing the displacement calibration of the LVDT's, the raw data can be transformed to a test record of hydraulic pressure versus hole diameter, D. For each increment of pressure, ΔQ_h, and hole deformation, ΔD, theoretical data analysis **(1)**,[3] assuming rigid jack plates and full 90° contact, give the theoretical rock mass modulus, E ($E_{\text{theoretical}}$) as a function $E = f\ (\Delta\ Q_h \cdot \Delta D \cdot\ T^*)$, where T^* is a coefficient dependent upon Poisson's ratio. If E is measured on a linear segment of the loading curve, common terminology is modulus of deformation. If E is measured on an unloading linear segment, it is referred to as the recovery modulus.

5. Significance and Use

5.1 Results of this test method are used to predict displacements in rock mass caused by loads from a structure or from underground construction for the load range that the device can apply. It is one of several tests that should be performed.

5.2 Because the jack can apply directed loads, this test method can be performed to provide an estimate of anisotropy.

5.3 In theory, the analysis of test data is straight forward; the modulus estimate requires a record of applied hydraulic pressure versus borehole diameter change, and a knowledge of the rock's Poisson's ratio. In practice, the above procedure, using the original theoretical formula, frequently has resulted in computing a material modulus that was demonstrably too low.

5.4 For analyzing the test data it is assumed that the rock mass is linearly elastic, isotropic, and homogeneous. Within these assumptions, this test method can provide useful data for rock masses for which equivalent continuous properties cannot be found or estimated.

NOTE 1—Notwithstanding the statements on precision and bias contained in this test method; the precision of this test method is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D3740 does not in itself assure reliable testing. Reliable testing depends on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Interferences

6.1 It is assumed that the tensile and compressive moduli of the rock are equal and there is no tensile cracking induced in the rock mass because of jack loading. If tensile cracks are created at 90° to the loading direction, it has been shown **(1)** that the calculated modulus values can decrease by up to 29 %. Therefore, tensile cracking would result in a decrease in the

[3] The boldface numbers in parentheses refer to a list of references at the end of the standard.