Designation: D4729 – 19

Standard Test Method for In Situ Stress and Modulus of Deformation Using the Flat Jack Method[1]

This standard is issued under the fixed designation D4729; 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 The flat jack test measures the natural or altered in situ stress at a rock surface either for a surface outcrop or an underground excavation surface. The modulus of deformation and the long-term deformational properties (creep) may also be evaluated for the applied stress range, however long-term creep is not covered by this method.

1.2 This method covers square flat jacks that are placed in a rock slot and if required encapsulated in the slot.

1.3 Deformation readings are taken at the surface, but this standard does not exclude deformation readings being taken below the surface, such as using a flat jack which is set up to obtain displacement data internally.

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

1.4.1 The procedures used to specify how data are collected/recorded or calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.5 *Limitation*—The flat jack test measures the average stress normal to the surface of the test chamber, underground excavation, or outcrop. In situ stress levels must be determined by theoretical interpretations of these data.

1.6 *Assumptions and Factors Influencing the Data:*

1.6.1 The stress relief is assumed to be an elastic, reversible process. In nonhomogeneous or highly fractured materials, this may not be completely true.

1.6.2 The equations assume that the rock mass is isotropic and homogeneous. Anisotropic effects may be estimated by testing in different orientations.

1.6.3 The flat jack is assumed to be 100 % efficient. The design and size requirements of 7.1 were determined to satisfy this requirement to within a few percent.

1.6.4 The jack is assumed to be aligned with the principal stresses on the surface being measured. Shear stresses are not canceled by jack pressure. Orientating the tests in three directions in each plane tested prevents the misalignment from being excessive for at least one of the tests.

1.7 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. Add if appropriate, "Reporting of test results in units other than inch-pounds shall not be regarded as nonconformance with this standard."

1.7.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The slug unit is not given unless dynamic (F=ma) calculations are involved. For standards involving the determination of mass or the use of density and unit weight, include the following numbered paragraph.

1.7.2 The slug unit of mass is typically not used in commercial practice; that is, density, balances, and so on. Therefore, the standard unit for mass in this standard is either kilogram (kg) or gram (g) or both. Also, the equivalent inch-pound unit (slug) is not given/presented in parentheses.

1.7.3 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This practice implicitly combines two separate systems of units; the absolute and the gravitational systems. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

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

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C476 Specification for Grout for Masonry
C1196 Test Method for In Situ Compressive Stress Within Solid Unit Masonry Estimated Using Flatjack Measurements
C1197 Test Method for In Situ Measurement of Masonry Deformability Properties Using the Flatjack Method
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D5720 Practice for Static Calibration of Electronic Transducer-Based Pressure Measurement Systems for Geotechnical Purposes (Withdrawn 2018)[3]
D6026 Practice for Using Significant Digits in Geotechnical Data
D6027/D6027M Practice for Calibrating Linear Displacement Transducers for Geotechnical Purposes

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 *cancellation pressure, n*—the pressure in the flat jack required to return the rock to its initial position before the slot was cut.

3.2.2 *coefficient for test geometry, n*—a constant dependent upon the point at which pressure is measured, size of the flat jack, and its relationship with the slot dimension and nearness of surface.[4]

3.2.3 *demountable mechanical (DEMEC) strain gauges, n*—mechanical gauges using 'contact' measuring principles to make transfer-length strain measurements.

3.2.4 *skin stress, n*—the tangential stress at the surface of an opening.

3.2.5 *in situ stress, n*—the stress field existing in a rock mass at the surface or below the surface prior to or after excavation of an opening.

4. Summary of Test Method

4.1 The in situ stress in the rock mass is relieved by cutting a slot into the rock perpendicular to the surface of the underground excavation or rock outcrop using a diamond saw or overlapping drill holes. The deformation caused by this stress relief is measured.

4.2 A hydraulic flat jack (Fig. 1) is placed into the slot and grouted if the slot is too wide or the surface was left uneven and could puncture the flat jack. The flat jack is then pressurized until the above-measured (stress relief) displacement is canceled or recovered. This reapplied stress is approximately equal to the stress in the rock mass at the test location in a direction perpendicular to the plane of the jack. The deformational characteristics of the rock mass are evaluated by incrementally loading or unloading the flat jack and measuring the corresponding deformation.

5. Significance and Use

5.1 Flat jack tests are useful to assess rock mass deformability and stresses in the design stages of projects as well as for issues with existing projects; for example, stresses around an underground opening. The in situ stress values can be used as an important parameter for interpretation and validation of test results and analytical models.

5.2 This test method has been successfully used for other applications such as concrete dams and masonry structures. This test method is similar to the techniques and equipment used in C1196 and C1197. However, this standard is written more for rock and where irregular surfaces may be involved and both in situ stress and deformability are obtained in one test.

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 *Local Geologic Features*—Local features, particularly faults, shear zones, and alike, can influence the local stress field. Large inclusions in the rock can affect both the stress and deformational properties. Test locations should be carefully selected so that the effects of such features are reduced or, if they are the features of interest, accounted for fully.

6.2 *Influence of Excavations*—Other excavations intersecting the test site will cause complex stress concentration effects

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Lama, R.D., and Vutukuri, V.S., *Handbook on Mechanical Properties of Rocks; Testing Techniques and Results, Volume III*, Department of Mining Engineering, Broken Hill Division, Australia, 1978.

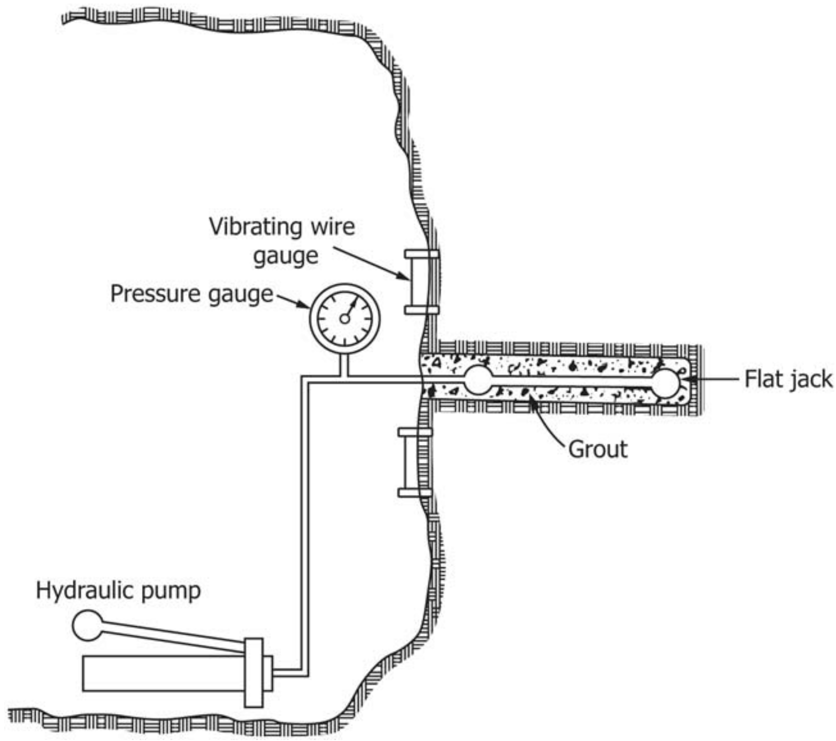

FIG. 1 General Diagram of Flat Jack Test Apparatus with Flat Jack Installed in the Tunnel Wall and Vibrating Wire Displacement Gauges

by superposition. Flat jack tests should be located at least three diameters of the intersecting feature away from that feature. If the underground excavation is excavated by conventional methods, then the surfaces for testing should be further excavated by non-blasting techniques to remove loose material resulting from stress relief or blasting.

6.3 *Temperature*—Temperature can have a significant effect on surface stress measurements, especially for rock outcrops. Therefore, temperature must be considered in the scope and purpose of the testing program.

6.4 *Tests in Orthogonal Directions*—The flat jack most accurately determines the stress parallel to the long axis of the underground excavation because this stress is the least affected by the presence of the opening. (The other tangential stress is highly concentrated.) In addition, if the underground excavation is in a stress field where one of the stresses is significantly larger than the others (3 or 4 times), certain locations in the underground excavation may be in very low compressive or even tensile stress. Flat jack tests in these locations can give what appears to be anomalous and misleading results unless the user is aware that testing can occur in zones with concentrations or reduction of stress.

7. Apparatus (See Figs. 1 and 2)

7.1 *Flat jacks*—Flat jacks shall be designed to operate at pressures of several thousand pounds per square inch when properly installed (Figs. 1, 2, 3, and 4). The jacks shall be constructed so that the two main plates move apart in essentially a parallel manner over the range of the jack. The range shall be at least 0.25 in. (6 mm). The jacks covered by this standard are square and the area of the jack shall be no less than 2 ft (0.6 m) wide. Any calibration factors for pressure for the flat jacks should be provided by the manufacture or obtained by calibrations by the user.

NOTE 2—Other flat jack shapes are available that may be better suited for specific applications. This standard only covers the basic square flat jack, however the basic principles discussed here will still apply.

7.2 *Instrumentation:*

7.2.1 *Pressure*—Electronic transducers or hydraulic gauges may be used to monitor flat jack pressure. The pressure transducer shall have an accuracy of at least ±20 lbf/in.^{2} (±0.14 MPa), including errors introduced by the readout system and a sensitivity of at least 10 lbf/in.^{2} (0.069 MPa).

7.2.2 *Deformation*—Deformation measurement devices including mechanical dial gauges, and electronic transducers such as LVDTs, vibrating wire or linear potentiometers. The devices can be either stationary, or portable, such as demountable mechanical (DEMEC) strain gauges, depending on the site requirements. The deformation device shall have an accuracy of at least ±0.0001 in. (±0.0025 mm) and a sensitivity of at least 0.00005 in. (0.0013 mm).

7.2.3 *Internal Gauges*—Strain gauges inside the flat jack shall be calibrated prior to installation of the jack. The effects of the hydraulic oil and ambient pressure increase on the gauges shall be determined prior to testing.

7.3 *Grout, Mortar, or Other Suitable Encapsulation Compound*—Any suitable encapsulation compound may be used that meets the requirements of the rock and other test criteria discussed in this standard. The encapsulating material used to secure or minimize expansion of the flat jack in the slot or to protect the flat jack from any irregularities on the wall of the slot that could puncture the flat jack. The encapsulation