Designation: D4553 − 18

Standard Test Method for Determining In Situ Creep Characteristics of Rock[1]

This standard is issued under the fixed designation D4553; 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 preparation, equipment, test procedure, and data documentation for determining in situ creep characteristics of a rock mass using a rigid plate loading method.

1.2 This test method is designed to be conducted in an adit or small underground chamber; however, with suitable modifications, this test could be conducted at the surface.

1.3 The test is usually conducted parallel or perpendicular to the anticipated axis of thrust, as dictated by the design load or other orientations, based upon the application.

1.4 Flexible plate apparatus can be used if the anticipated creep displacement is within the tolerance of the travel of the flat jacks.

1.5 *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. Reporting of test results in units other than inch-pound shall not be regarded as nonconformance with this standard.

1.5.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In the system, the pound (lbf) represents a unit of force (weight), while the units for mass is slugs. The slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.6 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this test method.

1.6.1 For purposes of comparing a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal of significant digits in the specified limit.

1.6.2 The procedures used to specify how data are collected/recorded and calculated in the 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 these test methods to consider significant digits used in analysis methods for engineering data.

1.7 *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.* For specific precaution statements, see Section 8.

1.8 *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]

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
D4394 Test Method for Determining In Situ Modulus of Deformation of Rock Mass Using Rigid Plate Loading Method
D4403 Practice for Extensometers Used in Rock
D4879 Guide for Geotechnical Mapping of Large Underground Openings in Rock (Withdrawn 2017)[3]
D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions:*

[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.
Current edition approved July 1, 2018. Published August 2018. Originally approved in 1985. Last previous edition approved in 2008 as D4553 – 08, which was withdrawn January 2017 and reinstated July 2018. DOI: 10.1520/D4553-18.

[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.

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

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *creep*—a time-dependent displacement of a plate pushed into the surface of the rock by a constant normal load. It is not directly related with laboratory creep data because of the nonuniformity of stress within the rock mass underneath the plate.

3.2.2 *displacement*—movement of the rigid plate, grout pad, or rock in response to and in the same direction as the applied load.

3.2.3 *load*—total force acting on the rock face.

3.2.4 *rigid plate*—plate with a deflection of less than 0.0005 in. (0.0127 mm) from the center to the edge of the plate when maximum load is applied.

4. Summary of Test Method

4.1 Areas on two opposing faces of a test adit underground chamber are flattened and smoothed.

4.2 A grout pad and rigid metal plate are installed against each face and a hydraulic loading system is placed between the rigid plates.

4.3 The two faces are rapidly loaded to the desired creep load, without shock, the load maintained, and the displacement of the plate measured as a function of time.

5. Significance and Use

5.1 Results of this test method are used to predict time-dependent deformation characteristics of a rock mass resulting from loading. It is a test that may be required depending on rock type or anticipated loads, or both.

5.2 This test method may be useful in structural design analysis where loading is applied over an extensive period.

5.3 This test method is normally performed at ambient temperature in the field, but equipment can be modified or substituted for operations at other temperatures.

5.4 Results of this test method may be useful in verifying laboratory creep data and structural mathematical modeling analyses.

5.5 Creep characteristics are determined under a nonuniform state of stress within the rock mass underneath the plate.

5.6 If during a field investigation, time-dependent characteristics are detected, then an in situ creep test shall be performed.

NOTE 1—The quality of the result produced by this standard 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/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Interferences

6.1 A completely inflexible plate used to load the rock face is difficult to construct. However, if the plate is constructed as rigid as feasible, the rock face is smoothed, and a thin, high-modulus material is used for the pad, the error in the measured displacements will be minimal.

6.2 The rock under the loaded area is generally not homogeneous, as assumed in theory. The rock will respond to the load according to its local deformational characteristics and orientation of discontinuities. The use of the average plate displacement will mitigate this problem. If this creep test is performed immediately after a plate loading test—Test Method D4394, for instance, the results of the creep test will be different than if it had been performed on virgin rock.

7. Apparatus

7.1 *Surface Preparation Equipment*—Test site preparation equipment shall include an assortment of excavation tools, such as drills and chipping hammers. Blasting shall not be allowed during a preparation of the test site.

7.2 *Instrumentation:*

7.2.1 *Displacement Measuring Equipment*—For displacement measurements, dial gauges or linear variable differential transformers (LVDTs) are generally used. An accuracy of at least ±0.0001 in. (0.0025 mm), including the error of the readout equipment, and a sensitivity of at least 0.00005 in. (0.0013 mm) is recommended. Errors in excess of 0.0004 in. (0.01 mm) can invalidate test results when the modulus of rock mass exceeds 5×10^6 psi (3.5×10^4 MPa).

7.2.2 *Load Cell*—A load cell is recommended to measure the load on the bearing plate. An accuracy of ±1000 lbf (4.4 kN) or ±5 % of maximum test load, including errors introduced by the readout system, and a sensitivity of at least 500 lbf (2.2 kN) are recommended. Long-term stability of the instrumentation system shall be verified throughout the test.

7.3 *Loading Equipment:*

7.3.1 *Hydraulic Ram or Flat Jacks*—This equipment, capable of applying and maintaining desired pressures to within ±3 %, is usually used to apply the load. A spherical bearing of suitable capacity shall be coupled to one of the bearing plates. If a hydraulic ram is used, the load shall be corrected to account for the effects of ram friction. If flat jacks are used, the jacks shall not be expanded beyond a thickness equal to 3 % of the diameter of a metal jack and care shall be taken that the jacks do not operate at the upper end of their range.

7.3.2 The loading equipment includes a device for applying the load and the reaction members, usually thick-walled aluminum or steel pipes, to transmit the load.

7.3.3 *Load Maintaining Equipment*—Equipment such as a servo-control system or air over hydraulic oil is required.

7.3.4 *Bearing Pads*—The bearing pads shall have a modulus of elasticity of around 4×10^6 psi (3×10^4 MPa) and shall be capable of conforming to the rock surface and bearing plate. High early strength grout or molten sulfur bearing pads are recommended.

7.3.5 *Bearing Plates*—The bearing plates shall approximate a rigid die as closely as practical. A bearing plate that has been found satisfactory is shown in Fig. 1. Although the exact design and materials may differ, the stiffness of the bearing plate shall

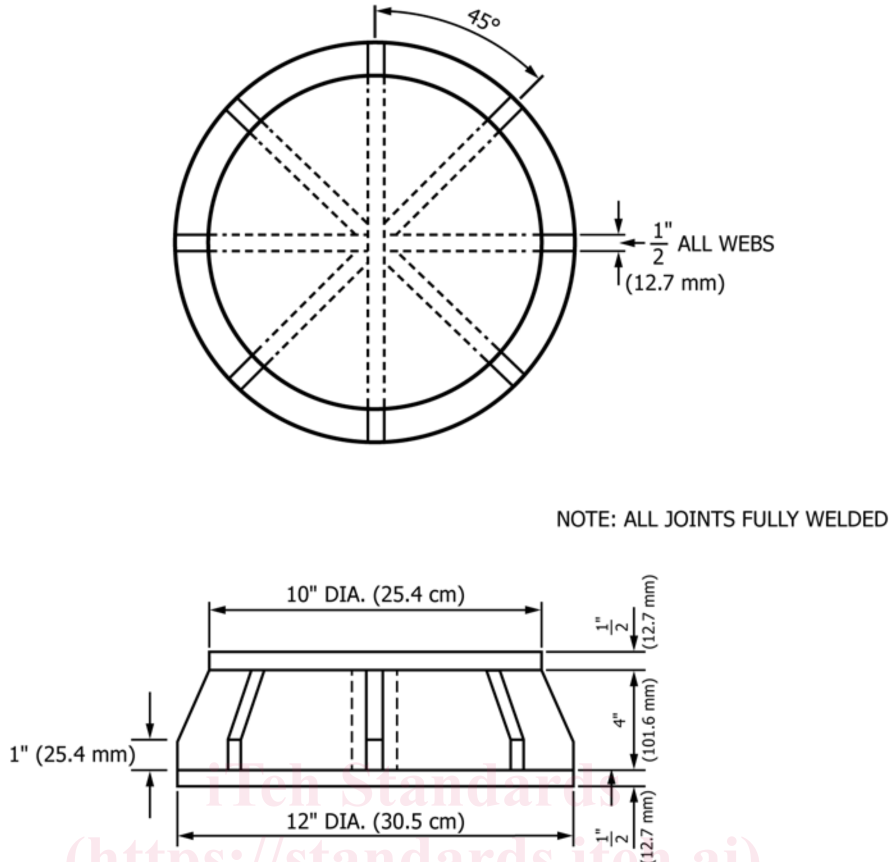

FIG. 1 Rigid Bearing Plate for 12 in. (30.5 cm) Diameter In Situ Creep Test

be the minimum stiffness necessary to not produce measurable deflection of the plate under maximum load.

8. Safety Hazards

8.1 Enforce safety by applicable safety standards.

8.2 Pressure lines should be bled of air to preclude violent failure of the pressure system.

8.3 Total displacement should not exceed the expansion capabilities of the flatjacks; normally this is approximately 3 % of the diameter of a metal jack.

9. In Situ Conditions

NOTE 2—The guidelines presented in this section are the domain of the agency or organization requesting the testing and are intended to facilitate definition of the scope and development of site-specific requirements for the testing program as a whole.

9.1 Test each structurally distinctive zone of rock mass selecting areas that are geologically representative of the mass. Test those portions of the rock mass with features such as faults, fracture zones, cavities, inclusions, and the like to evaluate their effects. Design the testing program so that effects of local geology can be clearly distinguished and the impact of excavation minimized.

9.2 The size of the bearing plate will be determined by the local geology, pressures to be applied, and the size of the adit to be performed. These parameters should be considered prior to excavation of the adit. Acceptable adit dimensions are approximately six times the plate diameter; recommended plate diameter is commonly 1 ½ to 3 ¼ ft (0.5 to 1 m). Other sizes are used depending upon site specifics. A map of the adit and test site shall be prepared in accordance with Guide D4879.

9.3 The effects of anisotropy should be investigated by appropriately oriented tests; for example, parallel and perpendicular to the bedding of a sedimentary sequence, or parallel and perpendicular to the long axes of columns in a basalt flow.

9.4 Tests shall be performed at a site not affected by structural changes resulting from excavations of the adit. The zone of rock that contributes to the measured displacement during the plate loading depends on the diameter of the plate and the applied load. Larger plates and higher loads measure the response of rock further away from the test adit. Thus, if the rock around the adit is damaged by the excavation process, and the deformational/creep properties of the damaged zone are the primary objective of the test program, small-diameter plate tests on typically excavated surfaces are adequate.

9.5 Site conditions may dictate that site preparation and pad construction be performed immediately after excavation.

10. Procedure

10.1 Verify the compliance of equipment and apparatus with the performance specifications in Section 7. If requirements are not stated, the manufacturer's specifications for the equipment may be appropriate as a guide, however, care should be taken for sufficient performance. Performance verification is generally done by calibrating the equipment and measurement system. Accomplish calibration and documentation in accordance with the quality assurance procedures in Annex A1.

10.2 Ensure that the test results are defensible and traceable by following at least the minimum guidelines for personnel qualifications, calibrations, test setup, test procedure, equipment performance and verification, and vetting of test data are followed in Annex A1.

10.3 Conduct the test across a "diameter" or chord of the adit with the two test surfaces nearly parallel and in planes oriented perpendicular to the thrust of the loading assembly. A schematic of an acceptable test setup is shown in Fig. 2. A wooden platform (not shown) allows for ease of construction and alignment of test components.

NOTE 3—The procedure shown is generalized but the user should not be confined by this procedure with regards to the actual testing portion. The user of this standard needs to realize that this is an expensive time consuming test and that running the test is a small part compared to the setup of the test. Therefore, if possible it may be prudent to collect as much data as possible before removing the equipment because in most instances you will not get a second chance to do this test. It is easier to do this if you have multiple tests and more than one apparatus. For example, data can be collected at one test site while the next site is being set up.

10.4 *Bearing Surface Preparation:*

10.4.1 *Method*—Prepare the surface by a method that will cause minimal damage to the finished rock surface. In the initial preparation of the finished test surface, many short drill holes may be required to remove unsound rock. Residual rock between the drill holes may be removed by burnishing or moving the bit back and forth until a smooth face is achieved. Alternatively, in hard, competent rock, controlled blasting with very small charges is advised to remove the unwanted/residual materials. In weaker materials, coarse grinding or cutting devices may be used.

10.4.2 *Size*—The prepared rock surface shall extend at least one-half the diameter of the bearing plate beyond the edge of the plate.

10.4.3 *Rock Quality*—To the extent practicable, prepare the bearing surface in sound rock. Remove loose and broken rock from the excavation. Deeper breaks may be detected by a dull hollow sound when the rock surface is struck with a hammer; remove such material.

10.4.4 *Smoothness*—The prepared rock face shall be as smooth as practicable. The deviation from a plane between the highest and lowest points should not exceed 1 in. (25 mm).

10.4.5 *Cleaning*—After the surface has been prepared, scrub and rinse it with clean water to remove any loose particles or dirt caused by the smoothing operation.

10.5 Construct detailed geometrical and geological plan and cross sectional views of the test site and bearing surface areas. Guide D4879 shall be followed when appropriate.

10.6 *Bearing Pad Construction*—Construct the bearing pad, with the bearing plate in position, by pouring the pad material between the rock surface and the plate. Contain the pad material by suitable form work around the edges of the plate. The only exception to this method is for near vertical tests where grout pads are used. In this case, the lower bearing plate may be placed directly upon the pad prior to curing. Exercise care to avoid air pockets or other cavities within the pad. The thickness of the bearing pad shall be no more than 15 % of the plate diameter, d, at any point. The dimensional requirements are shown in Fig. 3.

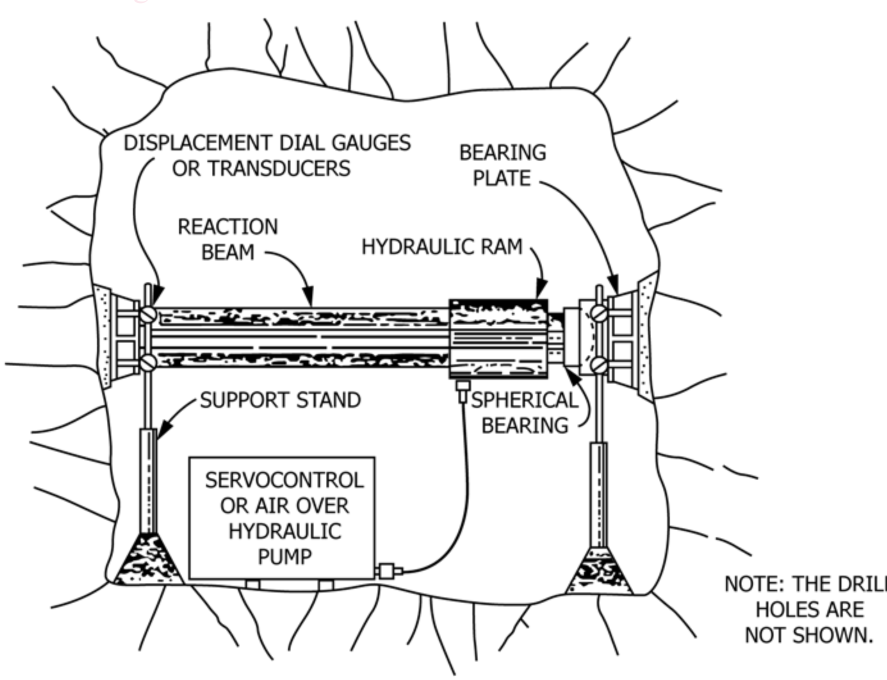

FIG. 2 Typical Rigid Plate Bearing Test Setup Schematic in Underground Adit or Tunnel