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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Determining In Situ Creep Characteristics of Rock¹

This standard is issued under the fixed designation D 4553; 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 subjected to controlled loading.

1.2 This test method is designed to be conducted in an underground opening; 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 The values stated in inch-pound units are to be regarded as the standard.

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

2. Referenced Documents

2.1 ASTM Standards:

D 4394 Test Method for Determining the In Situ Modulus of Deformation of Rock Mass Using the Rigid Plate Loading Method²

D 4403 Practice for Extensometers Used in Rock²

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *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.

3.1.2 *displacement*—movement of the rigid plate, grout

pad, or rock in response to and in the same direction as the applied load.

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

3.1.4 *rigid plate*—plate with a deflection of less than 0.0005 in. (0.0125 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 opening are flattened, smoothed, and made parallel.

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, 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.

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

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

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² *Annual Book of ASTM Standards*, Vol 04.08.

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, 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 should include an assortment of excavation tools, such as drills and chipping hammers. Blasting shall not be allowed during final preparation of the test site.

7.2 Instrumentation:

7.2.1 Displacement Measuring Equipment—For displacement measurements, dial gages or linear variable differential transformers (LVDTs) are generally used. A sensitivity of at least ± 0.0001 in. (0.0025 mm), including the error of the readout equipment, and an accuracy of at least 0.0005 in. (0.0125 mm) are required. 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 reasonable. 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.

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 at least 4×10^6 psi (3×10^4 MPa) (30 GPa) 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 be at least the minimum stiffness necessary to produce no measurable deflection of the plate under maximum load.

8. Precautions

8.1 All equipment and apparatus shall comply with the performance specifications in Section 7 and apparatus shall be verified. If no requirements are stated in Section 7, the manufacturer's specifications for the equipment may be appropriate as a guide to assure acceptable performance. Performance

verification is generally done by calibrating the equipment and measurement system (see Fig. 2).

8.2 Enforce safety by applicable safety standards. Pressure lines must be bled of air to preclude violent failure of the pressure system.

9. In Situ Conditions

9.1 Areas that are geologically representative of the mass shall be selected. The plates shall be contained in the same geologic member. The testing program shall be designed 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 opening in which the test is to be performed. These parameters shall be considered prior to excavation of the opening. Optimum opening dimensions are approximately six times the plate diameter. Recommended plate diameter is commonly 1 ft (0.3 m) to 3 ft (0.9 m). Other plate sizes may be used depending upon site specifics.

9.3 The effects of anisotropy shall be investigated by appropriately oriented tests; for example, 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 opening. The zone of rock that contributes to the measured displacement during loading depends on the diameter of the plate and the applied load. Larger plates and higher loads measure the response of rock farther away from the test opening. Thus, if the rock around the opening is damaged by the excavation process and the 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 A schematic of an optimum test setup is shown in Fig. 3. A properly located platform (not shown) allows for alignment of all test components.

10.2 Conduct the test across a "diameter" or chord of the opening with the two test surfaces nearly parallel and in planes oriented perpendicular to the thrust of the loading assembly.

10.3 Surface Preparation:

10.3.1 Method—Prepare the surface by a method that causes 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. Any 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 may be required to remove the unwanted materials. In weaker materials, coarse grinding or cutting devices may be used.

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

10.3.3 Rock Quality—To the extent possible, prepare the bearing surface in sound rock. Remove loose and broken rock.