Designation: D4436 – 13ε1

Standard Test Method for Rock Bolt Long-Term Load Retention Test[1]

This standard is issued under the fixed designation D4436; 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.

ε[1] NOTE—Editorial corrections were made throughout in February 2014.

1. Scope*

1.1 The objective of this test method is to determine the time over which rock bolt tension decreases from the installed value to a designated minimum value.

1.2 This test method is applicable to any anchor system which is not fully encapsulated immediately upon installation, including mechanical, cement grout, resin (epoxy, polyester, and the like) or other similar systems.

1.3 *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-pounds shall not be regarded as nonconformance with this test method.

1.3.1 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.

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 analytical methods for engineering design.

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

D4435 Test Method for Rock Bolt Anchor Pull Test

D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions*—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 *load*—the total axial force on the rock bolt.

3.2.2 *design load*—the load specified for the rock bolt during the life of the project.

3.2.3 *installation load*—the load on the bolt immediately after installation.

3.2.4 *stand time*—the time required for the bolt load to decrease from the installation load to the design load.

4. Summary of Test Method

4.1 A rock bolt is installed in the same manner and in the same material as its intended support use. The load on the bolt is monitored over a period of time, usually several weeks.

[1] This test method is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.05 on Inorganic Constituents in Water.

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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**

5. Significance and Use

5.1 Rock bolts are used for support in a variety of mining and civil engineering situations.[3] After a bolt is installed, the load generally decreases over time due to deterioration of the borehole wall, creep, and other factors. This process may be arrested by fully encapsulating the bolt shortly after installation. This encapsulation is generally done by pumping the bolt hole full of cement grout, though synthetic resins may also be used. The rate of load loss determines the interval during which the bolt must be encapsulated during construction.

5.2 The local characteristics of the rock, such as roughness of the borehole and induced fractures, are significant factors in the load loss characteristics of the bolt. To obtain realistic values, the test holes should be drilled using the same methods as those used for the construction boreholes.

5.3 In establishing a testing program, the following factors should be considered:

5.3.1 Load retention tests should be conducted in all rock types where construction bolts will be installed. If the rock is anisotropic, for example, bedded or schistose, the tests should be conducted in the same orientations relative to the anisotropy as the construction bolts will be installed.

5.3.2 In each rock type, at each orientation, and for each anchor system, a sufficient number of tests should be conducted to determine the average and minimum long-term capacities within a fixed uncertainty band at the 95 % confidence level. The allowable uncertainty band depends on the project and involves such factors as rock quality, expected project lifetime, and importance of the areas to be bolted. The uncertainty band determination will require considerable engineering judgment. As a rough guideline, at least six long-term tests for a single set of variables have been found necessary to satisfy the statistical requirements.

5.3.3 The design load and installation load on the rock bolt system should be predetermined. The installation load is less than the anchor capacity, as determined by Test Method D4435. The design load is less than the installation load; the amount depends on rock properties and the minimum time required to encapsulate the bolts. Alternatively, this method can be run for a predetermined time interval based on construction requirements, and a realistic design load can be determined from the data.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of 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. Apparatus

6.1 *Load Cell*—A load cell shall be used to measure the tension in the rock bolt. The cell may be of the mechanical, photoelastic, hydraulic, rubber compression pad, or electronic type. The electronic type is recommended. The cell shall have an accuracy of at least ±200 lbf (±890 N), including errors introduced by the excitation and read-out system, and a resolution of least 100 lbf (445 N).

6.2 *Anchor Systems*—The anchors used for testing shall be from the manufacturer's standard production stock. Mechanical anchors shall be inspected to make sure that no defective anchors are tested. Grout or resin shall be fresh (within the shelf life) and obtained from unopened containers. If grouted anchors are to be tested, make sure resin cartridge sizes are compatible with hole diameter, rock bolt bar diameter and length of anchorage required. For anchorages utilizing injected grout, make sure mixing and injection equipment and systems are compatible with manufacturer's recommendations.

6.3 *Rock Bolt and Accessories*—The rock bolt shall be of sufficient diameter and strength so that its elastic range is not exceeded during the tests. Standard bearing plates, washers, and the like may be used as required to align the load cell. A spherical bearing is desirable on very uneven surfaces. Rock bolts used with grout or resin anchors shall have identical ungrouted bolt lengths.

6.4 *Drilling Equipment*—The same type of drilling equipment and drill bits that will be used for installing rock bolts during the construction phase of the project shall be used as much as practical to drill the test holes.

6.5 *Torque Wrench*—If expandable shell mechanical anchors are used, a torque wrench shall be used to set them. The torque wrench shall also be used to load the bolts. It shall have a capacity at least 20 % greater than the manufacturer's recommended anchor-setting torque. The torque wrench shall have an accuracy of at least ±2 % of the full-scale reading and a resolution of at least 1 % of the full-scale reading.

6.6 *Hydraulic Pulling System*—As an alternative to the torque wrench, a hydraulic ram and reaction frame may be used to tension the bolts.

6.7 *Borehole Diameter Measuring Gauge*— A gauge shall be used to measure the diameter of the borehole at the anchor location. It shall have an accuracy of at least ±0.02 in. (0.5 mm) and resolution of at least 0.01 in. (0.25 mm).

6.8 *Thermometer*—A thermometer shall be used to measure temperature in the borehole, within the anchor zone if resin or cement grout anchorages are being tested. The temperature of the resin or grout shall also be measured at the time of injection. The thermometer should have an accuracy of at least ±0.5°F (±0.1°C) and a resolution of at least 1°F (0.5°C). See Note 2.

NOTE 2—The accuracy and resolution for the thermometer are presented in both Fahrenheit and Celsius units such that either type of thermometer can be used as long as the accuracy and resolution requirements as stated are met. The Celsius values are not direct conversions from Fahrenheit.

7. Procedure

7.1 Do not locate the test area in a zone that will be affected by future excavations, as rock response to stress changes can produce load changes in the bolt.

[3] For additional information see, "Suggested Method for Monitoring Rock Bolt Tension Using Load Cells," *Suggested Methods for Rock Bolt Testing,* International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests, 1974.

7.2 *Drilling the Test Hole:*

7.2.1 Drill the test hole using the same procedure that will be used during construction. Wash or blow the borehole clean of all cuttings.

7.2.2 The hole need not be as deep as the proposed length of the construction rock bolts. It shall, however, be deep enough to set the anchor past the zone of disturbance caused by the excavation and conform to the manufacturer's specifications for optimum performance, considering also compatibility with actual field conditions. For mechanical shell anchors, drill the hole 1 ft (300 mm) past the end of the anchor. A hole approximately 6 ft (1.8 m) in length has generally been found to be adequate.

7.2.3 Inspect the test hole visually using a flashlight, or mirror to reflect sunlight down the hole. If more than one-half of the bottom of the hole cannot be seen, the hole is not sufficiently straight for the test and shall not be used.

7.2.4 Measure the test hole diameter in two perpendicular directions at the top and bottom of the anchor location, using the borehole diameter measuring gauge, for a total of four measurements.

7.3 *Preparation of Anchors*—If any anchor preparations, such as degreasing or rust removal, will be done during construction, prepare the test anchors in the same way. If no special preparation is done during construction, do not prepare the anchors.

7.4 *Setting the Anchor:*

7.4.1 If mechanical anchors are used, lightly lubricate the downhole end of the rock bolt and screw on the anchor. When in position, torque the bolt to the manufacturer's recommendations to set the anchor. A pair of jam-nuts on the upper end of the rod may be used to apply torque without producing axial load in the bolt. If the manufacturer's torque cannot be achieved because of anchor slippage due to shear failure in the rock, note the maximum torque reading and install subsequent anchors to 80 % of this value. Do not test anchors where rotation occurs between rock surface and anchor. In all cases, record any slipping or other anomalous behavior as shown in Fig. 1.

7.4.2 Install grout or resin anchors according to the manufacturer's recommendations.

Rock Bolt Long Term Load Retention Test
Test Data Sheet—Sample Form

Project ____________ Anchor: Type ____________
Feature ____________ Depth ____________
Test Location ____________ Inst. Torque ____________
Rock Type ____________ Bolt: Type ____________
Test Number ____________ Length ____________
Orientation ____________ Diameter ____________

Equipment Description	Serial No.	Date of Next Calibration

Borehole diameter ________ ________ ________ ________

Average ________

Date	Time	By	Displacement	Load

Remarks:

Test Supervisor ____________ Date ____________
Quality Assurance ____________ Date ____________
Project Engineer ____________ Date ____________

FIG. 1 Rock Bolt Long Term Load Retention Test Sample Form

7.4.3 Read and record the temperature in the borehole within the anchor zone, the temperature of the resin or grout at the time of injection, and the ambient air temperature to the nearest 1°F (0.5°C). Ideally the test anchorages should be installed under the same temperature conditions as expected during construction. The time required for resin or grout anchorages to reach their design strengths is temperature dependent and may vary significantly. Consult the resin or grout manufacturer's literature for recommended curing times under various temperature conditions. Curing times may be varied between 1 to 5 days under similar temperature conditions to assess the effects of curing time on strength. To evaluate the influence of grouted bond length on anchor strength, several anchorage lengths should be tested, ideally under similar temperature conditions and curing times.

7.5 *Loading the Bolt:*

7.5.1 The torque wrench is recommended for tensioning the bolt. Alternatively, the hydraulic pulling system may be used to apply load. In this case, attach a pulling rod to the rock bolt above the nut. Apply the load hydraulically, then tighten the nut. As the nut is tightened, the hydraulic pressure decreases because the load is transferred from the ram to the nut.

7.5.2 Tension the bolt until the load cell indicates that the installation load has been achieved.

7.5.3 Read and record the installation load to the nearest 100 lbf (0.44 kN).

7.6 Read and record the load to the nearest 100 lbf (0.44 kN) on the bolt at least twice daily for a period of 2 weeks after installation, and once daily thereafter. Bolts in rapidly yielding material may require more frequent readings.

8. Calculation

8.1 For each test, plot the load on the rock bolt as a function of time, as shown in Fig. 2. If either design load or stand time is specified, the other may be determined from the graph.

8.2 For each group of tests in a similar rock type, with the same anchor type and orientation (if applicable), calculate the mean and uncertainty of the loads at the 95 % confidence level.[4]

[4] To calculate the mean and uncertainty of the results see, "Statistical Considerations," *Rock Testing Handbook,* U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, 1980, Section 104-80.

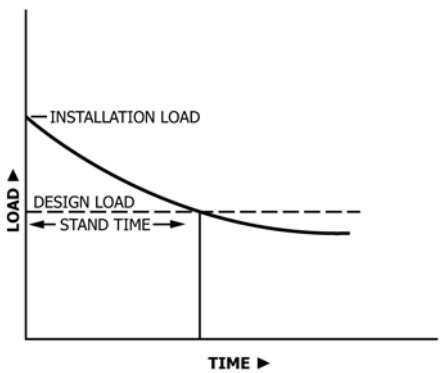

FIG. 2 Typical Load versus Time Curve for a Rock Bolt

9. Report: Test Data Sheet(s)/Form(s)

9.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s) as given below, is covered in 1.4 and Practice D6026.

9.2 Record as a minimum the following general information (data):

9.2.1 Project information, including, as applicable, the project name and number.

9.2.2 Test location.

9.2.3 Bolt type, length, and diameter.

9.2.4 Borehole diameter for each borehole and the average diameter of the boreholes tested.

9.2.5 Describe the rock materials in which the anchors were tested, including the composition, texture, and any structural features which could affect anchor behavior, such as joints, weathering, and the like.

9.2.6 Type(s) of anchors tested, including anchor depth and instrument torque.

9.2.7 Names of the personnel who performed the test(s) and checked or reviewed the test(s) data. Include the dates the testing and reviewing was performed.

9.2.8 A summary of the test program including test number, anchor type, rock type, orientation, and test depth.

9.2.9 List the equipment, other than anchors, with model numbers, serial numbers, or dimensions as appropriate. Include the range, accuracy, and resolution of any devices used to make measurements.

9.3 Record as a minimum the following test information:

9.3.1 For each reading, the time and load in lbf (N). If desired, the displacement, in. (mm).

9.3.2 The temperature in °F (°C). If resin or grouted anchorages were tested, also record the grout and ambient temperatures.

9.3.3 A plot of load versus time for each test, a description of the nature of any failures or any other observations pertinent to the test.

9.3.4 For the evaluation of grouted rock bolts, the results of several tests shall be presented graphically to show the influence of grout cure time and bond length on anchor strength. Data concerning temperature effects shall be presented to indicate the effects of temperature on cure times and the recommended installation procedures to be followed during construction.

10. Precision and Bias

10.1 *Precision*—Test data on precision is not presented due to the nature of the rock materials tested by this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in situ testing program at a given site. Subcommittee D18.12 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

10.2 *Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

11. Keywords

11.1 anchors (rock); field testing; loading tests; mines; pull testing; rock

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this standard since the last issue (D4436 – 08) that may impact the use of this standard. (Approved Nov. 1, 2013.)

(1) Revised standard throughout.
(2) Added 1.3.1, Note 2, and 7.4.3.
(3) Rewrote Section 9.