



Standard Test Method for Rock Bolt Anchor Pull Test¹

This standard is issued under the fixed designation D 4435; 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 objective of this test method is to measure the working and ultimate capacities of a rock bolt anchor. This method does not measure the entire roof support system. This method also does not include tests for pretensioned bolts or mine roof support system evaluation.

1.2 This test method is applicable to mechanical, cement grout, resin, (epoxy, polyester, and the like), or other similar anchor systems.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *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. Terminology

2.1 *Definitions of Terms Specific to This Standard:*

2.1.1 *displacement*—The movement of the rock bolt head.

2.1.2 *failure*—the inability of the anchor system or rock to sustain increased load without rapidly increasing deformation. In some instances, the peak load itself cannot be sustained.

2.1.3 *load*—the total axial force on the rock bolt.

2.1.4 *pressure, stress*—the force per unit area.

2.1.5 *ultimate capacity*—the maximum load sustained by the anchor system.

2.1.6 *working capacity*—the load on the anchor system at which significantly increasing displacement begins.

3. Summary of Test Method

3.1 A rock bolt is installed in the same manner and in the same material as its intended construction use. The bolt is pulled hydraulically and the displacement of the bolt head is measured concurrently. The bolt is pulled until the anchor system or rock fails. The ultimate and working capacities of the bolt are calculated from the plot of load versus displacement.

4. Significance and Use

4.1 Rock bolts are used for support in a variety of mining

and civil engineering situations². The pull test may be used to provide a quantitative measure of the relative performance of different anchor systems in the same rock type. Anchor systems may be different mechanical anchors or different bond materials or lengths for grouted anchors. Such data can be used to choose an anchor type and determine bolt length, spacing, and size.

4.2 The objective of the method is to measure anchor performance, and not the performance of the rock bolt itself. Thus, to ensure that the bolt response during the test is minimal and predictable, high strength, short-length (6 to 8 ft (1.8 to 2.5 m)) bolts have been specified. The bolt should be just long enough to ensure that no failure of the rock/mass occurs.

4.3 Ideally, the rock bolt anchor should fail by shear at the anchor-rock interface or bond. Therefore, the local characteristics of the rock, such as roughness and induced fractures, are significant factors in the anchor strength. To obtain realistic strength values, the test holes should be drilled using the same methods as the construction rock bolt holes.

4.4 Rocks with significant time-dependent behavior, such as rock salt or shale, may respond to the anchor system itself and change the anchor strength. In these cases, consideration should be given to testing bolts over a period of time.

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

4.5.1 Anchor pull tests should be conducted in all rock types in which construction bolts will be installed. If the rock is anisotropic, for example, bedded or schistose, the tests should be conducted in various orientations relative to the anisotropy, including those at which the construction bolt may be installed.

4.5.2 In each rock type, at each orientation, and for each anchor system, a sufficient number of tests should be conducted to determine the average bolt capacities within a fixed uncertainty at the 95 % confidence level. The allowable uncertainty band depends on the project and involves such factors as the rock quality, expected project lifetime, and importance of the areas to be bolted. Its determination will require considerable engineering judgment. As a rough guideline, at least 10 to 12 pull tests for a single set of variables have been found necessary to satisfy the statistical requirements.

¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

Current edition approved Nov. 30, 1984. Published January 1985.

² For additional information see, "Suggested Method for Determining the Strength of a Rock Bolt Anchor (Pull Test)," *Suggested Methods for Rock Bolt Testing*, International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests, 1974.

5. Apparatus

5.1 *Loading System*—The system for pulling the rock bolts shall consist of a hollow-center hydraulic ram and mounting/reaction frame. The hydraulic ram shall be of sufficient capacity to fail the anchor and shall have a travel range of at least 2 in. (50 mm). The mounting/reaction frame shall be usable against uneven rock surfaces. The loading system shall apply a force that deviates by no more than 5° from the long axis of the bolt during the test.

5.2 *Load Transducer*—An electronic load cell is recommended to measure the load on the rock bolt. The cell shall have an accuracy of at least ±200 lbf (±890 N), including errors introduced by the excitation and readout system, and a resolution of at least 100 lbf (445 N). Other types of load transducers may be used if their performance meets these specifications. Alternatively, a pressure gage or electronic transducer may be used to measure the pressure applied to the ram, provided that the load measurement requirements above are satisfied, including the effects of friction in the hydraulic ram, and the like.

5.3 *Displacement Transducer*—A dial gage is recommended to measure the displacement of the rock bolt head. It shall have an accuracy of at least ±0.001 in. (0.025 mm), a resolution of at least 0.0005 in. (0.013 mm), and a range of at least 2 in. (50 mm). It shall be mounted along the axis of the rock bolt within 5°. The end of the rock bolt, or pulling rod if used, shall be smooth with a counter-sink area approximately ¼ in. (6 mm) in diameter to accommodate the measuring tip of the dial gage. Other types of displacement transducers may be used provided they satisfy the requirements of this section.

5.4 *Displacement Transducer Support*—The displacement transducer shall be supported from a point no closer than 3 ft (0.9 m) to the reaction frame, if attached to the same rock face. The support shall be sufficiently rigid that no deflection or

instability occurs during testing.

5.5 *Anchor Systems*—The anchors used for testing shall be from the manufacturer’s standard production stock. Mechanical anchors shall be inspected to ensure that no defective anchors are tested. Grout or resin shall be fresh (within the shelf life) and obtained from unopened containers.

5.6 *Rock Bolt and Accessories*—The rock bolt shall be of sufficient diameter and strength that its elastic range is not exceeded during testing. Standard bearing plates, washers, and the like may be used as required.

5.7 *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 far as possible to drill the test holes.

5.8 *Torque Wrench*—If expandable shell mechanical anchors are used, a torque wrench shall be used to set them. The wrench 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.

5.9 *Borehole Diameter Measuring Gage*—A gage 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. (0.05 mm) and resolution of at least 0.01 in. (0.25 mm)

5.10 Fig. 1 shows a typical test setup.

6. Procedure

6.1 *Drilling the Test Hole:*

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

6.1.2 The hole need not be as deep as the proposed length of the rock bolts. It shall, however, be deep enough to set the

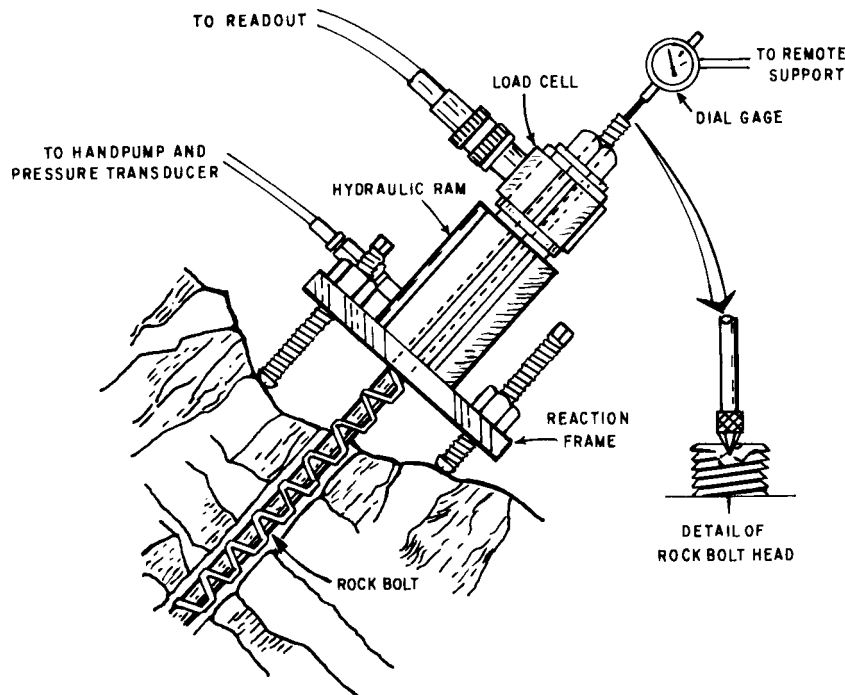


FIG. 1 Typical Rock Bolt Pull Test Schematic

increments or increments of 500 lbf (2.2 kN), whichever is less.

6.4.6 Read and record displacement and load after each pressure increment or decrement.

6.4.7 Failure is the peak load sustained by the bolt, as shown on Fig. 3, or a total deflection of 0.5 in. (1.25 cm).

6.4.8 Pull the bolt 0.5 in. (12.5 mm) beyond the failure displacement. Record the load every 0.05 in. (1 mm).

6.5 *Data Recording*—As a minimum for this method, record all the data shown in Fig. 2.

7. Calculation

7.1 Calculate the stress on the bolt, σ_b , in psi (MPa) as follows:

$$\sigma_b = \frac{P}{A} \tag{1}$$

where:

P = load on the bolt, lbf (N), and

A = cross-sectional area of the bolt, in.²(mm²).

7.2 Calculate the elastic deformation of the bolt, U_b , in in. (mm) as follows:

$$U_b = \frac{\sigma_b}{E} \times L \tag{2}$$

where:

σ_b = stress on the bolt, psi (MPa),

L = exposed length of bolt between the anchor and the head, in. (mm), and

E = elastic modulus of the steel in the bolt, psi (MPa).

7.3 Calculate the corrected bolt head displacement, U_c , which is the same as the displacement of the anchor, as follows:

$$U_c = U_t - U_b \tag{3}$$

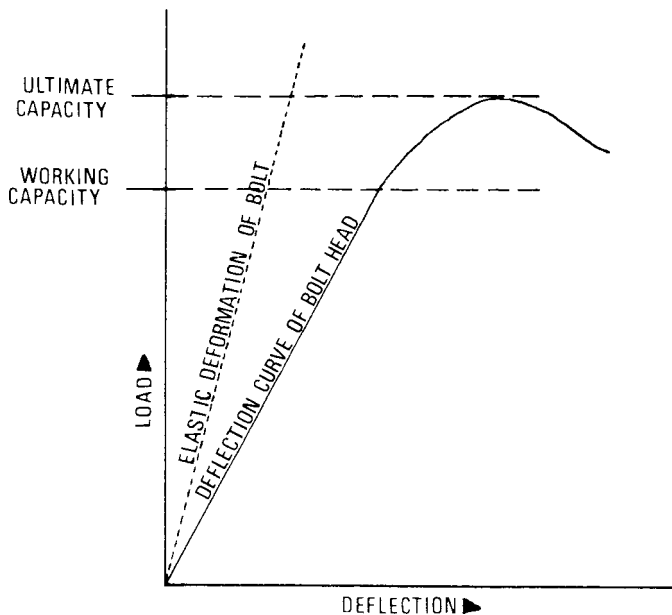


FIG. 3 Typical Load versus Deflection Curve for Rock Bolt Pull Test

where:

U_b = elastic deformation of the bolt, and

U_t = total displacement of bolt head.

7.4 Determine the working and ultimate capacities of the anchor system from the plot of load versus anchor displacement. A typical curve is shown in Fig. 3. Interpretation of the curve often requires some engineering judgment.

7.5 For each group of tests on a similar rock type with the same anchor type and orientation (if applicable), calculate the mean and uncertainty of the results at the 95 % confidence level³.

8. Report

8.1 The report shall include the following:

8.1.1 Describe the rock material(s) in which the anchors were tested, including the composition, texture, and any structural features which could affect anchor capacities, such as joints, weathering, and the like,

8.1.2 Briefly describe the types of anchors tested,

8.1.3 A summary table of the test program including test number, anchor type, rock type, orientation, and test depth,

8.1.4 List the equipment, other than anchors, with model numbers or dimensions as appropriate. Include the range, accuracy, and resolution of transducers,

8.1.5 Present the equations used to reduce the data, including those required to convert transducer output into engineering units,

8.1.6 Prepare summary tables of results, including the working and ultimate capacity of each anchor type in each rock type, with anchor type, number of tests, mean working capacity, range, and uncertainty of the mean,

8.1.7 Include a plot of load versus corrected bolt head displacement for each test, and

8.1.8 Append the data sheets for each test.

9. Precision and Bias

9.1 *Precision*—Due to the nature of rock materials tested by this test method, it is, at this time, either not feasible or too costly to produce multiple specimens which have uniform physical properties. Therefore, since specimens which would yield the same test results cannot be tested, Subcommittee D18.12 cannot determine the variation between tests since any variation observed is just as likely to be due to specimen variation as to operator or laboratory testing variation. Subcommittee D18.12 welcomes proposals to resolve this problem that would allow for development of a valid precision statement.

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

10. Keywords

10.1 anchors (rock); displacement; field testing; loading tests; mines; pull testing; rock; shear testing

³ 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.

 **D 4435**

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