AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428

Standard Test Method for Triaxial Compressive Strength of Undrained Rock Core Specimens Without Pore Pressure Measurements[1]

This standard is issued under the fixed designation D 2664; 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 determination of the strength of cylindrical rock core specimens in an undrained state under triaxial compression loading. The test provides data useful in determining the strength and elastic properties of rock, namely: shear strengths at various lateral pressures, angle of internal friction, (angle of shearing resistance), cohesion intercept, and Young's modulus. It should be observed that this method makes no provision for pore pressure measurements. Thus the strength values determined are in terms of total stress, that is, not corrected for pore pressures.

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

1.3 *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:*

D 4543 Practice for Preparing Rock Core Specimens and Determining Dimensional and Shape Tolerances[2]

E 4 Practices for Force Verification of Testing Machines[3]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[4]

3. Significance and Use

3.1 Rock is known to behave as a function of the confining pressure. The triaxial compression test is commonly used to simulate the stress conditions under which most underground rock masses exist.

4. Apparatus

4.1 *Loading Device*—A suitable device for applying and measuring axial load to the specimen. It shall be of sufficient capacity to apply load at a rate conforming to the requirements specified in 7.2. It shall be verified at suitable time intervals in accordance with the procedures given in Practices E 4 and comply with the requirements prescribed in the method.

4.2 *Pressure-Maintaining Device*—A hydraulic pump, pressure intensifier, or other system of sufficient capacity to maintain constant the desired lateral pressure, σ_3.

NOTE 1—A pressure intensifier as described by Leonard Obert in U.S. Bureau of Mines Report of Investigations No. 6332, "An Inexpensive Triaxial Apparatus for Testing Mine Rock," has been found to fulfill the above requirements.

4.3 *Triaxial Compression Chamber*[5]—An apparatus in which the test specimen may be enclosed in an impermeable flexible membrane; placed between two hundred platens, one of which shall be spherically seated; subjected to a constant lateral fluid pressure; and then loaded axially to failure. The platens shall be made of tool steel hardened to a minimum of Rockwell 58 HRC, the bearing faces of which shall not depart from plane surfaces by more than 0.0005 in. (0.0127 mm) when the platens are new and which shall be maintained within a permissible variation of 0.001 in. (0.025 mm). In addition to the platens and membrane, the apparatus shall consist of a high-pressure cylinder with overflow valve, a base, suitable entry ports for filling the cylinder with hydraulic fluid and applying the lateral pressure, and hoses, gages, and valves as needed.

4.4 *Deformation and Strain-Measuring Devices*—High-grade dial micrometers or other measuring devices graduated to read in 0.0001-in. (0.0025-mm) units, and accurate within 0.0001 in. (0.0025 mm) in any 0.0010-in. (0.025-mm) range, and within 0.0002 in. (0.005 mm) in any 0.0100-in. (0.25-mm) range shall be provided for measuring axial deformation due to loading. These may consist of micrometer screws, dial micrometers, or linear variable differential transformers securely attached to the high pressure cylinder.

4.4.1 Electrical resistance strain gages applied directly to the rock specimen in the axial direction may also be used. In addition, the use of circumferentially applied strain gages will permit the observation of data necessary in the calculation of

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

[3] *Annual Book of ASTM Standards*, Vols 03.01, 14.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] Assembly and detail drawings of an apparatus that meets these requirements and which is designed to accommodate 2⅛-in. (53.975-mm) diameter specimens and operate at a lateral fluid pressure of 10 000 psi (689 MPa) are available from Headquarters. Request Adjunct No. 12-426640-00.

Poisson's ratio. In this case two axial (vertical) gages should be mounted on opposite sides of the specimen at mid-height and two circumferential (horizontal) gages similarly located around the circumference, but in the direction perpendicular to the axial gages.

4.5 *Flexible Membrane*—A flexible membrane of suitable material to exclude the confining fluid from the specimen, and that shall not significantly extrude into abrupt surface pores. It should be sufficiently long to extend well onto the platens and when slightly stretched be of the same diameter as the rock specimen.

NOTE 2—Neoprene rubber tubing of 1⁄16-in. (1.588-mm) wall thickness and of 40 to 60 Durometer hardness, Shore Type A or various sizes of bicycle inner tubing, have been found generally suitable for this purpose.

5. Sampling

5.1 The specimen shall be selected from the cores to represent a true average of the type of rock under consideration. This can be achieved by visual observations of mineral constituents, grain sizes and shapes, partings and defects such as pores and fissures.

6. Test Specimens

6.1 *Preparation*—The test specimens shall be prepared in accordance with Practice D 4543.

6.2 Moisture condition of the specimen at the time of test can have a significant effect upon the indicated strength of the rock. Good practice generally dictates that laboratory tests be made upon specimens representative of field conditions. Thus it follows that the field moisture condition of the specimen should be preserved until the time of test. On the other hand, there may be reasons for testing specimens at other moisture contents, including zero. In any case the moisture content of the test specimen should be tailored to the problem at hand and reported in accordance with 9.1.6.

7. Procedure

7.1 Place the lower platen on the base. Wipe clean the bearing faces of the upper and lower platens and of the test specimen, and place the test specimen on the lower platen. Place the upper platen on the specimen and align properly. Fit the flexible membrane over the specimen and platen and install rubber or neoprene O-rings to seal the specimen from the confining fluid. Place the cylinder over the specimen, ensuring proper seal with the base, and connect the hydraulic pressure lines. Position the deformation measuring device and fill the chamber with hydraulic fluid. Apply a slight axial load, approximately 25 lbf (110 N), to the triaxial compression chamber by means of the loading device in order to properly seat the bearing parts of the apparatus. Take an initial reading on the deformation device. Slowly raise the lateral fluid pressure to the predetermined test level and at the same time apply sufficient axial load to prevent the deformation measuring device from deviating from the initial reading. When the predetermined test level of fluid pressure is reached, note and record the axial load registered by the loading device. Consider this load to be the zero or starting load for the test.

7.2 Apply the axial load continuously and without shock until the load becomes constant, or reduces, or a predetermined amount of strain is achieved. Apply the load in such a manner as to produce a strain rate as constant as feasible throughout the test. Do not permit the strain rate at any given time to deviate by more than 10 % from that selected. The strain rate selected should be that which will produce failure of a similar test specimen in unconfined compression, in a test time of between 2 and 15 min. The selected strain rate for a given rock type shall be adhered to for all tests in a given series of investigation (Note 3). Maintain constant the predetermined confining pressure throughout the test and observe and record readings of deformation as required.

NOTE 3—Results of tests by other investigators have shown that strain rates within this range will provide strength values that are reasonably free from rapid loading effects and reproducible within acceptable tolerances.

7.3 To make sure that no testing fluid has penetrated into the specimen, the specimen membrane shall be carefully checked for fissures or punctures at the completion of each triaxial test. If in question, weigh the specimen before and after the test.

8. Calculation

8.1 Make the following calculations and graphical plots:

8.1.1 Construct a stress difference versus axial strain curve (Note 5). Stress difference is defined as the maximum principal axial stress, σ_1, minus the lateral pressure, σ_3. Indicate the value of the lateral pressure, σ_3, on the curve.

NOTE 4—If the specimen diameter is not the same as the piston diameter through the chamber, a correction must be applied to the measured load to account for differences in area between the specimen and the loading piston where it passes through the seals into the chamber.

NOTE 5—If the total deformation is recorded during the test, suitable calibration for apparatus deformation must be made. This may be accomplished by inserting into the apparatus a steel cylinder having known elastic properties and observing differences in deformation between the assembly and steel cylinder throughout the loading range. The apparatus deformation is then subtracted from the total deformation at each increment of load in order to arrive at specimen deformation from which the axial strain of the specimen is computed.

8.1.2 Construct the Mohr stress circles on an arithmetic plot with shear stresses as ordinates and normal stresses as abscissas. Make at least three triaxial compression tests, each at a different confining pressure, on the same material to define the envelope to the Mohr stress circles.

NOTE 6—Because of the heterogeneous nature of rock and the scatter in results often encountered, it is considered good practice to make at least three tests of essentially identical specimens at each confining pressure or single tests at nine different confining pressures covering the range investigated. Individual stress circles shall be plotted and considered in drawing the envelope.

8.1.3 Draw a "best-fit," smooth curve (the Mohr envelope) approximately tangent to the Mohr circles as in Fig. 1. The figure shall also include a brief note indicating whether a pronounced failure plane was or was not developed during the test and the inclination of this plane with reference to the plane of major principal stress.

NOTE 7—If the envelope is a straight line, the angle the line makes with the horizontal shall be reported as the angle of interval friction, ϕ (or the slope of the line as tan ϕ depending upon preference) and the intercept of this line at the vertical axis reported as the cohesion intercept, *C*. If the envelope is not a straight line, values of ϕ (or tan ϕ) should be determined