AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Unconfined Compressive Strength of Intact Rock Core Specimens[1]

This standard is issued under the fixed designation D 2938; 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 specifies the apparatus, instrumentation, and procedures for determining unconfined compressive strength of intact rock core specimens.

1.2 The values stated in inch-pound units are to be regarded as the standard. The SI values given in parentheses are for information only.

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 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[2]

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

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

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

3. Summary of Test Method

3.1 A rock core sample is cut to length and the ends are machined flat. The specimen is placed in a loading frame and, if required, heated to the desired test temperature. Axial load is continuously increased on the specimen until peak load and failure are obtained.

4. Significance and Use

4.1 Unconfined compressive strength of rock is used in many design formulas and is sometimes used as an index property to select the appropriate excavation technique.

4.2 The strength of rock cores measured in the laboratory usually do not accurately reflect large-scale *in situ* properties because the latter are strongly influenced by joints, faults, inhomogeneities, weakness planes, and other factors. Therefore, laboratory values for intact specimens must be employed with proper judgement in engineering applications.

5. Apparatus

5.1 *Loading Device*, of sufficient capacity to apply load at a rate conforming to the requirements set forth in 9.5. It shall be verified at suitable time intervals in accordance with the procedures given in Practices E 4, and comply with the requirements prescribed therein. The loading device may be equipped with a displacement transducer that can be used to advance the loading ram at a specified rate.

5.2 *Elevated-Temperature Enclosure*—The elevated temperature enclosure may be either an enclosure that fits in the loading apparatus or an external system encompassing the complete test apparatus. The enclosure may be equipped with humidity control for testing specimens in which the moisture content is to be controlled. For high temperatures, a system of heaters, insulation, and temperature measuring devices are normally required to maintain the specified temperature. Temperature shall be measured at three locations, with one sensor near the top, one at midheight, and one near the bottom of the specimen. The average specimen temperature based on the midheight sensor shall be maintained to within ±1°C of the required test temperature. The maximum temperature difference between the midheight sensor and either end sensor shall not exceed 3°C.

NOTE 1—An Alternative to measuring the temperature at three locations along the specimen during the test is to determine the temperature distribution in a dummy specimen that has temperature sensors located in drill holes at a minimum of six positions: along both the centerline and specimen periphery at midheight and each end of the specimen. The temperature controller set point shall be adjusted to obtain steady-state temperatures in the dummy specimen that meet the temperature requirements at each test temperature (the centerline temperature at midheight shall be within ±1°C of the required test temperature, and all other specimen temperatures shall not deviate from this temperatures by more than 3°C). The relationship between controller set point and dummy specimen temperature can be used to determine the specimen temperature during testing provided that the output of the temperature feedback sensor (or other fixed-location temperature sensor in the triaxial apparatus) is maintained constant within ±1°C of the required test temperature. The relationship between temperature controller set point and steady-state specimen temperature shall be verified periodically. The dummy specimen

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

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

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

is used solely to determine the temperature distribution in a specimen in the elevated temperature enclosure—it is not to be used to determine compressive strength.

5.3 *Temperature Measuring Device*—Special limits-of-error thermocouples or platinum resistance thermometers (RTDs) having accuracies of at least ±1°C with a resolution of 0.1°C.

5.4 *Platens*—Two steel platens are used to transmit the axial load to the ends of the specimen. They shall have a hardness of not less than 58 HRC. The bearing faces shall not depart from a plane by more than 0.0125 mm when the platens are new and shall be maintained within a permissible variation of 0.025 mm. The platen diameter shall be at least as great as the specimen diameter, but shall not exceed 1.10 times the speciemen diameter. The platen thickness shall be at least one-half the specimen diameter.

5.4.1 *Spherical Seating*—One of the platens should be spherically seated and the other a plain rigid platen. The diameter of the spherical seat shall be at least as large as that of the test specimen, but shall not exceed twice the diameter of the test specimen. The center of the sphere in the spherical seat shall coincide with the center of the loaded end of the specimen. The spherical seat shall be lubricated to ensure free movement. The movable portion of the platen shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated and tilted through small angles in any direction.

5.4.2 *Rigid Seating*—If a spherical seat is not used, the bearing faces of the platens shall be parallel to 0.0005 mm/mm of platen diameter. This criterion shall be met when the platens are in the loading device and separated by approximately the height of the test specimen.

6. Safety Precautions

6.1 Many rock types fail in a violent manner when loaded to failure in compression. A protective shield should be placed around the test specimen to prevent injury from flying rock fragments. Elevated temperatures increase the risks of electrical shorts and fire.

7. Sampling

7.1 The specimen shall be selected from the cores to represent a valid average of the type of rock under consideration. This can be achieved by visual observations of mineral constituents, grain sizes and shape, partings and defects such as pores and fissures, or by other methods such as ultrasonic velocity measurements.

8. Test Specimens

8.1 Prepare test specimens in accordance with Practice D 4543.

8.2 The moisture condition of the specimen at time of test can have a significant effect upon the deformation 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 time of test. On the other hand, there may be reasons for testing specimens at other moisture contents including zero. In any case, tailor the moisture content of the test specimen to the problem at hand and report it in accordance with 11.1.3. If the moisture content of the specimen is to be determined, follow the procedures in Test Method D 2216.

8.3 If moisture condition is to be maintained, and the elevated temperature enclosure is not equipped with humidity control, seal the specimen using a flexible membrane or apply a plastic or silicone rubber coating to the specimen sides.

9. Procedure

9.1 Check the ability of the spherical seat to rotate freely in its socket before each test.

9.2 Place the lower platen on the base or actuator rod of the loading device. 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. A small axial load, approximately 100 N, may be applied to the specimen by means of the loading device to properly seat the bearing parts of the apparatus.

9.3 When appropriate, install elevated-temperature enclosure.

9.4 If testing at elevated temperature, raise the temperature at a rate not exceeding 2°C/min until the required temperature is reached (Note 2). The test specimen shall be considered to have reached temperature equilibrium when all temperature measuring device outputs are stable for at least three readings taken at equal intervals over a period of no less than 30 min (3 min for tests performed at room temperature). Stability is defined as a constant reading showing only the effects of normal instrument and heater unit fluctuations.

NOTE 2—It has been observed that for some rock types microcracking will occur for heating rates above 1°C/min. The operator is cautioned to select a heating rate that microcracking is not significant.

9.5 Apply the axial load continuously and without shock until the load becomes constant, reduces, or a predetermined amount of strain is achieved. Apply the load in such a manner as to produce either a stress rate or a strain rate as constant as feasable throughout the test. Do not permit the stress rate or strain rate at any given time to deviate by more than 10 percent from that selected. The stress rate or strain rate selected should be that which will produce failure in a test time between 2 and 15 min. The selected stress rate or strain rate for a given type shall be adhered to for all tests in a given series of investigation (Note 3). Record the maximum load sustained by the specimen.

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. Lower strain rates are permissible, if required by the investigation.

10. Calculation

10.1 Calculate the compressive strength in the test specimen from the maximum compressive load on the specimen and the initial computed cross-sectional area as follows:

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

where:
σ = Compressive strength
P = Maximum load

A = Cross sectional area.

NOTE 4—Tensile stresses are used as being positive. A consistent application of a compression-positive sign convention may be employed if desired. The sign convention adopted needs to be stated explicitly in the report. The formulas given are for engineering stresses. True stresses may be used, if desired, provided that specimen diameter at the time of peak load is known.

11. Report

11.1 The report shall include the following:

11.1.1 Source of sample including project name and location (often the location is specified in terms of the drill hole number and depth of specimen from the collar of the hole).

11.1.2 Lithologic description of the rock, formation name, and load direction with respect to lithology.

11.1.3 Moisture condition of specimen before test.

11.1.4 Specimen diameter and height, conformance with dimensional requirements.

11.1.5 Temperature at which test was performed.

11.1.6 Rate of loading or deformation rate.

11.1.7 Unconfined compressive strength.

NOTE 5—If failure is ductile, with the load on the specimen still increasing when the test is terminated, the strain at which the compressive strength was calculated shall be reported.

11.1.8 Type and location of failure. A sketch of the fractured specimen is recommended.

11.1.9 If the actual equipment or procedure has varied from the requirements contained in this test method, each variation and the reasons for it shall be discussed.

12. Precision and Bias

12.1 Data are being evaluated via an interlaboratory test program for rock properties to determine the precision of this test method.

12.2 Bias cannot be determined since there is no standard value of compressive strength that can be used to compare with values determined using this method.

13. Keywords

13.1 compression testing; compressive strength; loading tests; rock