Designation: D 3967 – 95a

AMERICAN SOCIETY FOR TESTING AND MATERIALS
100 Barr Harbor Dr., West Conshohocken, PA 19428
Reprinted from the Annual Book of ASTM Standards. Copyright ASTM

Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens[1]

This standard is issued under the fixed designation D 3967; 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 testing apparatus, specimen preparation, and testing procedures for determining the splitting tensile strength of rock by diametral line compression of a disk.

NOTE 1—The tensile strength of rock determined by tests other than the straight pull test is designated as the "indirect" tensile strength and, specifically, the value obtained in Section 8 of this test is termed the "splitting" tensile strength.

1.2 The values stated in SI 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:*

E 4 Practices for Load Verification of Testing Machines[2]

E 691–92 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

3. Significance and Use

3.1 By definition the tensile strength is obtained by the direct uniaxial tensile test. But the tensile test is difficult and expensive for routine application. The splitting tensile test appears to offer a desirable alternative, because it is much simpler and inexpensive. Furthermore, engineers involved in rock mechanics design usually deal with complicated stress fields, including various combinations of compressive and tensile stress fields. Under such conditions, the tensile strength should be obtained with the presence of compressive stresses to be representative of the field conditions. The splitting tensile strength test is one of the simplest tests in which such stress fields occur. Since it is widely used in practice, a uniform test method is needed for data to be comparable. A uniform test is also needed to insure positively that the disk specimens break diametrally due to tensile pulling along the loading diameter.

4. Apparatus

4.1 *Loading Device*, to apply and measure axial load on the specimen, of sufficient capacity to apply the load at a rate conforming to the requirements in 7.3. It shall be verified at suitable time intervals in accordance with Practices E 4 and shall comply with the requirements prescribed therein.

4.2 *Bearing Surfaces*—The testing machine shall be equipped with two steel bearing blocks having a Rockwell hardness of not less than 58 HRC (see Note 2).

NOTE 2—False platens, with bearing faces conforming to the requirements of this standard, may be used. These shall be oil hardened to more than 58 HRC, and surface ground. With abrasive rocks these platens tend to roughen after a number of specimens have been tested, and hence need to be surfaced from time to time.

4.2.1 *Flat Bearing Blocks*—During testing the specimen can be placed in direct contact with the machine bearing plates (or false platens, if used) (see Fig. 1). 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 bearing block diameter shall be at least as great as the specimen thickness.

4.2.2 *Curved Bearing Blocks*, may be used to reduce the contact stresses. The radius of curvature of the supplementary bearing plates shall be so designed that their arc of contact with the specimen will in no case exceed 15° or that the width of contact is less than $D/6$, where D is the diameter of the specimen.

NOTE 3—Since the equation used in 8.1 for splitting tensile strength is derived based on a line load, the applied load shall be confined to a very narrow strip if the splitting tensile strength test is to be valid. But a line load creates extremely high contact stresses which cause premature cracking. A wider contact strip can reduce the problems significantly. Investigations show that an arc of contact smaller than 15° causes no more than 2 % of error in principal tensile stress while reducing the incidence of premature cracking greatly.

4.2.3 *Spherical Seating*—One of the bearing surfaces should be spherically seated and the other a plain rigid block. 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 side of the specimen. The spherical seat shall be lubricated to assure free movement. The movable portion of the platen shall be held

[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 Dec. 10, 1995. Published April 1996. Originally published as D 3967 – 81. Last previous edition D 3967 – 95.

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

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

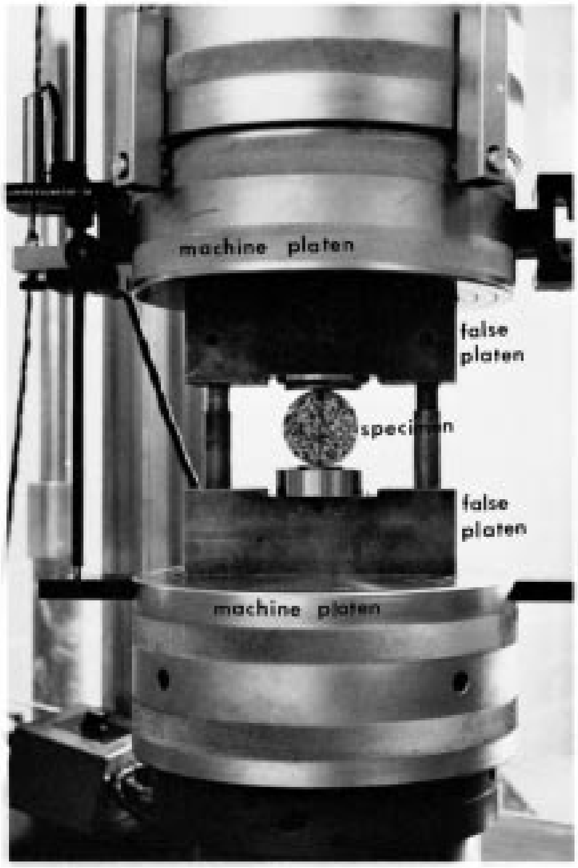

FIG. 1 One of the Proposed Testing Setup for Splitting Tensile Strength

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.

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

4.3 *Bearing Strips* (0.01 *D* thick cardboard cushion, where *D* is the specimen diameter; or up to 0.25 in. thick plywood cushion are recommended to place between the machine bearing surfaces (or supplementary bearing plates; if used) and the specimen to reduce high stress concentration.

NOTE 4—Experiences have indicated that test results using the curved supplementary bearing plates and bearing strips, as specified in 4.2.2 and 4.3, respectively, do not significantly differ from each other, but there may be some consistent difference from the results of tests in which direct contact between the specimen and the machine platen is used.

5. Sampling

5.1 The specimen shall be selected from the core 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 shape, partings, and defects such as pores and fissures.

6. Test Specimens

6.1 *Dimensions*—The test specimen shall be a circular disk with a thickness-to-diameter ratio (t/D) between 0.2 and 0.75. The diameter of the specimen shall be at least 10 times greater than the largest mineral grain constituent. A diameter of 50 mm (1$\frac{15}{16}$ in.) (NX wireline core) will generally satisfy this criterion.

NOTE 5—When cores smaller than the specified minimum must be tested because of the unavailability of material, notation of the fact shall be made in the test report.

NOTE 6—If the specimen shows apparent anisotropic features such as bedding or schistosity, care shall be exercised in preparing the specimen so that the orientation of the loading diameter relative to anisotropic features can be determined precisely.

6.2 *Number of specimens*—At least ten specimens shall be tested to obtain a meaningful average value. If the reproducibility of the test results is good (coefficient of variation less than 5 %), a smaller number of specimens is acceptable.

6.3 The circumferential surface of the specimen shall be smooth and straight to 0.50 mm (0.020 in.).

6.4 Cut the ends of the specimen parallel to each other and at right angles to the longitudinal axis. The ends of the specimen shall not deviate from perpendicular to the core axis by more than 0.5°. This requirement can be generally met by cutting the specimen with a precision diamond saw.

6.5 Determine the diameter of the specimen to the nearest 0.25 mm (0.01 in.) by taking the average of at least three measurements, one of which shall be along the loading diameter.

6.6 Determine the thickness of the specimen to the nearest 0.25 mm (0.01 in.) by taking the average of at least three measurements, one of which shall be at the center of the disk.

6.7 The moisture conditions of the specimen at the time of test can have a significant effect upon the indicated strength of the rock. The field moisture condition for the specimen shall be preserved until the time of test. On the other hand, there may be reasons for testing specimens at other moisture contents, including zero, and preconditioning of specimen when moisture control is needed. In any case, tailor the moisture content of the test specimen to the problem at hand and report it in accordance with 9.1.6.

7. Procedure

7.1 *Marking*—The desired vertical orientation of the specimen shall be indicated by marking a diametral line on each end of the specimen. These lines shall be used in centering the specimen in the testing machine to ensure proper orientation, and they are also used as the reference lines for thickness and diameter measurements.

NOTE 7—If the specimen is anisotropic, take care to ensure that the marked lines in each specimen refer to the same orientation.

7.2 *Positioning*—Position the test specimen to ensure that the diametral plane of the two lines marked on the ends of the specimen lines up with the center of thrust of the spherically seated bearing surface to within 1.25 mm (0.05 in.).

NOTE 8—A good line loading can often be attained by rotating the specimen about its axis until there is no light visible between the specimen and the loading platens. Back lighting helps in making this observation.

7.3 *Loading*—Apply a continuously increasing compressive load to produce an approximately constant rate of loading or deformation such that failure will occur within 1 to 10 min of loading, which should fall between 0.05 and 0.35 MPa/s (500 and 3000 psi/min) of loading rate, depending on the rock type.

NOTE 9—Results of tests by several investigators indicate that rates of loading at this range are reasonably free from rapid loading effects.

8. Calculation

8.1 The splitting tensile strength of the specimen shall be calculated as follows:

$$\sigma_t = 2P/\pi LD \tag{1}$$

and the result shall be expressed to the appropriate number of significant figures (usually 3),

where:
σ_t = splitting tensile strength, MPa (psi),
P = maximum applied load indicated by the testing machine, N (or lbf),
L = thickness of the specimen, mm (or in.), and
D = diameter of the specimen, mm (or in.).

9. Report

9.1 The report shall include as much of the following as possible:

9.1.1 Sources of the specimen including project name and location, and if known, storage environment. The location is frequently specified in terms of the borehole number and depth of specimen from collar of hole.

9.1.2 Physical description of the specimen including rock type; location and orientation of apparent weakness planes, bedding planes, and schistosity; large inclusions or inhomogeneities, if any.

9.1.3 Dates of sampling and testing.

9.1.4 Specimen diameter and length, conformance with dimensional requirements, direction of loading if anisotropy exists. Type of contact between the specimen and the loading platens.

9.1.5 Rate of loading or deformation rate.

9.1.6 General indication of moisture condition of the specimen at time of test such as as-received, saturated, laboratory air dry, or oven dry. It is recommended that the moisture condition be more precisely determined when possible and reported as either water content or degree of saturation.

9.1.7 Splitting tensile strength of each specimen as calculated, average splitting tensile strength of all specimens, standard deviation or coefficient of variation.

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

10. Precision and Bias

10.1 An interlaboratory study was conducted in which seven laboratories each tested five specimens of four different rocks. The specimens were cored by a single laboratory from a common set of samples and randomly distributed to the testing laboratories for testing. The study was carried out in accordance with Practice E 691. Details of the study are given in ISR Research Report No. PS #D18.12-R01, 1992, and its Addendum, 1994. The table below gives the repeatability limit (within a laboratory) and reproducibility limit (between laboratories) for the method.

10.1.1 The probability is approximately 95 % that two test results obtained in the same laboratory on the same material will not differ by more than the repeatability limit. Likewise, the probability is approximately 95 % that two test results obtained in different laboratories on the same material will not differ by more than reproducibility limit.

TABLE Splitting Tensile Strength (MPa)

	Berea Sandstone	Salem Limestone	Tennessee Marble	Barre Granite
Average Value	3.85	4.92	9.39	13.66
Repeatability Limit	1.24	1.56	3.63	4.31
Reproducibility Limit	1.37	1.74	5.38	4.98

10.2 The variability of rock and resultant inability to determine a true reference value prevent development of a meaningful statement of bias.

11. Keywords

11.1 compression testing; indirect tensile strength; loading tests; rock; splitting tensile strength; tension (tensile) properties/tests