Designation: D3967 – 23

Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens with Flat Loading Platens[1]

This standard is issued under the fixed designation D3967; 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 disk shaped specimens.

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 9 of this test is termed the "splitting" tensile strength. This test method is also sometimes referred to as the Brazilian test method.

1.2 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units, which are provided for information only and are not considered standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this test method.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.3.1 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, the 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 analysis methods for engineering design.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

E4 Practices for Force Calibration and Verification of Testing Machines

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E2586 Practice for Calculating and Using Basic Statistics

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

4. Summary of Test Method

4.1 Samples are selected from rock cores or cored from platen samples for testing as described. A section of rock core sample is cut perpendicular to the core axis to produce disk shape specimens until the required number of specimens are obtained. Each specimen is then marked to indicate the desired orientation of the applied loading on the specimen by drawing a diametral line on each end surface of the specimen. Each specimen is positioned inside the testing machine in such a way that the diametral line is coincidental with the loading axis of the testing machine fitted with flat loading platens. Each

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

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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 specimen is then tested by applying a continuously increasing compressive load until it fails within 1 to 10 minutes of the start of loading.

5. Significance and Use

5.1 By definition, the tensile strength is obtained by the direct tensile test. However, the direct 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 complex 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.

5.2 The splitting tensile strength test is one of the simplest tests in which such stress fields occur. Also, by testing across different diametral directions, any variations in tensile strength for anisotropic rocks can be determined. 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 make sure that the disk specimens break diametrically due to tensile stresses perpendicular to the loading axis.

NOTE 2—The quality of the results produced by this standard is dependent on the competence of the 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 *Loading Device*—A device of sufficient capacity to apply and measure the load at a rate conforming to the requirements in 8.5. It shall be verified at suitable time intervals in accordance with Practices E4 and shall comply with the requirements prescribed therein.

6.1.1 *Bearing Platens*—The loading device shall be equipped with two opposing steel bearing platens having a Rockwell hardness of not less than 58 HRC through which loading is transmitted. The bearing faces shall not depart from a plane by more than 0.0125 mm (0.0005 in.) when the platens are new and shall be maintained within a permissible variation of 0.025 mm. The bearing platens' diameter shall be at least as great as the specimen's thickness (see Note 3).

6.1.2 *Spherical Seating*—One of the bearing surfaces on the loading device should be spherically seated, and the other one a plain rigid platen. The diameter of the spherical seat shall be at least as large as the test specimen, but the diameter of the spherical seat shall not exceed twice the diameter of the specimen. Center of the sphere in the spherical seat coincides with the center of the loaded side of the specimen. The spherical seat shall be lubricated to ensure its free movement. The movable part 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. If the spherical seat's diameter exceeds twice the diameter of the test specimen, then the spherical seat shall be placed in the locked position with the faces of the bearing platens meeting the requirements of 6.1.1.

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

6.2 *False, Flat Bearing Platens*—During testing, the specimen can be placed in direct contact with the loading device bearing platens or false platens with bearing faces conforming to the requirements of this standard, may be used (see Fig. 1 for false flat platens). These shall be oil hardened to more than 58 HRC, and surface ground.

6.2.1 *False Flat Bearing Platens*—The bearing faces of false flat bearing platens shall not depart from a plane by more than 0.0125 mm (0.0005 in.) when the platens are new and shall be maintained within a permissible variation of 0.025 mm. The bearing platen's diameter shall be at least as great as the specimen thickness.

NOTE 3—The apparatus bearing or false platens, due to the contact 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. Bearing platens can be round or rectangular.

6.3 *Bearing Strips (optional)*—The load bearing strips shall be made of plywood, free of imperfections, 3 mm thick, width less than 8 % of the specimen diameter and equal in length to the specimen thickness or slightly longer (Fig. 2). The use of

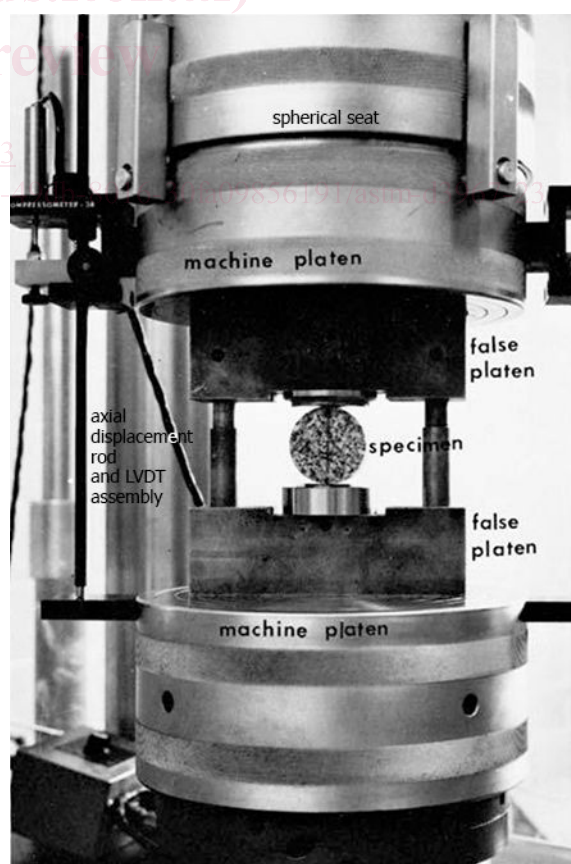

FIG. 1 One Proposed Testing Setup for Splitting Tensile Strength

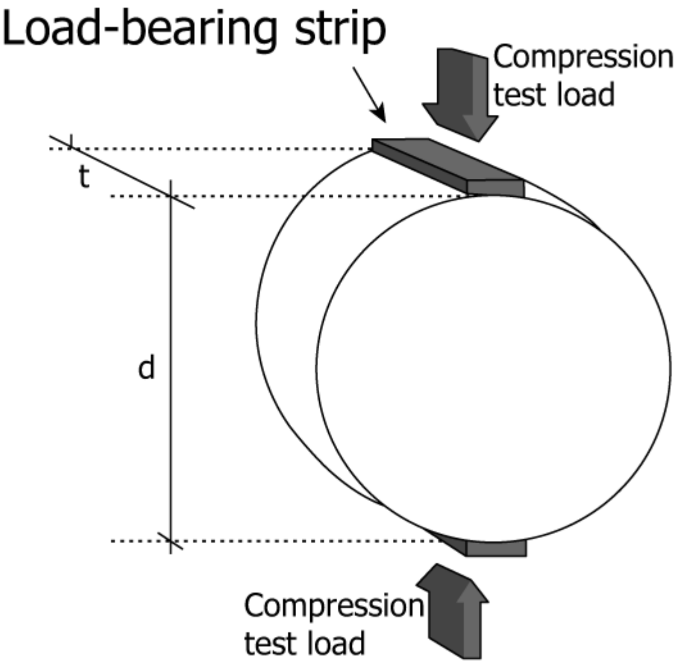

FIG. 2 Optional Load-bearing Strips for Cylindrical Specimens for the Splitting Tensile Strength Test

other sheet wood material, like OSB, MDF, or Hardboard shall not be regarded as non-conformance with this test method, so long as the material is shown to be of the correct hardness for the test specimens and is free of defects and does not significantly affect the test. The bearing strips shall not be reused and can be adhered to the specimen in the correct position as long as the adherent does not significantly affect the test. Load bearing strips are to be placed between the machine bearing surfaces and the specimen to reduce high stress concentration.[3]

NOTE 4—Since the equation used in 9.1 for splitting tensile strength is derived based on a line load, the applied load should be confined to a very narrow strip if the splitting tensile strength test is valid. But a line load creates extremely high contact stresses, which cause premature cracking. A wider contact strip can reduce the problems significantly. Studies show that an arc of contact smaller than 15° causes no more than a 2 % of error in principal tensile stress while reducing the incidence of premature cracking greatly.[3].

NOTE 5—Experience has indicated that in the range of specimen sizes typical in laboratory testing, an approximately constant value of the splitting tensile strength can be obtained when the relative width of the bearing strip is less than 8 % of the specimen diameter.

6.4 *Miscellaneous*—Camera.

7. Sampling, Test Specimens, and Test Units

7.1 The samples shall be selected by visual observation to include a range of specimens or grouped together based on rock type, mineral constituents, grain sizes and shape, partings, and defects such as pores, discontinuities, and fissures.

7.2 *Test Specimens:*

7.2.1 *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 54 mm (NX core) will generally satisfy this criterion.

NOTE 6—When cores smaller than the specified minimum must be tested because of the unavailability of material, make notation of the fact in the test report.

NOTE 7—If the specimen shows apparent anisotropic features such as bedding or schistosity, the user of this standard may be required to exercise care in preparing the specimen so that the test orientation of the cross sectional area subject to the load relative to anisotropic features can be determined separately.

7.2.2 *Number of Specimens*—It is suggested that at least ten tests be performed on the same stratigraphy and isotropic. If the reproducibility of the test results is good (coefficient of variation less than 5 %), a smaller number of specimens is acceptable. More than ten specimens may be required for more complex rock specimens where anisotropy may affect the results and such data is essential to the user. Unless specified by the client, professional judgment shall be exercised to determine the number of specimens necessary to estimate the tensile strength adequately for the intended use of the data.

7.2.3 The circumferential surface of the specimen shall be smooth and straight to 0.50 mm (0.02 in.).

7.2.4 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.

7.2.5 Determine the diameter of the specimen to the nearest 0.25 mm (0.01 in.) by recording at least three measurements, one of which shall be along the cross sectional area of loading and calculating the average.

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

7.2.7 The moisture conditions of the specimen at the time of the 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 testing. On the other hand, there may be reasons for testing specimens at other moisture contents and preconditioning of specimen when a specific moisture content is needed. In any case, tailor the moisture content of the test specimen to the problem at hand and record it in accordance with 10.4.2.

NOTE 8—It is recommended that the moisture condition be more precisely determined when possible and reported as water content by Test Methods D2216 or degree of saturation.

8. Procedure

8.1 *Test Orientation*—The desired test 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 make sure proper orientation, and they are also used as the reference lines for thickness and diameter measurements.

[3] Size effect and boundary conditions in the Brazilian test Experimental verification, C. Rocco 1, G. V. Guinea2,j. Planas 2 and M. Elices *Materials and Structures/Matriaux et Constructions*, Vol. 32, April 1999, pp 210-217

8.2 *Optional Bearing Strips*—Add bearing strips on each side of the disc where indicated by the reference line, in accordance with 6.3, when the test specimen surface may not provide a perfect line load. Bearing strips maybe attached with a small amount of adhesive or double stick tape to hold in place.

8.3 Take photographs of each test specimen prior to testing.

NOTE 9—If the specimen is anisotropic, take care to make sure that the marked lines in each specimen refer to the same orientation.

8.4 Set up specimen in the testing machine.

8.4.1 *Clean*—Ensure contact surfaces of loading platens are free of any debris from previous tests.

8.4.2 *Positioning*—Position the test specimen between the top and bottom loading platens so 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.). Each specimen is positioned inside the testing machine in such way that the marked diametral line is coincidental with the loading axis of the testing machine with the false flat platens.

8.4.3 *Preloading*— To achieve it, slowly bring the loading platens together until the top platen barely and gently contacts the specimen, with little or no load on it. Assure the positioning criterion noted in 8.4.1 is still met.

NOTE 10—Application of bearing strips, as it is noted in 6.3, or putting masking tape around specimen's circumference will help to better positioning of the specimen and provide a good line loading.

8.5 *Loading*—After preloading, apply a continuously increasing compressive load to produce an approximately constant rate of loading such that failure will occur within 1 to 10 min of loading, which should fall between 3.40 and 20.70 MPa/min (500 and 3,000 psi/min) of loading rate, depending on the rock type. The maximum load sustained by the specimen shall be recorded. Load readings shall be recorded to the appropriate number of significant figures (usually 3).

NOTE 11—Results of tests by several investigators indicate that rates of loading at this range are reasonably free from rapid loading effects.

8.6 Take post testing photographs of each specimen.

8.7 Determine what type of tensile break and if a valid break. See Fig. 3 and note this does not include any discontinuity angles measured normal to the loading plane as shown in Fig. 4 or any combination of both.[4] Professional judgment will be required to determine if a break is valid or not, where the true indirect tension failure occurred on the stress-displacement plot and which test values should be grouped together.

9. Calculation

9.1 The splitting tensile strength of the specimen with the flat platens with valid breaks shall be calculated accordingly as follows:

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

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),
t = thickness of the specimen, mm (or in.), and
D = diameter of the specimen, mm (or in.).

9.2 Calculations for test specimens with questionable or invalid breaks shall be handled separately. Professional judgment will be required.

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

10.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.3 and in Practice D6026.

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

10.2.1 Sample/specimen identifying information, such as Project No., Boring No., Sample No., Depth (units). When possible, also record sources of the specimen including project name and location, dates of sampling, and if known, curatorial history from the date the samples were collected to when the specimens are tested.

10.2.2 Physical description of the specimen including rock type; location and orientation of apparent weakness planes,

[4] Pure tensile failure across the rock matrix.Brazilian Tensile Strength of Anisotropic Rocks: Review and New Insights, Tianshou Ma, Nian Peng, Zhu Zhu, Qianbing Zhang , Chunhe Yang and Jian Zhao Energies 2018 issue 11 p.304. http://www.mdpi.com/journal/energies.

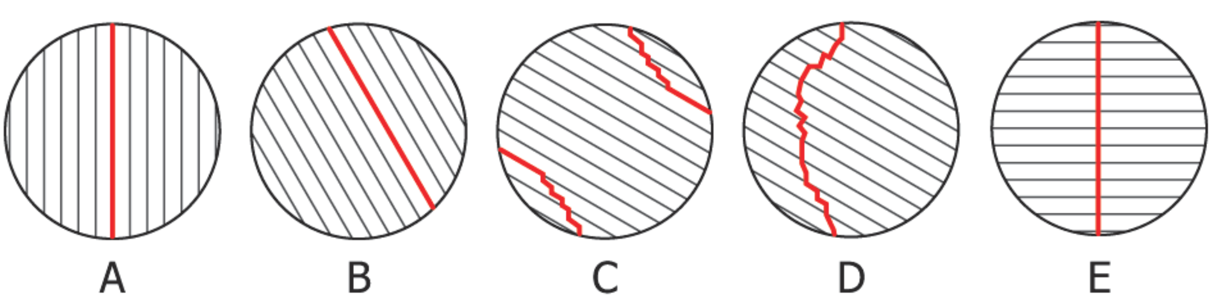

FIG. 3 Schematic of Five Kinds of Typical Failure Modes in Specimens That Are Not Homogeneous, Isotropic (where the capital letter relates to (A) Pure tensile failure along the bedding; (B) Pure shear failure along the bedding; (C) Mixed-mode bedding and rock matrix (primarily caused by shear failure); (D) Mixed-mode failure bedding and rock matrix (primarily caused by tensile failure); and (E) pure tension across the bedding.)