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Designation: ~~D5607 – 08~~ D5607 – 16

Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force[1]

This standard is issued under the fixed designation D5607; 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 establishes requirements and laboratory procedures for performing direct shear strength tests on rock ~~specimens.~~ specimens under a constant normal load. It includes procedures for both intact rock strength and sliding friction tests, which can be performed on specimens that are homogeneous, or have planes of weakness, including natural or artificial discontinuities. Examples of an artificial discontinuity include a rock-concrete interface or a lift line from a concrete pour. Discontinuities may be open, partially or completely healed or filled (that is, clay fillings and gouge). Only one discontinuity per specimen can be tested. The test is usually conducted in the undrained state with an applied constant normal load. However, a clean, open discontinuity may be free draining, and, therefore, a test on a clean, open discontinuity could be considered a drained test. During the test, shear strength is determined at various applied stresses normal to the sheared plane and at various shear displacements. Relationships derived from the test data include shear strength versus normal stress and shear stress versus shear displacement (shear stiffness).

NOTE 1—The term "normal force" is used in the title instead of normal stress because of the indefinable area of contact and the minimal relative displacement between upper and lower halves of the specimen during testing. The actual contact areas during testing change, but the actual total contact surface is unmeasurable. Therefore nominal area is used for loading purposes and calculations.

NOTE 2—Since this test method makes no provision for the measurement of pore pressures, the strength values determined are expressed in terms of total stress, uncorrected for pore pressure.

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1.2 This standard applies to hard rock, medium rock, soft rock, and concrete.

1.3 This test method is only applicable to quasi-static testing of rock or concrete specimens under monotonic shearing with a constant normal load boundary condition. The constant normal load boundary condition is appropriate for problems where the normal stress is constant along the discontinuity. The constant normal load boundary condition may not be appropriate for problems where shearing is dilatancy controlled and the normal stress is not constant along the discontinuity.

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

1.4.1 The procedures used to specify how data are collected/recorded and 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, purpose for obtaining 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 commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering design

1.5 *Units*—The values stated in SI units are to be regarded as ~~the~~ standard. The values given in parentheses are mathematical conversions to inch-pound ~~units that~~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.

1.6 *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.*

[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.

Current edition approved ~~July 1, 2008~~Dec. 1, 2016. Published ~~July 2008~~January 2017. Originally approved in 1994. Last previous edition approved in ~~2006~~2008 as ~~D5607 – 02 (2006).~~D5607 – 08. DOI: ~~10.1520/D5607-08.~~10.1520/D5607-16.

***A Summary of Changes section appears at the end of this standard**

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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

D5079 Practices for Preserving and Transporting Rock Core Samples (Withdrawn 2017)[3]

D6026 Practice for Using Significant Digits in Geotechnical Data

E4 Practices for Force Verification of Testing Machines

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

2.2 *ISRM Standard:*[4]

Suggested Methods for Laboratory Determination of the Shear Strength of Rock Joints: Revised Version

3. Terminology

3.1 *Definitions*—For ~~common~~ definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *apparent ~~stress—~~stress, n—*nominal stress, that is, external load per unit ~~area. It is~~ area; calculated by dividing the externally applied load by the nominal area.

~~3.2.2 *Asperity:*~~

~~3.2.2.1 *quality*—the roughness of a surface.~~

~~3.2.2.2 *feature*—a surface irregularity ranging from sharp or angular to rounded or wavy.~~

~~3.2.2.3 *asperities*—the collection of a surface's irregularities that account for the surface's roughness.~~

3.2.2 *asperity:*

3.2.2.1 *quality, n*—the roughness of a surface.

3.2.2.2 *asperity feature, n*—a surface irregularity ranging from sharp or angular to rounded or wavy.

3.2.2.3 *asperities, n*—the collection of a surface's irregularities that account for the surface's roughness.

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~~3.2.3 *Discontinuity :*~~

~~3.2.3.1 An abrupt change, interruption, or break in the integrity or physical properties of rock, such as a bedding plane, fracture, cleavage, crack, joint, or fault.~~

~~3.2.3.2 A *gapped discontinuity* consists of opposing rock surfaces separated by an open or filled space. A *tight discontinuity* consists of opposing rock surfaces in intimate and generally continuous contact; it may be valid to treat such a discontinuity as a single surface.~~

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~~3.2.3.3 A discontinuity's opposing rock surfaces may be *planar* to *nonplanar* and *matching* to *misfit*.~~

3.2.3 *discontinuity, n*—an abrupt change, interruption, or break in the integrity or physical properties of rock, such as a bedding plane, fracture, cleavage, crack, joint, or fault where the opposing rock surfaces may be *planar* to *nonplanar* and *matching* to *misfit*.

3.2.4 *gapped discontinuity, n*—consists of opposing rock surfaces separated by an open or filled space.

3.2.5 *tight discontinuity, n*—consists of opposing rock surfaces in intimate and generally continuous contact; it may be valid to treat such a discontinuity as a single surface.

3.2.6 *intact shear ~~strength—~~strength, n—*the peak shear resistance (in units of stress) of an intact rock specimen or of a specimen containing a completely healed discontinuity.

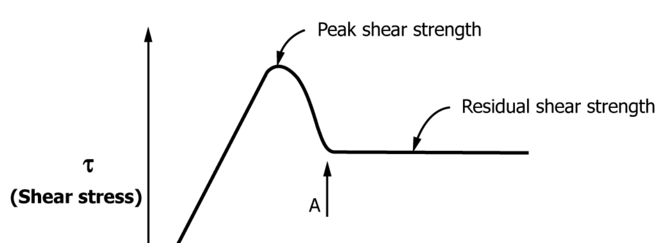
3.2.7 *nominal ~~area—~~area, n—*area obtained by measuring or calculating the cross-sectional area of the shear ~~plane. It is~~ plane and calculated after its relevant cross-sectional dimensions are determined.

3.2.8 *residual shear ~~strength—~~strength, n—*the shear stress, (see Fig. 1), corresponding to a specific normal stress, for which the shear stress remains essentially constant with increasing shear displacement. ~~In most cases, the shear stress after reaching Point A is the residual shear strength.~~

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] "ISRM Suggested Methods for Laboratory Determination of the Shear Strength of Rock Joints: Revised Version", R. Ulusay (ed.), The ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 2007-2014, DOI: 10.1007/978-3-319-07713-0, Springer-Verlag Wien 2013.



3.2.8.1 *Discussion—*

FIG. 1 Generalized Shear Stress and Shear Displacement Curve

In most cases, the shear stress after reaching Point A is the residual shear strength.

3.2.9 *shear ~~stiffness—~~stiffness, n—*represents the resistance of the specimen to shear displacements under an applied shear force prior to reaching the peak shear ~~strength. It~~strength, which is calculated by dividing the applied apparent shear stress by the resulting shear displacement (slope of the curve prior to peak shear strength, Fig. 1).

3.2.10 *sliding friction shear ~~strength—~~strength, n—*the peak shear resistance (in units of stress) of a rock specimen ~~containing~~along an open discontinuity.

4. Summary of Test Method

4.1 While maintaining a constant force normal to the nominal shear plane of the specimen, an increasing external shear force is applied along the designated shear plane to cause shear displacement. The applied normal and shear forces and the corresponding normal and shear displacements are measured and recorded. These data are the basis for calculating the required parameters.

5. Significance and Use

5.1 Determination of shear strength of a rock specimen is an important aspect in the design of structures such as rock slopes, dam foundations, tunnels, shafts, waste repositories, caverns for storage, and other purposes. Pervasive discontinuities (joints, bedding planes, shear zones, fault zones, schistosity) in a rock mass, and genesis, crystallography, texture, fabric, and other factors can cause the rock mass to behave as an anisotropic and heterogeneous discontinuum. Therefore, the precise prediction of rock mass behavior is difficult.

5.2 For nonplanar joints or discontinuities, shear strength is derived from a combination base material friction and overriding of asperities (dilatancy), shearing or breaking of the asperities, and rotations at or wedging of the asperities. Sliding on and shearing of the asperities can occur simultaneously. When the normal force is not sufficient to restrain dilation, the shear mechanism consists of the overriding of the asperities. When the normal load is large enough to completely restrain dilation, the shear mechanism consists of the shearing off of the asperities.

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5.3 Using this test method to determine the shear strength of an intact specimen may generate overturning moments which could result in an inclined shear break.

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5.4 Shear strength is influenced by the overburden or normal pressure; therefore, the larger the overburden pressure, the larger the shear strength.

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5.5 In some cases, it may be desirable to conduct tests in situ rather than in the laboratory to determine the representative shear strength of the rock mass, particularly when design is controlled by discontinuities filled with very weak material. In situ direct shear testing limits the inherent scale effects found in rock mechanics problems where the laboratory scale may not be representative of the field scale.

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5.6 ~~In some cases, it may be desirable to conduct tests in situ rather than in~~The results can be highly influenced by how the specimen is treated from the time it is obtained until the time it is tested. Therefore, it may be necessary to handle specimens in accordance with Practice D5079 ~~the laboratory to determine the representative shear strength of the rock mass, particularly when design is controlled by discontinuities filled with very weak material.~~and to document moisture conditions in some manner in the data collection.

NOTE 3—The quality of the result 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 and the like. 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~~provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Testing Machine*—Loading device, to apply and register normal and shear forces on the specimens. It must have adequate capability to apply the shear force at a rate conforming to the specified ~~requirements.~~ requirements in 6.2-6.9. It shall be verified at suitable time intervals in accordance with the procedures given in Practices E4, and comply with the requirements prescribed therein. The resultant of the shear force passes through the center of the intended shear zone or the centroid of the shear plane surface area to ~~minimize adverse moments.~~reduce the potential for adverse moments. If possible, the testing machine should include both a stiff frame and a stiff specimen holder sufficiently rigid to inhibit distortions during testing for accurate determination of residual behavior.

NOTE 4—There are many different direct shear device designs. Although details may vary concerning how to encapsulate specimens into shear boxes as well as details for assembling the machine, the determinations are usually similar.

6.2 Fig. 2 is a schematic of an example shear box, an integral part of the machine.

6.3 *Load Monitoring Devices*—The load monitoring devices (such as load cells, proving rings, hydraulic gauges) should be accurate to within 1 % of the specified load and be calibrated in accordance with Practices E4.

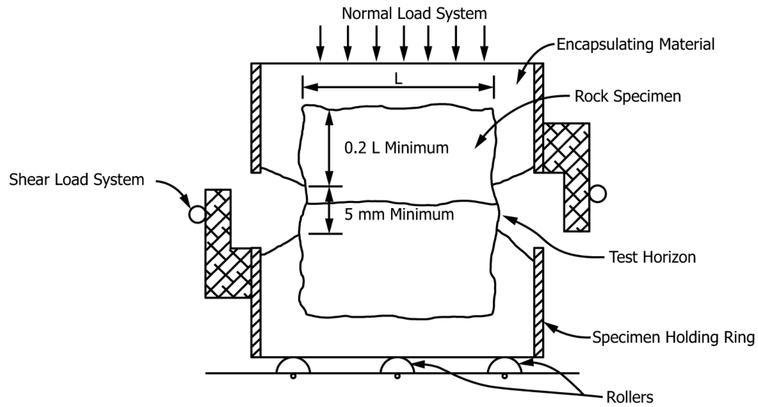

FIG. 2 Schematic Test Setup—Direct Shear Box with Encapsulated Specimen

6.4 *Pressure-Maintaining Device*—A hydraulic component that will hold a pressure, within ~~specified tolerances,~~ 1 % of the target load, within the hydraulic system.

6.5 *Specimen Holding Rings*—Aluminum or steel holding rings (see Fig. 3) with internal dimensions sufficient to accommodate specimens mounted in an encapsulating medium.

6.6 *Spacer Plates:*

6.6.1 *Split Spacer Plates*—Plastic (or other suitable material) plates of varying thicknesses for isolating an intact specimen's shear zone from the encapsulating compound (see Fig. 3).

6.6.2 *Non-split Spacer Plates*—Plastic (or other suitable material) plates of varying thicknesses that have a circular or oval hole in the center and are used for non-intact specimens.

6.7 *Displacement Measuring Device*—Linear variable differential transformers (LVDTs) may be used as normal and shear displacement measuring devices. Other devices such as dial indicators and direct current differential transformers (DCDTs), are satisfactory. Four devices are used to measure the normal displacement and provide a check on specimen rotation about an axis parallel to the shear zone and perpendicular to the shearing direction. Another device measures the shear displacement. These displacement devices should have adequate ranges of travel to accommodate the displacements, ±13 mm (±0.5 in.). Sensitivities of these devices should be 0.025 mm (0.001 in.) for shear displacement and 0.0025 mm (0.0001 in.) for normal displacement. ~~Ensure~~ Make sure that the devices are located away from the loading direction so as not to be damaged in sudden failures. Measuring devices are to be calibrated/verified at least once a year.

6.8 *Data Acquisition Equipment*—A computer may be used to control the test, collect data, and plot results. Typical data acquisition rates are near continuous (greater than 1 Hz sampling rate) with computer based systems.

6.9 *Computer System (Optional)*—Capable of 3D contact measurements using CAD software.

6.10 *3D Noncontact Measuring Device (Optional)*—Laser scanner, photogrammetry, slit scanner or stereo-topometric camera.

NOTE 1—Note the split plastic plates for isolating the shear zone.

FIG. 3 View Showing Pouring Encapsulating Material Around Upper Half of Specimen

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6.11 *Miscellaneous Items*—Carpenter's contour gauge for measuring joint surface roughness, roughness chart (see Fig. 4[5]), filler or modelling clay, calipers or micrometer accurately readable to 0.001 mm, spatula, circular clamps, utility knife, towels, indelible markers, plotting papers, encapsulating compound, and camera.

~~7. Reagents and Materials~~

~~7.1 *Miscellaneous Items*—Carpenter's contour gauge for measuring joint surface roughness, roughness chart (see Fig. 4[3]), filler or modelling clay, calipers, spatula, circular clamps, utility knife, towels, markers, plotting papers, encapsulating compound, and camera.~~

7. Test Specimens

7.1 ~~*Sampling:*~~ *Sampling*—A rock sample is grouped based on rock type, discontinuity orientation, and condition of discontinuities. Each sample is comprised of specimens having similar characteristics. A rock sample is collected and shipped using methods that reduce the potential for disturbance of test specimens (Practice D5079).

7.1.1 *Intact Specimen*—Care should be exercised in core drilling, handling, and sawing the ~~samples to minimize~~ sample to reduce the potential for mechanical damage to test specimens. No liquids other than water should be in contact with a test specimen.

NOTE 5—To obtain relevant parameters for the design, construction, or maintenance of major engineering structures, test specimens should be representative of the host properties as nearly as practicable.

[5] Barton, N., and Choubey, V., *The Shear Strength of Rock Joints in Theory and Practice*,*Rock Mechanics*, 10, 1977.

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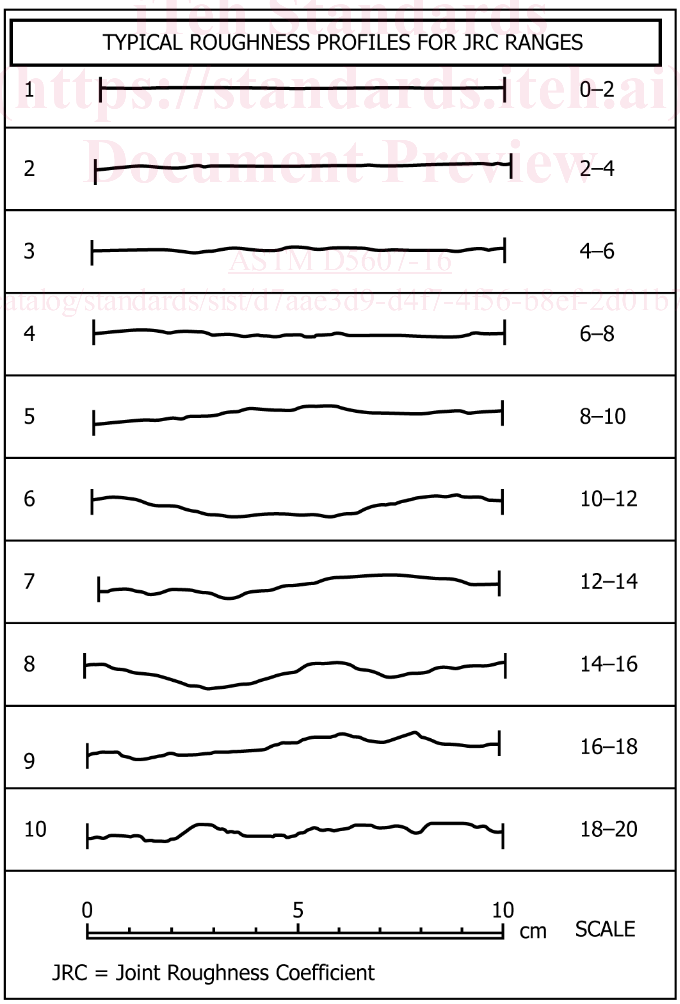

FIG. 4 Roughness Profiles and Corresponding JRC Values Associated With Each One[5]

7.1.2 *Specimen with a Single Discontinuity*—~~Rock samples are collected and shipped using methods that minimize disturbance of test zones.~~ A specimen's dimensions and the location of a discontinuity to be tested should allow sufficient clearance for adequate encapsulation. The in situ integrity of discontinuities in a sample is to be maintained from the time of sampling until the discontinuity is tested. Tape, plastic wrap, or other means may be utilized to preserve the in situ moisture content along the test zone. Plastic half rounds, core boxes, freezing, or other methods may be utilized to bridge the discontinuities and prevent differential movement from occurring along the discontinuity. This is especially important for discontinuities containing any soft, or weak material.

7.2 *Size and ~~Shape—~~Shape:* ~~The height of specimen shall be greater than the thickness of the shear (test) zone and sufficient to embed the specimen in the holding rings. Specimens may have any shape such that the cross-sectional areas can be readily determined. In most cases the least cross-sectional dimension of the specimen should be at least 10 times the largest grain size in the specimen. The test plane should have a minimum area of 1900 mm^2 (3 in.^{2}).~~

7.2.1 *Height*—The height of each specimen shall be greater than the thickness of the shear (test) zone and sufficient to embed the specimen in the holding rings.

7.2.2 *Shape*—Specimens may have any shape such that the cross-sectional areas can be determined. In most cases the least cross-sectional dimension of the specimen should be at least 10 times the largest grain size in the specimen or maximum asperity height along the shear surface.

7.2.3 *Area*—The test plane should have a minimum area of 1900 mm^2 (3 in.^{2}). The width should not change significantly during testing. The minimum width should be greater than 75 % of the maximum width.

7.2.4 *Orientation*—The portion of the specimen that remains fixed during testing should be of greater length than the moving half so that the joint is always supported and the nominal contact area remains constant. If this is not feasible, a reduction in the nominal area during shear may be required.

7.3 *Storage*—Samples should be stored out of the weather after they are obtained at the work site (field) in order to preserve their integrity.

7.4 *Moisture Condition*—If specimens are to be tested near the natural moisture condition of the host material, they should be stored and transported in ~~moisture-proof containers, or coated with thin~~accordance with Practice D5079~~sheets of plastic film and wax.~~.

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~~9. Calibration and Standardization~~

~~9.1 *Load Monitoring Devices*—The load monitoring devices (such as load cells, proving rings, hydraulic gauges) should be calibrated according to Practices E4.~~

~~9.2 *Displacement Measuring Devices*— Measuring devices are to be calibrated at least once a year.~~

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8. Procedure

8.1 *Moisture Condition*—If required, the moisture condition of the shear zone ~~are~~is determined and ~~reported according to Test Method~~recorded in accordance with Test Methods D2216.

8.2 *Test Specimen:*

8.2.1 *Measurements:*

8.2.1.1 *Cross-Sectional Area of Regular Geometrical ~~Shapes —~~Shapes*—~~The~~ Measure and record the relevant dimensions of the specimen at the shear zone cross section ~~are measured~~ to the nearest 0.025 mm (0.001 in.) using a caliper or micrometer. ~~Then, the apparent cross-sectional area of the intact specimen is calculated. For inclined core~~For inclined core, the apparent area can be determined by measuring the diameter and angle of ~~tip~~dip θ.

8.2.1.2 *Cross-Sectional Area of Nongeometrical ~~Shapes —~~Shapes*—The outline of the cross-sectional area of the specimen or shear plane is traced on paper and the area is measured with a ~~planimeter.~~planimeter and then recorded to the nearest 0.1 mm. The area can also be measured using a 3D contact measurement device and CAD software and then recorded.

8.2.1.3 *Joint Roughness of a Clean Discontinuity*—~~Before and after testing,~~ Use a carpenter contour gauge ~~is used~~ before and after testing to measure the joint roughness in the direction of anticipated shear displacement. ~~When all the~~ To use the carpenter contour gauge, lower the prongs of the gauge ~~are lowered on a flat and hard surface,~~onto a flat, hard surface until all of the tips of the prongs ~~will fall on~~ form a straight line. Place this straight line pronged gauge onto the shear plane and lower all the prongs to make contact with the shear surface. Remove the gauge. The tips of the gauge trace the shear plane surface along the line of shearing. Trace the tips of the prongs onto paper, and compare this tracing to match with one of the lines on Fig. 4; then, select and record the corresponding joint roughness coefficient. Discontinuity roughness can also be digitized using 3D non-contact measurement devices (that is, laser scanner, photogrammetry, slit scanner or stereo-topometric camera).

8.2.1.4 *Joint Roughness for Partially or Fully Healed Discontinuity*—After failure occurs in a shear test, contour gauges and the standard roughness chart are used to determine the joint roughness coefficient. The discontinuity roughness can also be digitized using the 3D non-contact measurement devices detailed in 8.2.1.3.

8.2.1.5 Take before and after test photographs of each specimen.

8.2.2 *Encapsulation:*