~~Designation:D 5607–95~~ Designation: D5607 – 08

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. 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.

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

~~1.3~~

1.3 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 are provided for information only and are not considered standard.

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

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

E4 Practices for ~~Load~~Force Verification of Testing Machines

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

~~D2216Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock~~ 122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

3. Terminology

~~3.1~~

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

3.2 *Definitions of Terms Specific to This Standard:*

[1] This test method is under the jurisdiction of ASTM Committee ~~D-18~~D18 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 5607–94. Last previous edition D 5607–94.~~

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

[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* ~~, Vol 03.01.~~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.**

~~3.1.1~~
3.2.1 *apparent stress*—nominal stress, that is, external load per unit area. It is calculated by dividing the externally applied load by the nominal area.

~~3.1.2~~
3.2.2 *Asperity*:

~~3.1.2.1~~
3.2.2.1 *quality*—the roughness of a surface.

~~3.1.2.2~~
3.2.2.2 *feature*—a surface irregularity ranging from sharp or angular to rounded or wavy.

~~3.1.2.3~~
3.2.2.3 *asperities*—the collection of a surface's irregularities that account for the surface's roughness.

~~3.1.3~~
3.2.3 *Discontinuity*:

3.~~1~~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.

~~3.1.3.2A~~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.

~~3.1.3.3A~~3.2.3.3 A discontinuity's opposing rock surfaces may be *planar* to *nonplanar* and *matching* to *misfit*.

~~3.1.4~~
3.2.4 *intact shear strength*—the peak shear resistance (in units of stress) of an intact rock specimen or of a specimen containing a completely healed discontinuity.

~~3.1.5~~
3.2.5 *nominal area*—area obtained by measuring or calculating the cross-sectional area of the shear plane. It is calculated after its relevant cross-sectional dimensions are determined.

~~3.1.6~~
3.2.6 *residual shear strength*—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.

~~3.1.7~~
3.2.7 *shear stiffness*—represents the resistance of the specimen to shear displacements under an applied shear force prior to reaching the peak shear strength. It 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).

~~3.1.8~~
3.2.8 *sliding friction shear strength*—the peak shear resistance (in units of stress) of a rock specimen containing 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, schistoesity) in a rock mass, and genesis, crystallography, texture, fabric, and other factors

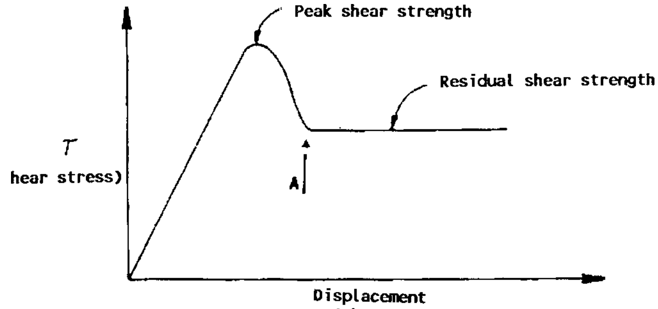

FIG. 1 Generalized Shear Stress and Shear Displacement Curve

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.

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.

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

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.

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 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. It shall be verified at suitable time intervals in accordance with the procedures given in Practices ~~E 4~~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.

NOTE ~~3—There~~ 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 *Pressure-Maintaining Device*—A hydraulic component that will hold a pressure, within specified tolerances, within the hydraulic system.

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

6.5 *Spacer Plates*:

6.5.1 *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).

6.5.2 *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.

6.6 *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 that the devices are located away from the loading direction so as not to be damaged in sudden failures.

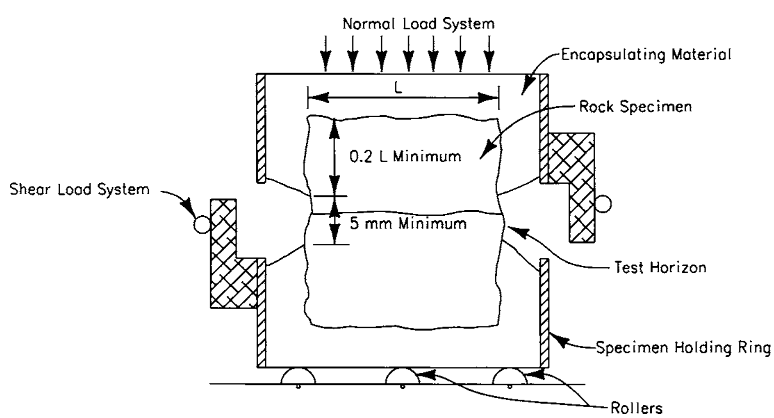

FIG. 2 Schematic Test Setup—Direct Shear Box with Encapsulated Specimen

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

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

6.7 *Data Acquisition Equipment*—A computer may be used to control the test, collect data, and plot results.

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.

8. Test Specimens

8.1 *Sampling*:

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

NOTE ~~4—To~~ 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.

8.1.2 *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.

8.2 *Size and 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 $in.^2$).

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

8.4 *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 sheets of plastic film and wax.

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 ~~E 4~~E4.

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

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

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

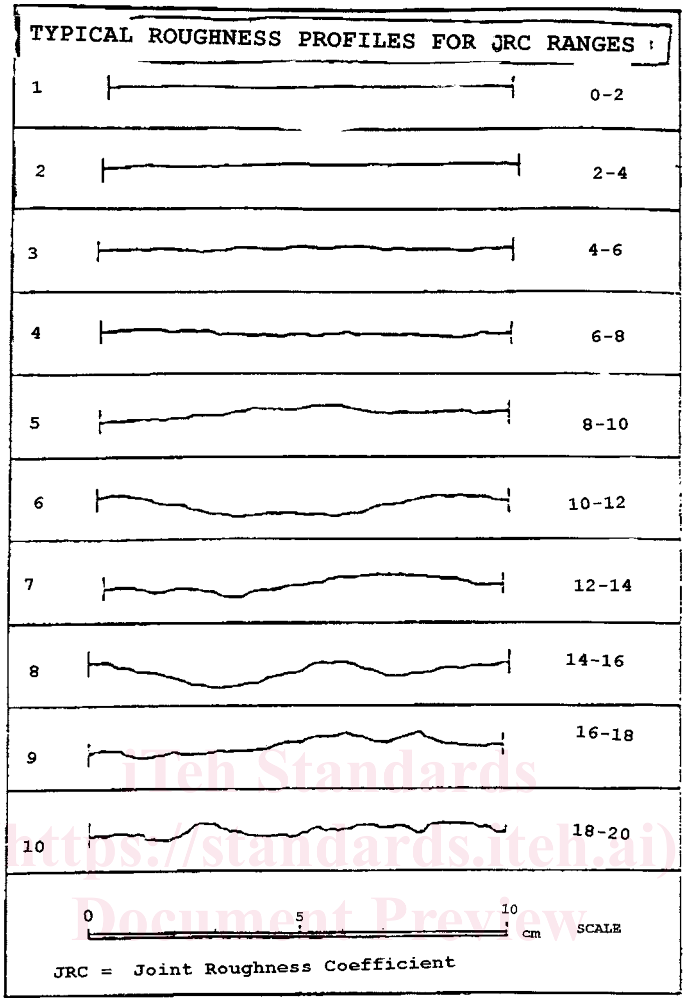

FIG. 4 Roughness Profiles and Corresponding JRC Values Associated With Each One[5]

10. Procedure

10.1 *Moisture Condition*—If required, the moisture condition of the shear zone are determined and reported according to Test Method ~~D 2216~~D2216.

10.2 *Test Specimen*:

10.2.1 *Measurements*:

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

10.2.1.2 *Cross-Sectional Area of Nongeometrical Shapes*—The outline of the cross-sectional area of the specimen or shear plane is traced on paper and the area measured with a planimeter.

10.2.1.3 *Joint Roughness of a Clean Discontinuity*—Before and after testing, a carpenter contour gauge is used to measure joint roughness in the direction of anticipated shear displacement. When all the prongs of the gauge are lowered on a flat and hard surface, the tips of the prongs will fall on 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.

10.2.1.4 *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.

10.2.1.5 Take before and after test photographs of each specimen.

10.2.2 *Encapsulation*:

10.2.2.1 *Specimen Encapsulation*—Place a thick plastic sheet on a suitable level surface. Place the lower half of the specimen holding ring on the plastic sheet.

(a) ~~*(a)*~~ Porous rock that is to be tested at its natural water content should be coated with a nonabsorbing sealer to prevent absorption of water from the encapsulating compound.

~~*(b)*~~ ~~*(b)*~~ *(b) Encapsulating Compound*—Prepare the encapsulating compound in accordance with the directions of the manufacturer. The preparation is necessary to impart required properties of quick setting and adequate strength to the cured encapsulating compound. A super strength gypsum cement is recommended for best results.

~~*(c)*~~ ~~*(c)*~~ *(c) For a Specimen Containing a Discontinuity*—Position the lower half of the specimen (if the discontinuity is gapped, that is, open jointed) centrally in the lower half of the specimen holder. Ensure that the shear horizon to be tested is secured in the correct position and orientation so that the shear force will be in the same plane as the test zone. Ensure that the bottom of the lower half of the specimen is resting on the plastic sheet. Provide adequate support to the specimen so that it is maintained in its position while the encapsulating material cures (see Fig. 5). Pour the encapsulating material carefully into the annular space between the lower half of specimen and the lower half of the specimen holding ring. Stop pouring just below the general plane of the test zone (see Fig. 6). Do not disturb the specimen holding ring assembly after pouring the encapsulating compound. After the bottom encapsulated material has sufficiently cured, place a split spacer plate of specified thickness on the lower ring such that its cutout edge encircles the encapsulated lower half of the specimen and encompasses the test zone thickness. If needed, apply a layer of silicon grease over the surface of the encapsulated material. Place the upper half of the test specimen onto the encapsulated lower half. Fill the annular space between the specimen testing surface and the semicircular or circular edge of the spacer plate with modeling clay. Adjust the position of the upper half of the specimen until the surfaces of the test horizon are correctly mated. Lower the upper half of the specimen holder onto the split spacer plate without disturbing the position of the top half of the specimen. Connect the two halves of the specimen holding ring with bolts. Pour encapsulating compound into the annular space between the top half of the specimen holder and the top half of the specimen. Do not disturb the assembly until the encapsulating compound cures. Remove the spacer plates to expose the test horizon for shear testing (see Fig. 7).

~~*(d)*~~ ~~*(d)*~~ *(d) For a Specimen With A Partially or Fully Tight Discontinuity or an Intact Specimen*—Position the specimen concentrically into the lower half of the holding ring, and pour the prepared encapsulating compound into the annular space between the specimen and the lower half of the specimen holding ring. Allow the compound to cure without disturbing the assembly. Place a split spacer plate of a thickness equal to the height of the shear test zone, and fill the annular space between the circular or semicircular edge of the spacer plate and the specimen with clay. Place the upper half of the specimen holding ring onto the lower half, and connect the two halves of the specimen holding ring with bolts, while not disturbing the encapsulated lower half of the specimen. Pour the encapsulating compound into the annular space between the upper half of the bolted holding ring and the upper half of the specimen (see Fig. 3). Allow the encapsulating compound to cure without disturbance. Remove the spacer plate, and expose the test zone for shear testing.

(e) ~~*(e)*~~ Discard the specimen if the test zone is contaminated with the encapsulating compound.

10.3 *Soaking of Encapsulated Specimen*— If the shear strength of a saturated specimen is desired, allow the encapsulated specimen to soak in water for at least 48 h before testing. The soaking period can be altered. Soaking is not recommended for rocks that may react with water such as evaporites.

10.4 *Mounting into the Shear Box*—Mount and orient the encapsulated specimen with its top and bottom holding rings in the bottom shear box of the testing machine. Lower the top half of the shear box onto the upper half of the specimen. Remove the bolts that connect the upper and lower halves of the specimen holding rings.

10.5 *Mounting of Displacement Devices*— Place four displacement measuring devices on the lower surface of the testing machine, at the four corners of the lower half of the shear box and contacting the upper half of the shear box. These devices are

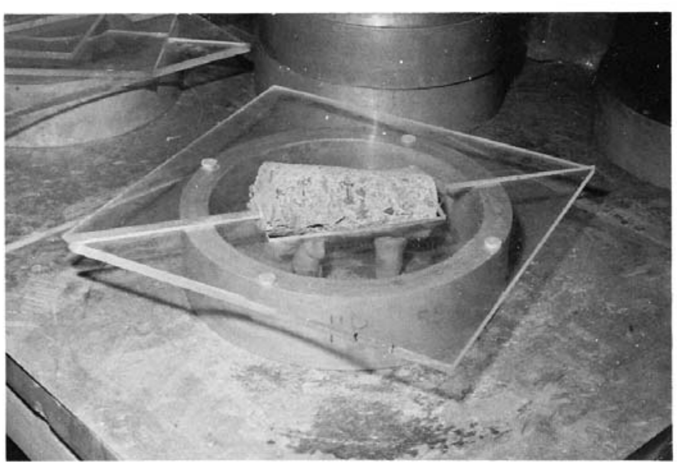

FIG. 5 Specimen Supported in Place By Modeling Clay Pins Which Are Removed After Encapsulating Material Cures and the Resulting Holes Filled With Encapsulating Material