Designation: D 5607 – 02

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 D 5607; 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 *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 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

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

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock Used in Engineering Design and Construction[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. Terminology

3.1 For common definitions of terms used in this standard, refer to Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

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.

3.2.2 *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.

3.2.3 *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.

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

3.2.4 *intact shear strength*—the peak shear resistance (in

[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] *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.

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

units of stress) of an intact rock specimen or of a specimen containing a completely healed discontinuity.

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.

3.2.6 *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.

3.2.7 *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).

3.2.8 *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, schistocity) 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.

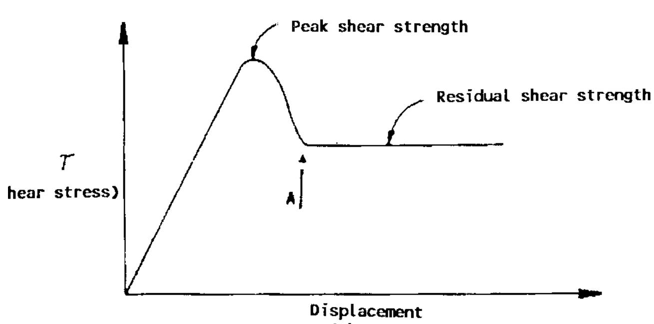

FIG. 1 Generalized Shear Stress and Shear Displacement Curve

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 D 3740 are generally considered capable of competent and objective testing/sampling/inspection and the like. Users of this standard are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors, Practice D 3740provides 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, 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 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 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

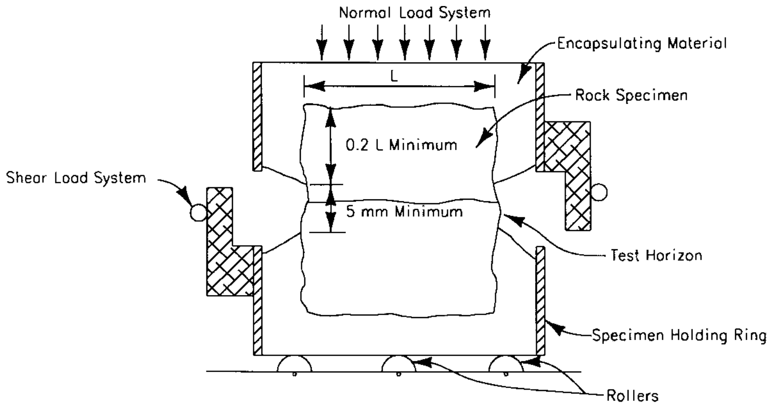

FIG. 2 Schematic Test Setup—Direct Shear Box with Encapsulated Specimen

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

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

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.

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 gage for measuring joint surface roughness, roughness chart (see Fig. 4[5]), filler or modelling clay, calipers, spatula, circular clamps, utility knife, towels, markers, plotting papers, encapsulating compound, and camera.

8. Test Specimens

8.1 *Sampling*:

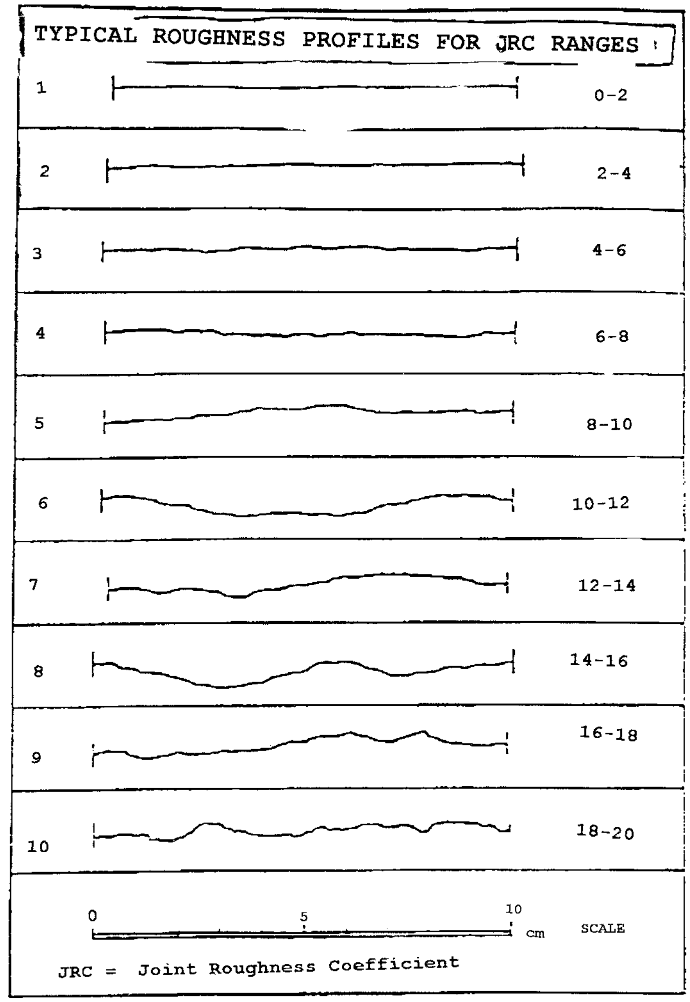

FIG. 4 Roughness Profiles and Corresponding JRC Values Associated With Each One[5]

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 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

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

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 gages) should be calibrated according to Practices E 4.

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

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.

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 gage is used to measure joint roughness in the direction of anticipated shear displacement. When all the prongs of the gage are lowered on a flat and hard surface, the tips of the prongs will fall on a straight line. Place this straight line pronged gage onto the shear plane and lower all the prongs to make contact with the shear surface. Remove the gage. The tips of the gage 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 gages 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*) *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*) *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

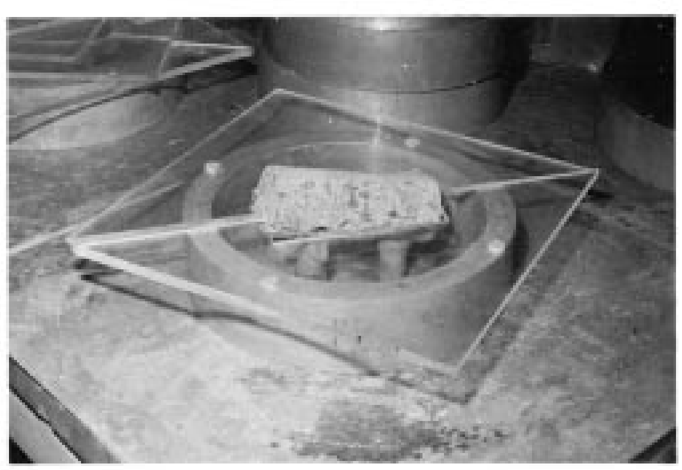

FIG. 5 Specimen Supported in Place By Modeling Clay Pins Which Are Removed After Encapsulating Material Cures and the Resulting Holes Filled With Encapsulating Material

NOTE 1—In both Fig. 5 and Fig. 6 the shear box is cylindrical. Square boxes work just as well.

FIG. 6 Lower Half of a Specimen Encapsulated in Holding Ring

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).

FIG. 7 Removing Spacer Plates After Encapsulating Material Has Cured

(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 used to measure normal displacement and to provide a check on rotation of the specimen during testing. Mount one displacement device on the machine in such a manner to measure the shear displacement of the specimen during the test. Ensure sufficient travel and contact for the device to measure displacements.

10.6 *Load Application*:

10.6.1 *Seating Load*—Apply a small seating normal load on the order of 450 to 900 N (100 to 200 lb), depending on specimen size. Account for the mass of the normal load system when placing a specified normal stress on the specimen.

10.6.2 *Sliding Friction Test*:

10.6.2.1 *Normal Load*—Continuously increase the load normal to the shear zone at a constant rate until the lowest selected load is attained, and record consequent normal displacements. Do not apply the shear load until normal displacement has stabilized. Stabilization is complete when the change in consequent normal displacement is less than 0.05 mm (0.002 in.) in 10 min. Maintain a constant normal load (force) during shear testing.

10.6.2.2 *Shear Load*—After the selected normal load has been stabilized, apply the shear load continuously at the selected rate of shear displacement. A minimum of 10 sets of readings is suggested to be taken before reaching the peak shear strength. After reaching the peak shear strength, loading should continue and readings taken until a residual shear strength is established (Fig. 1). An *X-Y* recorder may be used if continuous readings are required.

10.6.2.3 *Normal Load Increment*—Establish the residual shear strength. This may require reversing the shear load or resetting to account for travel restrictions of the displacement measuring instruments. Remove the shear load, and increase the normal load to another level. Again, apply the shear load to establish a second level of peak shear strength and residual shear strength. Bear in mind that with each repeat test the surface will be further damaged. Repeat the procedures in 10.6.2.1 and 10.6.2.2, as required. Prior to each repeat ensure that adequate travel is available for each displacement device.

10.6.2.4 *Measurements of Normal Displacements*—Measure normal displacements with the four vertical displacement measuring devices at each shear load observation. Compare the four readings and determine possible specimen rotation which would be indicated by differences in the readings of the four devices. Report the normal displacement of the specimen as the average of the four readings. Degree of joint closure and dilation angle can be determined from these measurements.

10.6.2.5 *Measurements of Shear Displacements*—Measure and record shear displacement at suitable intervals, that is, 0.025 or 0.05 mm (0.001 or 0.002 in.), with the horizontal displacement measuring device mounted on the shear box.

10.6.3 *Intact Shear Strength Test*:

10.6.3.1 *Normal Load*—Continuously increase normal load at a constant rate until the selected load is attained. Maintain a constant normal load on the shear surface during the test.

10.6.3.2 *Shear Load*—After stabilization of normal load, increase the shear load continuously in such a way as to attain failure. An *X-Y* recorder may be used if continuous readings are required.

10.6.3.3 Sliding friction tests (10.6.2) may then be performed.

10.6.3.4 Repeat procedures in 10.6.3.1 and 10.6.3.3 on other specimens. The number of specimens to be tested depends upon material availability, however, a minimum of three is recommended.

10.7 *Photographic Record*—Photograph each specimen before and after testing.

NOTE 6—In situations of seismic loading, a specimen may slide back and forth along joints or other discontinuities. Reversed shearing can also occur following vibrations of rock slopes or tunnels that may cause new shear stresses on discontinuities in a direction opposite to the initial shear stress. In such cases, determination of shear strength properties under reversible shear loads will be required.

11. Calculations

11.1 Calculate the nominal cross-sectional areas of test specimens from initial cross-sectional dimensions (see 10.2.1.1 or 10.2.1.2), and express results to the nearest 6.5 mm^2 (0.01 in.^{2}). For specimens which have a test feature which is not normal to the core axis, the area is determined by:

$$A = \frac{\pi D^2}{4 \cos\Theta} \quad (1)$$

where:
D = core diameter, and
Θ = angle of tip.

11.2 Calculate the following engineering stresses:

$$\text{Apparent normal stress } \sigma = \frac{P_n}{A} \quad (2)$$

$$\text{Apparent shear stress } \tau = \frac{P_s}{A} \quad (3)$$

where:
P_n = normal load,
P_s = shear load, and
A = nominal initial cross-sectional area (see Note 1).

11.3 Make the following data plots:

11.3.1 Curves to depict relationships of (a) shear stress versus shear displacement, (b) peak shear strength versus normal stress as shown on Fig. 8, and (c) residual shear strength versus shear displacement.

11.3.2 Curves for preselected normal stresses to show the relationships between (a) shear stress versus shear sisplacement, and (b) normal displacement versus shear displacement as shown in the example plot on Fig. 9.

12. Report

12.1 Report the following information:

12.1.1 Source of specimen including project name, feature, location, depth, drill hole number and angle, and conditions of storage environment. Also describe how specimens were prepared for storage, handling, and transportation.

12.1.2 Physical description of specimen including material type, and location and orientation (strike, dip) of discontinuities, such as: apparent weakness planes, bedding planes, schistocity, and large inclusions, if any.

12.1.3 General indication of the moisture condition of the test specimen at the time of testing, such as, moist, saturated, as-received, laboratory air dry, or oven dry. In some cases, it may be necessary to report the actual moisture content as determined using Test Method D 2216.

12.1.4 The initial shape and nominal cross-sectional area of the specimen. Include joint roughness coefficient from chart.

12.1.5 Date of sampling and testing.

12.1.6 The number of specimens tested.

12.1.7 The type of encapsulating material used.

12.1.8 The displacement measuring device readings and reduced displacements.

12.1.9 The applied loads (normal and shear) during testing.

12.1.10 Description of failure, including photographs of the specimen before and after the test.

12.1.11 Tables and graphical plots of individual and combined test results of testing as follows:

Fig. 8 Typical Presentation Sliding Friction Test Results (a) Shear Stress and Shear Displacement, and (b) Shear Strength and Normal Stress.

Fig. 9 (a) Shear Stress and Shear Displacement, and (b) Normal Displacement and Shear Displacement.

Fig. 10 General Information

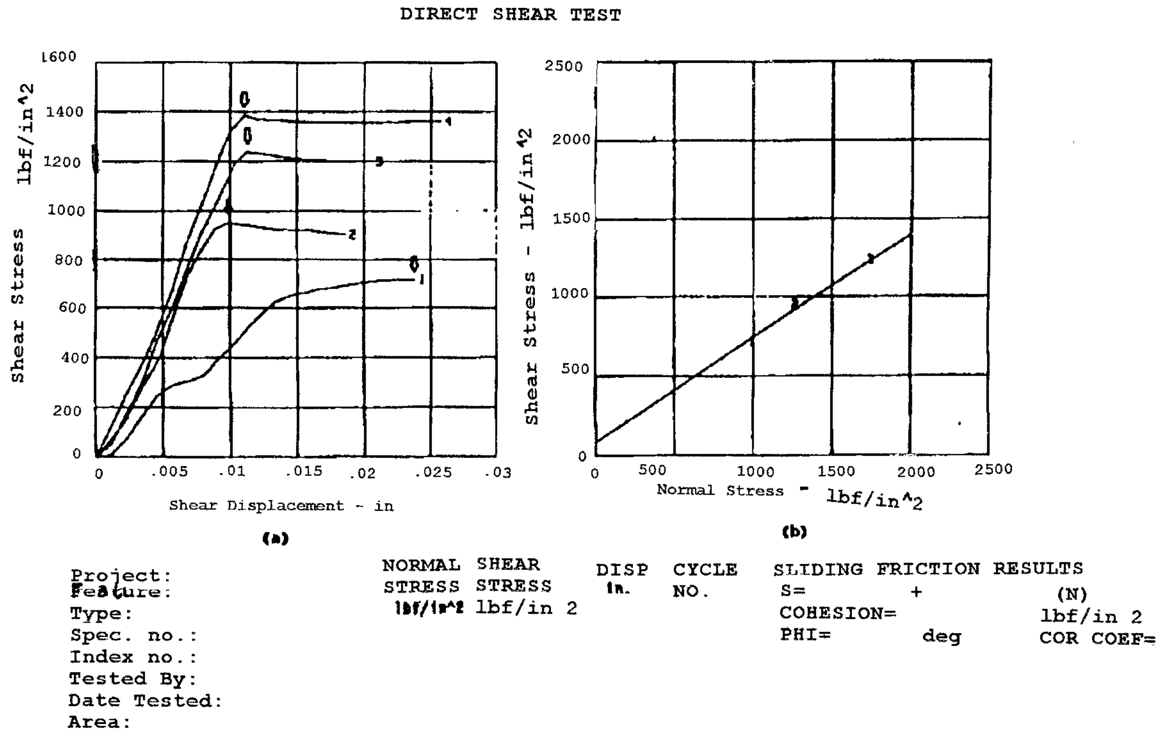

FIG. 8 Typical Presentation Sliding Friction Test Results: (a) Shear Stress and Shear Displacement and (b) Shear Strength and Normal Stress

Fig. 11 Test Records
Fig. 12 Final Reduced Data
Fig. 13 Data Summary

13. Precision and Bias

13.1 *Precision*—Data are proposed to be evaluated by means of an interlaboratory test program for rock properties to determine the precision of this test method.

13.2 *Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

14. Keywords

14.1 asperity; direct shear strength; discontinuity; displacement; rock; roughness; sliding friction; stress

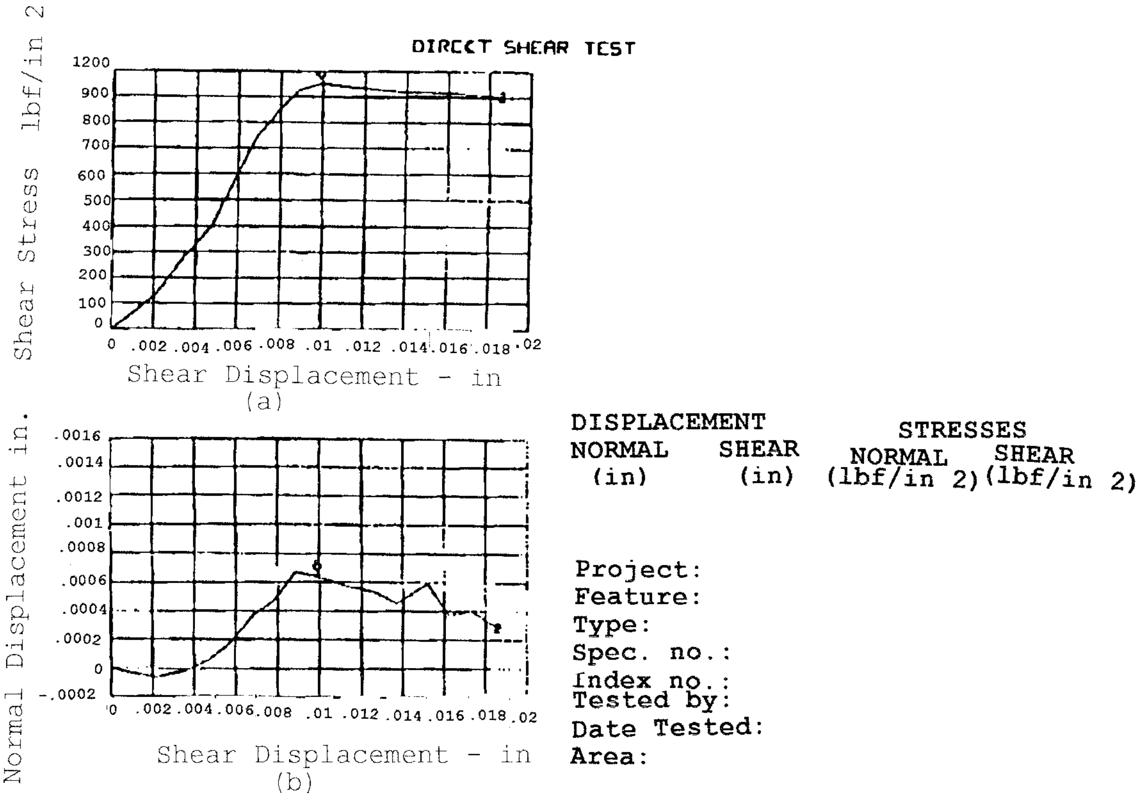

FIG. 9 At Selected Normal Stress σ_{L1}: (a) Shear Stress and Shear Displacement, and (b) Normal Displacement and Shear Displacement

Bureau of Reclamation	Direct Shear Test Data Sheet	
Project:	Feature:	
Tested by: Date:	Calculated by: Date:	Checked by: Date:
Sample Number	Type of Feature:	
Drill Hole	Surface Description:	
Depth feet meters	Angle from Core Axis	

Data from drill logs (if available)

Rock type:
Angle:
Infillings:
Roughness:
Photographs Taken:

	before	after
Surface	__ y __ n	__ y __ n
Profile	__ y __ n	__ y __ n

__ Calculated
__ Digitized

dia 1 ____________ average dia ____________ area ____________
dia 2 ____________

Surface Contours:

Parallel to Shearing:

top

bottom

Perpendicular to Shear:

top

bottom

Surface Contour Rating: ______________________________
(See Chart on Reverse)

FIG. 10 General Information

PROJECT SIXTH WATE	CONT. R AQUEDUCT	FEATURE JOINT BEHA	CONT. VIOR TESTS	SPEC. NO. 702-79.4	TESTED BY JSM	DATE 6/20/90
D DISTANCE 0.25	DIAMETER NX	AREA 2.344	B OR S S	DELTA LOAD 100	DELTA DISP 0.001	NorDeadLoa 78
TYPE SMOOTH-2	CONT	CONT	SYS 2 L/S	SCALE Y/N Y	BREAK ONLY	ClosureY/N Y
INDEX NO. 64L-94	CONT	CONT				
ARROW L#1 A	ARROW L#2 A	ARROW L#3 A	ARROW L#4 A	ARROW L#5 A	ARROW L#6 A	ARROW L#7 A
ARROW L#8 A	ARROW L#9 A	ARROW L#10 A				

NORMAL lbs	SHEAR lbs	DISP ins	TOUCH ins	Za ins	Zb ins	Zc ins	Zd ins	S/LIN	DATE TIME
75	-23	-.5607	.3092	.3911	.2516	.3293	.2649	3 1	20 Jun 14:31:0
250	-27	-.5598	.3103	.3913	.2526	.3308	.2665	3 2	20 Jun 14:31:3
500	-29	-.5591	.3111	.3913	.2520	.3344	.2667	3 3	20 Jun 14:32:1
1000	39	-.5657	.3171	.3913	.2485	.3436	.2849	3 4	20 Jun 14:33:4
1249	41	-.5655	.3175	.3916	.2498	.3442	.2846	3 5	20 Jun 14:35:4
1750	39	-.5660	.3180	.3914	.2510	.3458	.2839	3 6	20 Jun 14:37:1
2000	35	-.5655	.3184	.3915	.2513	.3472	.2836	3 7	20 Jun 14:37:5
1750	37	-.5660	.3180	.3910	.2513	.3462	.2836	3 8	20 Jun 14:38:1
1251	40	-.5659	.3179	.3917	.2505	.3451	.2842	3 9	20 Jun 14:38:5
-1000	44	-.5661	.3175	.3914	.2511	.3429	.2848	3 10	20 Jun 14:39:3
1000	88	-.5308	.3182	.3915	.2500	.3450	.2863	3 11	20 Jun 14:42:5
1001	102	-.5297	.3183	.3919	.2502	.3449	.2863	3 12	20 Jun 14:43:0
1009	240	-.5286	.3183	.3918	.2497	.3451	.2866	3 13	20 Jun 14:43:1
1022	452	-.5275	.3184	.3917	.2492	.3453	.2872	3 14	20 Jun 14:43:2
1033	659	-.5263	.3183	.3916	.2488	.3454	.2876	3 15	20 Jun 14:43:3
1038	763	-.5251	.3184	.3916	.2484	.3459	.2877	3 16	20 Jun 14:43:3
1038	794	-.5241	.3183	.3914	.2479	.3460	.2879	3 17	20 Jun 14:43:4
1031	856	-.5228	.3184	.3919	.2476	.3462	.2881	3 18	20 Jun 14:43:4
1020	1000	-.5218	.3184	.3916	.2469	.3467	.2883	3 19	20 Jun 14:43:5
1007	1138	-.5207	.3183	.3915	.2464	.3467	.2885	3 20	20 Jun 14:43:5
1004	1287	-.5197	.3183	.3916	.2459	.3472	.2887	3 21	20 Jun 14:44:0
1001	1427	-.5185	.3183	.3914	.2453	.3477	.2888	3 22	20 Jun 14:44:1
1001	1554	-.5174	.3182	.3914	.2446	.3479	.2889	3 23	20 Jun 14:44:1
1001	1612	-.5164	.3183	.3913	.2438	.3486	.2894	3 24	20 Jun 14:44:2
1001	1637	-.5154	.3184	.3913	.2433	.3492	.2898	3 25	20 Jun 14:44:2
1001	1664	-.5143	.3185	.3914	.2426	.3496	.2903	3 26	20 Jun 14:44:3
999	1686	-.5131	.3186	.3915	.2422	.3499	.2907	3 27	20 Jun 14:44:3
999	1712	-.5121	.3187	.3916	.2417	.3501	.2913	3 28	20 Jun 14:44:3
1000	1734	-.5109	.3187	.3915	.2413	.3503	.2917	3 29	20 Jun 14:44:4
1000	1756	-.5094	.3188	.3915	.2407	.3508	.2923	3 30	20 Jun 14:44:4
1000	1764	-.5082	.3189	.3916	.2400	.3510	.2931	3 31	20 Jun 14:44:5
-1000	1766	-.5070	.3190	.3918	.2396	.3511	.2936	3 32	20 Jun 14:44:5
1251	74	-.5076	.3202	.3916	.2399	.3535	.2959	3 33	20 Jun 14:46:4
1252	217	-.5066	.3203	.3916	.2394	.3542	.2959	3 34	20 Jun 14:46:4
1256	399	-.5054	.3203	.3918	.2388	.3545	.2961	3 35	20 Jun 14:46:5
1268	724	-.5042	.3202	.3918	.2385	.3544	.2963	3 36	20 Jun 14:46:5
1275	1001	-.5029	.3202	.3915	.2381	.3547	.2964	3 37	20 Jun 14:46:5
1281	1391	-.5019	.3200	.3917	.2380	.3544	.2961	3 38	20 Jun 14:46:5
1278	1797	-.5008	.3199	.3917	.2378	.3542	.2957	3 39	20 Jun 14:46:5
1277	2035	-.4998	.3197	.3916	.2377	.3541	.2956	3 40	20 Jun 14:46:5
1277	2242	-.4988	.3196	.3915	.2374	.3539	.2954	3 41	20 Jun 14:46:5
1272	2300	-.4977	.3196	.3916	.2370	.3540	.2957	3 42	20 Jun 14:46:5
1272	2273	-.4963	.3196	.3917	.2369	.3538	.2962	3 43	20 Jun 14:46:5
1268	2249	-.4949	.3197	.3917	.2365	.3539	.2967	3 44	20 Jun 14:46:5
1264	2234	-.4939	.3198	.3919	.2362	.3538	.2971	3 45	20 Jun 14:46:5
1262	2229	-.4924	.3196	.3912	.2360	.3537	.2976	3 46	20 Jun 14:47:0
1261	2220	-.4914	.3198	.3918	.2359	.3535	.2981	3 47	20 Jun 14:47:0
1261	2203	-.4903	.3198	.3916	.2356	.3534	.2986	3 48	20 Jun 14:47:0
-1261	2188	-.4889	.3199	.3916	.2355	.3536	.2991	3 49	20 Jun 14:47:0
1749	73	-.4922	.3215	.3918	.2372	.3560	.3009	3 50	20 Jun 14:49:2
1749	191	-.4911	.3215	.3917	.2373	.3562	.3008	3 51	20 Jun 14:49:2
1750	477	-.4899	.3214	.3919	.2368	.3561	.3007	3 52	20 Jun 14:49:2
1754	775	-.4888	.3213	.3915	.2364	.3567	.3006	3 53	20 Jun 14:49:3
1760	1140	-.4877	.3214	.3919	.2364	.3569	.3003	3 54	20 Jun 14:49:3
1765	1494	-.4865	.3211	.3917	.2361	.3566	.3001	3 55	20 Jun 14:49:3
1759	1857	-.4855	.3209	.3921	.2361	.3559	.2997	3 56	20 Jun 14:49:3
1756	2217	-.4843	.3209	.3920	.2359	.3563	.2994	3 57	20 Jun 14:49:4
1740	2555	-.4830	.3207	.3919	.2355	.3562	.2992	3 58	20 Jun 14:49:4
1740	2856	-.4819	.3205	.3918	.2354	.3559	.2990	3 59	20 Jun 14:49:4
1746	2974	-.4809	.3205	.3920	.2355	.3553	.2991	3 60	20 Jun 14:49:4
1748	2948	-.4795	.3205	.3918	.2352	.3556	.2994	3 61	20 Jun 14:49:4
1750	2930	-.4785	.3206	.3918	.2352	.3556	.2997	3 62	20 Jun 14:49:4
1757	2912	-.4772	.3207	.3917	.2352	.3558	.2999	3 63	20 Jun 14:49:4
1757	2896	-.4762	.3207	.3918	.2352	.3556	.3002	3 64	20 Jun 14:49:5

FIG. 11 Test Records

FINAL DATA

Project	SIXTH WATER AQUEDUCT
Feature	JOINT BEHAVIOR TESTS
Type	SMOOTH-2
Spec no.	702-79.4
Tested By	JSM
Date Tested	6/20/90
Area	2.344 Sq. in.

NORMAL STRESS lbf/in^2	SHEAR STRESS lbf/in^2	DISPLACEMENT SHEAR ins	DISPLACEMENT NORMAL ins
75	0	0.0000	0.0000
250	-2	.0009	-.0011
500	-3	.0016	-.0019
1000	27	-.0051	-.0078
1249	27	-.0048	-.0083
1750	26	-.0053	-.0088
2000	25	-.0048	-.0092
1750	26	-.0053	-.0088
1251	27	-.0053	-.0086
1000	29	-.0054	-.0083
1000	0	0.0000	-.0090
1001	6	.0011	-.0091
1009	65	.0023	-.0091
1022	155	.0033	-.0091
1033	243	.0045	-.0091
1038	288	.0057	-.0091
1038	301	.0067	-.0091
1031	328	.0080	-.0092
1020	389	.0090	-.0092
1007	448	.0102	-.0091
1004	512	.0112	-.0091
1001	571	.0123	-.0091
1001	626	.0135	-.0090
1001	650	.0145	-.0090
1001	661	.0155	-.0092
1001	672	.0165	-.0093
999	682	.0177	-.0094
999	693	.0188	-.0095
1000	702	.0200	-.0095
1000	711	.0214	-.0096
1000	715	.0226	-.0097
-1000	716	.0238	-.0098
1251	0	0.0000	-.0110
1252	61	.0011	-.0110
1256	139	.0022	-.0110
1268	277	.0034	-.0110
1275	395	.0047	-.0109
1281	562	.0058	-.0108
1278	735	.0068	-.0106
1277	836	.0078	-.0105
1277	925	.0089	-.0103

FIG. 12 Final Reduced Data

DATA SUMMARY

Project	SIXTH WATER AQUEDUCT
Feature	JOINT BEHAVIOR TESTS
Type	SMOOTH-2
Spec no.	702-79.4
Index no.	64L-94
Tested By	JSM
Date Tested	6/20/90
Area	2.344 Sq. in.

NORMAL LOAD (lbf)	SHEAR LOAD (lbf)	DISPACEMENT NORMAL (ins)	SHEAR (ins)	NORMAL STRESS (lbf/in^2)	SHEAR STRESS (lbf/in^2)
0	0	0.0000	0.0000	0	0
2344	1677	.0008	.0238	1000	715
2982	2226	-.0006	.0099	1272	950
4093	2901	-.0010	.0113	1746	1238
4679	3243	-.0013	.0110	1996	1384

SUM X*X = 9650516
SUM Y*Y = 4859596
SUM X*Y = 6845839
SUM X = 6014
SUM Y = 4286

SLIDING FRICTION RESULTS
S= 80 + .660 (N)
COHESION = 80 lbf/in^2
PHI= 33 degrees COR COEF= .9968

FIG. 13 Data Summary

REFERENCES

(**1**) Part 2: Suggested Method for Laboratory Determination of Shear Strength, *Rock Characterization Testing and Monitoring*, Editor E. T. Brown, Pergamon Press, 1981, pp. 135–137.

(**2**) RTH NO 203 Direct Shear Strength of Rock Core Specimens, *Rock Testing Handbook*, Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1980.

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition that may impact the use of this standard.

(1) Added required footnote for Summary of Changes Section.
(2) Standards D 653 and D 3740 were added to Referenced Document Section.
(3) Reference to Terminology D 653 was added to 3.1.
(4) The required caveat for D 3740 was added.
(5) Summary of Changes section was added.