Designation: D3080/D3080M – 11

Standard Test Method for

Direct Shear Test of Soils Under Consolidated Drained Conditions[1]

This standard is issued under the fixed designation D3080/D3080M; 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 the determination of the consolidated drained shear strength of one specimen of a soil material under direct shear boundary conditions. The specimen is deformed at a controlled rate on or near a single shear plane determined by the configuration of the apparatus.

1.2 Shear stresses and displacements are nonuniformly distributed within the specimen. An appropriate height cannot be defined for calculation of shear strains. Therefore, stress-strain relationships or any associated quantity such as the shear modulus, cannot be determined from this test.

1.3 The determination of strength envelopes and the development of criteria to interpret and evaluate test results are left to the engineer or office requesting the test.

1.4 The results of the test may be affected by the presence of coarse-grained soil or rock particles, or both, (see Section 7).

1.5 Test conditions, including normal stress and moisture environment, should be selected to represent the field conditions being investigated. The rate of shearing must be slow enough to ensure drained conditions.

1.6 Generally, three or more tests are performed on specimens from one soil sample, each under a different normal load, to determine the effects upon shear resistance and displacement. Results from a test series are combined to determine strength properties such as Mohr strength envelopes. Interpretation of multiple tests requires engineering judgment and is beyond the scope of this test method. This test method pertains to the requirements for a single test.

1.7 There may be instances when the gap between the shear box halves should be increased to accommodate sand sized particles greater than the specified gap. Presently there is insufficient information available for specifying the gap dimension based on particle size distribution.

1.8 *Units*—The values stated in either inch-pound units or SI units [given in brackets] are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.8.1 The gravitational system of inch-pound units is used. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The slug unit is not given, unless dynamic (F = ma) calculations are involved.

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

1.9.1 The method used to specify how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.10 *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]

D422 Test Method for Particle-Size Analysis of Soils
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))
D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.05 on Strength and Compressibility of Soils.

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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**

D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4220 Practices for Preserving and Transporting Soil Samples
D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing
D6026 Practice for Using Significant Digits in Geotechnical Data
D6027 Practice for Calibrating Linear Displacement Transducers for Geotechnical Purposes (Withdrawn 2013)[3]

3. Terminology

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

3.2 *Description of Terms Specific to This Standard:*

3.2.1 *Failure*—The stress condition at failure for a test specimen. Failure is often taken as the maximum shear stress attained, or in the absence of a peak condition, the shear stress at 10 percent relative lateral displacement. Depending on soil behavior and field application, other suitable criteria may be defined at the direction of the requesting agency.

3.2.2 *Nominal Normal Stress*—In the direct shear test, the applied normal (vertical) force divided by the area of the shear box. The contact area of the specimen on the imposed shear plane decreases during shear and hence the true normal stress is unknown.

3.2.3 *Nominal Shear Stress*—In the direct shear test, the applied shear force divided by the area of the shear box. The contact area of the specimen on the imposed shear plane decreases during shear and hence the true shear stress is unknown.

3.2.4 *Percent Relative Lateral Displacement*—The ratio, in percent, of the relative lateral displacement to the diameter or lateral dimension of the specimen in the direction of shear.

3.2.5 *Preshear*—In strength testing, the stage of a test after the specimen has stabilized under the consolidation loading condition and just prior to starting the shearing phase. It is used as an adjective to modify phase relations or stress conditions.

3.2.6 *Relative Lateral Displacement*—The displacement between the top and bottom shear box halves.

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

4. Summary of Test Method

4.1 This test method consists of placing the test specimen in the direct shear device, applying a predetermined normal stress, providing for wetting or draining of the test specimen, or both, consolidating the specimen under the normal stress, unlocking the shear box halves that hold the test specimen, and shearing the specimen by displacing one shear box half laterally with respect to the other at a constant rate of shearing deformation while measuring the shearing force, relative lateral displacement, and normal displacement (Fig. 1). The shearing rate must be slow enough to allow nearly complete dissipation of excess pore pressure.

5. Significance and Use

5.1 The direct shear test is suited to the relatively rapid determination of consolidated drained strength properties because the drainage paths through the test specimen are short, allowing excess pore pressure to dissipate more rapidly than other drained stress tests. The test can be made on any type of soil material. It is applicable for testing intact, remolded, or reconstituted specimens. There is however, a limitation on the maximum particle size (see 6.2).

5.2 The test results are applicable to assessing strength in a field situation where complete consolidation has occurred under the existing normal stresses. Failure is reached slowly under drained conditions so that excess pore pressures are dissipated. The shear rate must meet the requirements of 9.10. The results from several tests may be used to express the relationship between consolidation stress and drained shear strength.

NOTE 1—The equipment specified in this standard method is not appropriate for performing undrained shear tests. Using a fast displacement rate without proper control of the volume of the specimen will result in partial drainage and incorrect measurements of shear parameters.

5.3 During the direct shear test, there is rotation of principal stresses, which may or may not model field conditions. Moreover, failure may not occur on the weakest plane since failure is forced to occur on or near a plane through the middle of the specimen. The fixed location of the plane in the test can be an advantage in determining the shear resistance along recognizable weak planes within the soil material and for testing interfaces between dissimilar materials.

5.4 Shear stresses and displacements are nonuniformly distributed within the specimen, and an appropriate height is not defined for calculating shear strains or any associated engineering quantity. The slow rate of displacement provides for dissipation of excess pore pressures, but it also permits plastic flow of soft cohesive soils.

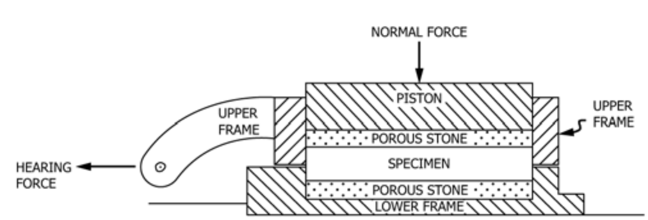

FIG. 1 Test Specimens in Single Shear Apparatus

5.5 The number of tests in a series normal stress level, rate of shearing, and general test conditions should be selected to approximate the specific soil conditions being investigated.

5.6 The area of the shear surface decreases during the test. This area reduction creates uncertainty in the actual value of the shear and normal stress on the shear plane but should not affect the ratio of these stresses.

NOTE 2—Notwithstanding the statement on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing the test and the suitability of the equipment and facilities used. Agencies which meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D3740 provides a means of evaluating some of these factors.

6. Apparatus

6.1 *Shear Device*—A device to hold the specimen securely between two porous inserts in such a way that torque is not applied to the specimen. The shear device shall provide a means of applying a normal stress to the faces of the specimen, for measuring change in thickness of the specimen, for permitting drainage of water through the porous inserts at the top and bottom boundaries of the specimen, and for submerging the specimen in water. The device shall be capable of applying a shear force to the specimen along a predetermined shear plane (single shear) parallel to the faces of the specimen. The frames that hold the specimen shall be sufficiently rigid to prevent their distortion during shearing. The various parts of the shear device shall be made of material not subject to corrosion by moisture or substances within the soil, for example, stainless steel, bronze, or aluminum, etc. Dissimilar metals, which may cause galvanic action, are not permitted.

6.2 *Shear Box,* a shear box, either circular or square, made of stainless steel, bronze, or aluminum, with provisions for drainage through the top and bottom. The box is divided by a straight plane into two halves of equal thickness which are fitted together with alignment screws. The shear box is also fitted with gap screws, which create the space (gap) between the top and bottom halves of the shear box prior to shear. The two halves should provide a bearing surface for the specimen along the shear plane during relative lateral displacement.

6.2.1 The minimum specimen diameter for circular specimens, or width for square specimens, shall be 2.0 in. [50 mm], or not less than ten (10) times the maximum particle size diameter, whichever is larger.

6.2.2 The minimum initial specimen thickness shall be 0.5 in. [13 mm], but not less than six (6) times the maximum particle diameter.

6.2.3 The minimum specimen diameter to thickness or width to thickness ratio shall be 2:1.

NOTE 3—A light coating of grease applied to the inside of the shear box may be used to reduce friction between the specimen and shear box. TFE-fluorocarbon coating may also be used on these surfaces instead of grease to reduce friction.

6.3 *Porous Inserts,* Porous inserts function to allow drainage from the soil specimen along the top and bottom boundaries. They also function to transfer shear stress from the insert to the top and bottom boundaries of the specimen. Porous inserts shall consist of silicon carbide, aluminum oxide, or metal which is not subject to corrosion by soil substances or soil moisture. The proper grade of insert depends on the soil being tested. The hydraulic conductivity of the insert should be substantially greater than that of the soil, but should be textured fine enough to prevent excessive intrusion of the soil into the pores of the insert. The diameter or width of the top porous insert or plate shall be 0.01 to 0.02 in. (0.2 to 0.5 mm) less than that of the inside of the shear box. The insert functions to transfer the shear stress to the soil and must be sufficiently coarse to develop interlock. Sandblasting or tooling the insert may help, but the surface of the insert should not be so irregular as to cause substantial stress concentrations in the soil. Porous inserts should be checked for clogging on a regular basis.

NOTE 4—Exact criteria for insert texture and hydraulic conductivity have not been established. For normal soil testing, medium grade inserts with a hydraulic conductivity of about 0.5 to 1.0×10^{3} ft/yr [5.0×10^{-4} to 1.0×10^{-3} cm/s] are appropriate for testing silts and clays, and coarse grade inserts with a hydraulic conductivity of about 0.5 to 1.0×10^{5} ft/yr [0.05 to 0.10 cm/s] are appropriate for sands. It is important that the hydraulic conductivity of the porous insert is not reduced by the collection of soil particles in the pores of the insert. Storing the porous inserts in a water filled container between uses will slow clogging. The inserts can be cleaned by flushing, boiling, or ultrasonic agitation.

6.4 *Loading Devices:*

6.4.1 *Device for Applying the Normal Force*—The normal force is typically applied by dead weights, a lever loading yoke activated by dead weights (masses), a pneumatic force cylinder, or a screw driven actuator. The device shall be capable of maintaining the normal force to within ± 1 percent of the specified force. It should apply the load quickly without significantly exceeding the steady value. Dead weight systems should be checked on a regular schedule. All systems with adjustable force application (e.g. pneumatic regulator or motor driven screw) require a force indicating device such as a proving ring, load cell, or pressure sensor.

6.4.2 *Device for Shearing the Specimen*—The device shall be capable of shearing the specimen at a uniform rate of displacement, with less than ±5 percent deviation. The rate to be applied depends upon the consolidation characteristics of the test material as specified in 9.10. The rate is usually maintained with an electric motor and gear box arrangement and the shear force is determined by a force indicating device such as a proving ring or load cell.

NOTE 5—In order to test a wide range of soils the apparatus should permit adjustment of the rate of displacement from 0.0001 to 0.04 in./min [0.0025 to 1.0 mm/min].

NOTE 6—Shearing the test specimen at a rate greater than specified may produce partially drained shear results that will differ from the drained strength of the material. The specimen must be sheared slowly enough to allow pore pressures to dissipate.

6.4.3 *Top Half of Shear Box*—The weight of the top half of shear box supported by the specimen shall be less than 1 percent of the applied normal force during shear: this will most likely require that the top shear box be supported by a counter force, the equipment modified or the specimen sheared under a greater applied normal force.

6.5 *Normal Force Measurement Device*—A proving ring or load cell (or calibrated pressure sensor when using a pneumatic loading system) accurate to 0.5 lbf [2.5 N], or 1 percent of the normal force during shear, whichever is greater, is required when using anything but dead weights to apply the normal force.

6.6 *Shear Force Measurement Device*—A proving ring or load cell accurate to 0.5 lbf (2.5 *N*), or 1 percent of the shear force at failure, whichever is greater.

6.7 *Deformation Indicators*—Either dial gauges or displacement transducers capable of measuring the change in thickness (normal displacement) of the specimen, with a readability of at least 0.0001 in. [0.002 mm] and to measure relative lateral displacement with readability of at least 0.001 in. [0.02 mm]. D6027 provides details on the evaluation of displacement transducers.

6.8 *Shear Box Bowl*—A metallic box which supports the shear box and provides either a reaction against which one half of the shear box is restrained, or a solid base with provisions for aligning one half of the shear box, which is free to move coincident with applied shear force along a plane. The bowl also serves as the container for the test water used to submerge the specimen.

6.9 *Controlled High Humidity Environment*—if required, for preparing specimens, such that water content gain or loss during specimen preparation is minimized.

6.10 *Test Water*—Water is necessary to saturate the porous stones and fill the submersion reservoir. Ideally, this water would be similar in composition to the specimen pore fluid. Options include extracted pore water from the field, potable tap water, demineralized water, or saline water. The requesting agency should specify the water option. In the absence of a specification, the test should be performed with potable tap water.

6.11 *Trimmer or Cutting Ring,* for trimming oversized samples to the inside dimensions of the shear box with a minimum of disturbance. An exterior jig may be needed to maintain the shear box alignment.

6.12 *Balances*—a balance or scale conforming to the requirements of Specification D4753 readable (with no estimate) to 0.1% or better.

6.13 *Apparatus for Determination of Water Content*—as specified in Test Method D2216.

6.14 *Equipment for Compacting Specimens*—if applicable, as specified in Test Methods D698 or D1557.

6.15 *Miscellaneous Equipment*—including timing device with a second hand, distilled or demineralized water, spatulas, knives, straightedge, wire saws, etc., used in preparing the specimen.

7. Test Specimen Preparation

7.1 *Intact Specimens*—Prepare intact specimens from large intact samples or from samples secured in accordance with Practice D1587, or other intact tube sampling procedures. Intact samples shall be preserved and transported as outlined for Group C or D samples in Practice D4220. Handle specimens carefully to minimize disturbance, changes in cross section, or loss of water content. If compression or any type of noticeable disturbance would be caused by the extrusion device, split the sample tube lengthwise or cut off a small section to facilitate removal of the sample with minimum disturbance. Prepare trimmed specimens, whenever possible, in an environment which will minimize the gain or loss of specimen moisture.

7.1.1 The sample selected for testing should be sufficiently large so that a minimum of three specimens can be prepared from similar material. While this standard test method applies to the measurements on one specimen, the requesting agency will typically specify a series of tests which cover a range of stress levels. The series should be performed on similar material.

7.1.2 Extreme care shall be taken in preparing intact specimens of sensitive soils to prevent disturbance to the natural soil structure.

7.1.3 Assemble the shear box halves and determine the mass of the empty box. Trim the lateral dimensions of the specimen to fit snuggly into the shear box using either a shape cutting shoe or a miter box. With the specimen in the shear box, trim the top and bottom surface of the specimen to be flat and parallel.

7.1.4 Determine and record the initial mass of the box plus specimen and height of the wet specimen for use in calculating the initial water content and total mass density of the material.

NOTE 7—If large particles are found in the soil after testing, a particle size analysis should be performed in accordance with Method D422 to confirm the visual observations, and the result should be provided with the test report.

NOTE 8—A controlled high-humidity room or laboratory glove box provides an appropriate atmosphere for trimming the specimen.

7.2 *Laboratory Fabricated Specimens*—Test specimens can be fabricated by reconstitution (7.3) or compaction (7.4). Acquire enough material to conduct the required series of tests. Blend the material to produce a uniform batch and if necessary divide into appropriate quantities for each required water content. Mix the soil with sufficient water to produce the desired water content. Allow the moist material to stand prior to specimen preparation in accordance with the following guide:

USCS Classification (D2487)	Minimum Standing Time, h
SW, SP	No Requirement
SW-SM, SP_SM, SM (>5% fines)	3
SC, ML, CL, SP-SC	18
MH, CH	36

7.3 *Reconstituted Specimens*—Specimens shall be prepared using the compaction method, water content, and mass density prescribed by the individual assigning the test. Specimens may be molded by either kneading or tamping each layer until the accumulative mass of the soil placed in the shear box is compacted/reconstituted to a known volume, or by adjusting the number of layers, the number of tamps per layer, and the force per tamp. The top of each layer shall be scarified prior to the addition of material for the next layer. The compacted layer boundaries shall be positioned so they are not coincident with the shear plane defined by the shear box halves, unless this is the stated purpose for a particular test. The tamper used to compact the material shall have an area in contact with the soil equal to or less than ½ the area of the shear box.

7.3.1 Secure the halves of the shear box together and assemble in the bowl. Place a moist porous insert in the bottom of the shear box. Determine the mass of wet soil required for a single layer and place it in the shear box. Distribute the material uniformly and compact the soil to achieve the desired condition. Continue placing and compacting soil in additional layers until the entire specimen is reconstituted.

NOTE 9—The required thickness of the compacted lift may be determined by directly measuring the thickness of the lift, or from the marks on the tamping rod which correspond to the thickness of the lift being placed.

7.3.2 Determine and record the height and initial mass of the test specimen.

7.3.3 Place the top moist porous insert on top of the specimen.

7.4 *Compacted Specimens*—Test specimens may also be prepared by compacting soil using the procedures and equipment used to determine moisture-density relationships of soils (Test Methods D698 or D1557), and then trimming the direct shear test specimen from the larger compaction specimen as though it were an intact sample. The shear plane of the direct shear specimen should not be aligned with any of the compaction lift interfaces.

8. Calibration

8.1 Calibration is required to determine the deformation of the apparatus when subjected to the consolidation load, so that for each normal consolidation load the apparatus deflection may be subtracted from the observed deformations. Therefore, only deformation due to specimen consolidation will be reported for completed tests. Calibration for the equipment load-deformation characteristics need to be performed on the apparatus when first placed in service, or when apparatus parts are changed. The following series of steps provide one method of calibrating the apparatus. Other methods of proven accuracy for calibrating the apparatus are acceptable.

8.2 Assemble the direct shear device with a metal calibration disk or plate of a thickness approximately equal to the typical test specimen and a diameter or width that is slightly less than the direct shear box.

8.3 Assemble the normal force loading yoke and apply a small normal load equivalent to about 1 lbf/in^2 [5 kPa].

8.4 Position the normal displacement indicator. Adjust this indicator so that it can be used to measure either consolidation or swell from the calibration disk or plate reading. Record the zero or "no load" reading.

8.5 Apply increments of normal force up to the equipment limitations, and record the normal displacement indicator reading and normal force. Remove the applied normal force in reverse sequence of the applied force, and record the normal displacement indicator readings and normal force. Average the values and plot the load deformation of the apparatus as a function of normal load. Retain the results for future reference in determining the thickness of the test specimen and compression within the test apparatus itself.

8.6 If the apparatus deformation correction exceeds 0.1 % of the initial specimen thickness at any load level during a test, the correction must be applied to every measurement of the test.

9. Procedure

9.1 Assemble the shear box and shear box bowl in the load frame.

9.1.1 *Intact Specimen*—Place moist porous inserts over the exposed surfaces of the specimen in the shear box, place the shear box with the intact specimen and porous inserts into the shear box bowl and align the bowl in the load frame.

NOTE 10—The decision to dampen the porous inserts or use dry inserts depends on the problem under study. For intact samples obtained below the water table, the porous inserts are usually dampened. For swelling soils, the sequence of consolidation, wetting, and shearing should prevent swelling until the specimen is equilibrated under the final normal stress.

9.1.2 *Reconstituted Specimen*—Place and align the assembled shear box, specimen, porous inserts and bowl into the load frame.

NOTE 11—For some apparatus, the top half of the shear box is held in place by a notched rod which fits into a receptacle in the top half of the shear box. The bottom half of the shear box is held in place in the shear box bowl retaining bolts. For some apparatus, the top half of the shear box is held in placed by an anchor plate.

9.2 Connect and adjust the position of the shear force loading system so that no force is imposed on the shear load measuring device. Record the zero value of the shear load measuring device.

9.3 Position and adjust the shear displacement measurement device. Obtain an initial reading or set the measurement device to indicate zero displacement.

9.4 Place the load transfer plate and moment break on top of the porous insert.

9.5 Place the normal force loading yoke into position and adjust it so the loading bar is aligned. For dead weight lever loading systems, level the lever. For pneumatic or motor drive loading systems, adjust the yoke until it sits snugly against the recess in the load transfer plate, or place a ball bearing on the load transfer plate and adjust the yoke until the contact is snug.

9.6 Apply a small seating normal load to the specimen. Verify that the components of the normal loading system are seated and aligned. The top porous insert and load transfer plate must be aligned so that the movement of the load transfer plate into the shear box is not inhibited. The specimen should not undergo significant compression under this seating load.

NOTE 12—The seating normal load applied to the specimen should be sufficient to assure all the components are in contact and alignment but not so large as to cause compression of the specimen. For most applications, a load resulting in approximately 1 lbf/in.^{2} [5 kPa] will be adequate but other values meeting the objective are acceptable.

9.7 Attach and adjust the normal displacement measurement device. Obtain an initial reading for the normal displacement measurement device along with a reading of the normal load (either weights or measurement device).

9.8 *Consolidation*—The final consolidation normal load may be applied in one increment or in several intermediate increments depending on the type of material, the stiffness of the specimen, and the magnitude of the final stress. Load increments must be small enough to prevent extrusion of the material from around the porous inserts. For stiff cohesive or coarse grained material a single increment is normally acceptable. For soft materials, it may be necessary to limit the load increment ratio to unity as described in Test Method D2435 (11.4) and apply a number of intermediate load increments. Based on the above considerations and instructions of the requesting agency, calculate and record the normal force required to achieve each intermediate normal stress level progressing the specimen from the seating load to the final consolidation normal stress.

9.8.1 Apply the first load increment and, if required, fill the shear box bowl with test water, and keep it full for the duration of the test. In the absence of specification, the bowl should be filled with potable water.

NOTE 13—Flooding the specimen with water eliminates negative pore pressure due to surface tension and also prevents evaporative drying during the test. If and when to inundate the specimen as well as the water chemistry is part of the test specification which should be provided by the requesting agency.

9.8.2 For each intermediate stress level, apply the load as quickly as practical. Maintain each load level until primary consolidation is essentially complete based on either a) interpretation of time versus normal deformation, b) experience with the material or c) a default value of 24 h. Record the normal deformation at the end of each increment and the increment duration.

9.8.3 For the maximum normal stress level and for the final normal stress level, apply the normal load to the specimen as quickly as practical and immediately begin recording the normal deformation readings against elapsed time. Test Method D2435 provides details of the loading procedure and suggestions for appropriate time recording schedules. For these load increments, verify completion of primary consolidation before proceeding to the next stage of the test by interpreting either the plot of normal displacement versus log of time or square root of time (in min). Test Method D2435 provides interpretation details of both methods.

9.8.4 If the test specification requires consolidation to a specific stress and then rebounding to a lower stress prior to shearing, then the maximum stress should be maintained for at least one cycle of secondary compression.

9.8.5 If the material exhibits a tendency to swell under the maximum normal stress, the soil must be inundated with water and must be permitted to achieve equilibrium (essentially stop swelling) under this normal stress before continuing on to the next stage of the test.

9.9 Just before shearing and after consolidation of the final increment is completed, record the preshear normal displacement and then remove the alignment screws or pins from the shear box. Use the gap screws to separate the shear box halves to approximately the diameter of the maximum sized particle in the test specimen or 0.025 in. [0.64 mm] as a minimum default value for fine grained materials. Back out the gap screws after creating the gap.

NOTE 14—The gap screws in most equipment raise the upper box half relative to the lower box half by prying apart the halves. Creating the gap in this manner will apply a tensile stress increment along the potential failure surface. This can unintentionally weaken the material. The top cap should not move upwards while creating the gap.

9.10 *Determine Shearing Rate*—The specimen must be sheared at a relatively slow rate so that insignificant excess pore pressure exists at failure. Determination of the appropriate rate of displacement requires an estimate of the time required for pore pressure dissipation and amount of deformation required to reach failure. These two factors depend on the type of material and the stress history. The following procedures should be used to compute the required shear rate. 9.10.1 and 9.10.2 may be used to compute times to failure when the maximum consolidation increment yields well defined normal deformation versus time curves and the material has a low overconsolidation ratio. 9.10.3 provides default values to be used in all other situations.

9.10.1 When data for the maximum consolidation increment yield a well defined normal deformation versus log time curve which extends into secondary compression, the curve should be interpreted as in Test Method D2435 and the time to failure should be computed using the following equation:

$$t_f = 50t_{50} \tag{1}$$

where:

t_f = total estimated elapsed time to failure, min,
t_{50} = time required for the specimen to achieve 50 percent consolidation under the maximum normal stress increment, min.

9.10.2 When data for the maximum consolidation increment do not satisfy the requirements of 9.10.1 but yield a well defined normal deformation versus root time curve, the curve should be interpreted as in Test Method D2435 and the time to failure should be computed using the following equation:

$$t_f = 11.6t_{90} \tag{2}$$

where:

t_{90} = time required for the specimen to achieve 90 percent consolidation under the maximum normal stress (increment), min.

9.10.3 When data for the maximum consolidation increment do not satisfy the requirements of 9.10.1 or 9.10.2 or when the specimen is significantly overconsolidated (OCR greater than about 2) under the maximum consolidation stress, default values for the time to failure should be computed based on a normally consolidated coefficient of consolidation for the soil. In the absence of soil specific consolidation data the time should be based on the soil type. The following table provides these default values.

USCS Classification (D2487)	Minimum Time to Failure, t_f
SW, SP (<5% fines)	10 min
SW-SM, SP_SM, SM (>5% fines)	60 min
SC, ML, CL, SP-SC	200 min
MH, CH	24 h

NOTE 15—The tabulated times are based on estimates of typical normally consolidated coefficient of consolidation values for each soil type and a 1 cm drainage path. A particular soil can vary considerably from these typical values. Square root of time interpretations can yield erroneously fast rates of consolidation for partly saturated or very stiff materials. Shearing overconsolidated specimens will soften the material in

the shear zone causing a reduction in the coefficient of consolidation. Consequently, the calculation of t_f based on deformation vs. time curves may produce an inappropriate estimate of the time required to fail the specimen under drained conditions. For overconsolidated clays which are tested under normal stresses less than the soil's pre-consolidation pressure, it is suggested that a time to failure be estimated using a value of t_{50} based on the coefficient of consolidation in the normally consolidated range for the soil. Care should be exercised if the time curve interpretation yields considerably shorter times than the tabulated values.

9.10.4 Estimate the relative lateral displacement required to fail the specimen. This displacement will depend on many factors including the type of material and the stress history. In the absence of specific experience relative to the test conditions, as a guide, use d_f = 0.5 in. [10 mm] if the material is normally or lightly over consolidated fine-grained soil, otherwise use d_f = 0.2 in. [5 mm].

9.10.5 Determine the appropriate maximum displacement rate from the following equation:

$$R_d = \frac{d_f}{t_f} \tag{3}$$

where:

R_d = displacement rate, in./min [mm/min], and
d_f = estimated relative lateral displacement at failure, in. [mm].

9.11 *Drained Shearing*—For some types of apparatus, the displacement rate is achieved using combinations of gear wheels and gear lever positions. For other types of equipment the displacement rate is achieved by adjusting the motor speed. Select and record a displacement rate that is equal to or slower than the value computed in 9.10.5.

9.11.1 Record the initial time, normal and relative lateral displacements, and normal and shear forces.

9.11.2 Start the apparatus and initiate shear.

9.11.3 Obtain data readings of time, normal and relative lateral displacement, and shear force at the desired interval of displacement or time. Data readings should be taken often enough to accurately define a shear stress-displacement curve. At a minimum, data should be recorded at relative lateral displacements of about 0.1, 0.2, 0.3, 0.4, 0.5, 1, 1.5, 2, 2.5, 3, and then every 2 percent relative lateral displacement until test completion.

NOTE 16—Additional readings may be helpful especially at the beginning of the test in identifying trends in behavior and the value of the peak shear stress of over consolidated or brittle material.

9.11.4 It may be necessary to stop the test and re-gap the shear box halves to maintain clearance between the shear box halves. The test should be checked periodically to confirm that a gap persists throughout the shearing phase of the test.

9.11.5 The specimen should be sheared to at least 10 percent relative lateral displacement unless specific termination criteria are provided by the specifying agency. Stop the motor drive to terminate shearing.

NOTE 17—The shape of the shear force versus displacement curve will depend on the soil type and stress history. The curve may have a well defined peak or may increase monotonically throughout the test. In general, it is better to continue the test to large deformation rather than terminate based on shear force variation.

9.11.6 Remove the normal force from the specimen and disassemble the loading apparatus.

9.12 For cohesive test specimens, separate the shear box halves with a sliding motion along the failure plane and in the direction of shearing. Do not pull the shear box halves apart perpendicularly to the failure surface, since this motion would damage the specimen. Photograph, sketch, or describe in writing the failure surface. This step in the procedure is not applicable to cohesionless specimens.

9.13 Remove the specimen from the shear box and determine the water content and dry mass according to Test Method D2216. If applicable, collect the extruded material in a separate container and determine the dry mass.

10. Calculation

10.1 *General*—Typical units are shown for both IP and SI systems and SD stands for significant digits. Furthermore, the prefix used for each variable has been chosen based on current practice. Other prefixes are permissible and will require different numerical values for the Unit Conversion Factors. Other units are permissible, provided consistency of units is maintained throughout the calculations. See 1.8 for additional comments on the use of inch-pound units.

10.2 Calculate the following for each reading during shear:

10.2.1 Nominal shear stress, acting on the specimen is:

$$\tau = \frac{F_s}{A} \tag{4}$$

where:

τ = nominal shear stress, lbf/in.^{2} [kPa] (3 SD),
F_s = shear force, lbf [kN] (3 SD), and
A = area of the shear box, in.^{2} [m^2] (3 SD).

10.2.2 Nominal normal stress acting on the specimen is,

$$\sigma_n = \frac{F_n}{A} \tag{5}$$

where:

σ_n = nominal normal stress, lbf/in.^{2} [kPa] (3 SD), and
F_n = normal force acting on the specimen, lbf [kN] (3 SD).

NOTE 18—Factors which incorporate assumptions regarding the actual specimen surface area over which the shear and normal forces are measured can be applied to the calculated values of shear or normal stress, or both. If a correction(s) is made, the factor(s) and rationale for using the correction should be explained with the test results.

10.2.3 *Displacement Rate*—The average displacement rate along the shear surface is:

$$R_d = \frac{d_h}{t_e} \tag{6}$$

where:

R_d = displacement rate, in./min [mm/min] (3 SD),
d_h = relative lateral displacement, in. [mm] (3 SD),
t_e = elapsed time of test, min (3 SD).

10.2.4 *Percent Relative Lateral Displacement*—The percent relative lateral displacement along the shear surface is:

$$P_d = 100 \cdot \frac{d_h}{D} \tag{7}$$

where:

P_d = percent relative lateral displacement, % (3 SD), and
D = specimen diameter or lateral dimension in direction of shear, in. [mm] (3 SD).

10.3 Compute the initial void ratio, initial dry density, initial water content, and initial degree of saturation based on the specific gravity, initial wet mass, final dry mass, and initial volume of the total specimen. Specimen volume is determined by measurements of the shear box lengths or diameter and the measured thickness of the specimen.

10.4 Compute the preshear void ratio, dry density, and water content based on the values used in 10.3 plus the measured normal deformation.

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

11.1 The methodology used to specify how data are recorded on the data sheet(s)/form(s), as given below is covered in 1.9 and Guide D6026.

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

11.2.1 Sample identification, project and location.

11.2.2 Test number, date, apparatus identification, and technician.

11.2.3 Description of type of shear device used in test.

11.2.4 Description of appearance of the specimen, based on Practice D2488 (Test Method D2487 may be used as an alternative), Atterberg limits (Test Method D4318), and grain size data (Method D422), if obtained (see 7.2).

11.2.5 Description of soil structure, that is whether the specimen is intact, remolded, reconstituted, or otherwise prepared.

11.2.6 Initial thickness and diameter (width for square shear boxes).

11.2.7 Dry mass of test specimen.

11.2.8 Initial and pre-shear water content.

11.2.9 Initial and pre-shear wet density, see Note 19.

11.2.10 Initial and pre-shear dry density and void ratio, see Note 19.

11.2.11 Initial and pre-shear degree of saturation, see Note 19.

11.2.12 Table of normal stress, final normal displacement, and duration of load increment during consolidation.

11.2.13 Table of nominal normal stress, nominal shear stress, relative lateral displacement or percent relative lateral displacement, normal displacement, and rate of deformation during shear.

11.2.14 Plot of deformation versus log of time or square root of time for those load increments used to determine the shear rate.

11.2.15 Plot of nominal shear stress versus lateral displacement or percent relative lateral displacement.

11.2.16 Plot of normal displacement versus lateral displacement or percent relative lateral displacement.

11.2.17 For cohesive material, observations made relative to the shear surface.

11.2.18 Departure from the procedure outlines, such as special loading sequences or special wetting requirements.

NOTE 19—In most cases, there is significant soil loss during shear and the specimen shape is such that the final phase relations (density, water content, and saturation) cannot be determined with any degree of reliability. Therefore these values are not required but may be included in the test report.

12. Precision and Bias

12.1 *Precision*—Test data on precision are not presented due to the nature of the soil or rock, or both materials tested by this standard. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. In addition, it is either not feasible or too costly to produce multiple specimens that have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as to operator or laboratory testing variation.

12.2 Subcommittee D18.05 is seeking any pertinent data from users of these test methods that might be used to make a limited statement on precision.

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

13. Keywords

13.1 compacted specimens; consolidated; direct-shear test; drained test conditions; intact; Mohr strength envelope; reconstituted specimens; shear strength

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D3080–04, that may impact the use of this test method. (Approved November 1, 2011)

(*1*) Extensive editorial changes to clarify text and renumber sections to accommodate more substantial changes. The following items are only the substantial changes. Section and note numbers are referenced to this revision. Summary of changes do not state specific relocations of section material or notes.
(*2*) Changed standard number and modifications to make dual units.
(*3*) Section 1.1 to clarify the Method covers only one test.
(*4*) Added section 1.6 on test series.
(*5*) Added section 1.8 on Units.
(*6*) Add reference in Section 2.
(*7*) Added definitions 3.2.2, 3.2.4, 3.2.5, and 3.2.6.
(*8*) Modified section 4.1 relative to strain rate.
(*9*) Section 5.2 added statement on shear rate.

(*10*) Added Note 1 relative to fast tests.
(*11*) Section 5.5 added requirement.
(*12*) Added section 5.6 on contact area changes.
(*13*) Section 6.2 added requirement to shear box.
(*14*) Section 6.3 new requirement to check stones.
(*15*) Note 4 (and throughout) change permeability to hydraulic conductivity.
(*16*) Note 4 added guidance on stone care.
(*17*) Section 6.4.1 added option to use screw driven load frame for normal force.
(*18*) Section 6.4.2 moved shear rate requirement to suggestion in Note 5
(*19*) Added guidance to Note 6.
(*20*) Section 6.4.3 added title.
(*21*) Added Section 6.5 specifying normal force measurement.
(*22*) Section 6.7 changed SI resolution.
(*23*) Section 6.8 added function.
(*24*) Added section 6.10 for specification of test water.
(*25*) Section 7 changed title and reorganized some of the sections.
(*26*) Section 7 separated into Intact, Reconstituted and Compacted sections.
(*27*) Section 7.1 changed undisturbed to intact throughout standard.
(*28*) Section 7.1 clarified that standard is for one test but sample should be large enough for test series.
(*29*) Section 7.1 added method to trim specimens.
(*30*) Section 7.2 added method to process material and changed USCS symbols.
(*31*) Section 7.3 clarified method to form specimen.
(*32*) Section 7.4 added requirement.
(*33*) Section 8.1 added some flexibility to method which was previously in note.
(*34*) Section 8.2 changed specification on calibration disk.
(*35*) Added section 8.3 and renumbered subsequent sections.
(*36*) Added section 8.6 specifying when correction is necessary.
(*37*) Section 9.1 altered method to be consistent with section 7.
(*38*) Added clarification to Note 10.
(*39*) Section 9.2 added requirement.
(*40*) Section 9.4 added moment break.
(*41*) Section 9.6 added clarification to seating load.
(*42*) Note 12 added clarification.
(*43*) Section 9.7 added requirement.
(*44*) Section 9.8 added clarification and reference to D2435.
(*45*) Section 9.8.1 new procedural step.
(*46*) Added Note 13 for clarification.
(*47*) Added Section 9.8.2 for intermediate consolidation increments.
(*48*) Section 9.8.3 added requirements for time deformation data.
(*49*) Section 9.8.4 new requirement for overconsolidated tests
(*50*) Section 9.8.5 moved information from prior note.
(*51*) Section 9.9 changed gap specification.
(*52*) Added Note 14 identifying potential problem.
(*53*) Section 9.10 completely reorganized and added some discussion to clarify method of interpretation. Added numbering of equations.
(*54*) Section 9.10.1 specification for the log time method.
(*55*) Section 9.10.2 specification for the root time method and changed equation 2.
(*56*) Section 9.10.3 added default time based on material type and high OCR specimen.
(*57*) Added Note 15 with rationale and clarification.
(*58*) Added section 9.10.4 which was mandatory material in a note.
(*59*) Section 9.10.5 new terms in same equation.
(*60*) Section 9.11 reorganized for shearing and add specification of shear rate.
(*61*) Section 9.11.3 increase rate of data collection.
(*62*) Add section 9.11.4 which was information in a note and is now required.
(*63*) Section 9.11.5 change termination requirement.
(*64*) Added note 17 for clarification.
(*65*) Section 9.12 add clarification.
(*66*) Section 9.13 add requirement.
(*67*) Add Section 10.1 for clarification.
(*68*) Section 10.2 clarify units and significant digits.
(*69*) Equation 5 fix equation symbol.
(*70*) Equation 6 change symbol for displacement rate.
(*71*) Section 10.2.4 change equation and symbols.
(*72*) Section 10.4 add requirement,
(*73*) Section 11 change reporting requirements in several locations.
(*74*) Section 12 change to standard precision caveat.
(*75*) Change title of Figure 1.