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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 of the failure zone 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 results of the test are affected by the presence of coarse-grained soil or rock particles, or both, which may make the testing data invalid in some cases. Check requirements of maximum soil particle size in 6.2.1 and 6.2.2.

1.4 Test conditions, including normal stress, access to water during consolidation and shearing, and specimens conditions should be selected to represent the field conditions being investigated and are left to the engineer or office requesting the test. The rate of shearing must be slow enough to ensure drained conditions.

1.5 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. The development of criteria to interpret and evaluate test results is left to the engineer or office requesting the test. 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.

1.6 This test method limits the maximum particle size of the test specimen based on the size of the shear box. Likewise, the gap size during shear is specified. It is acceptable for the testing requester to require a certain gap size between the upper and lower shear box halves to accommodate certain sand size particles. Presently there is insufficient information available for specifying the gap dimension based on particle size distribution.

1.7 *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 nonconformance with the standard.

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

1.7.2 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This practice implicitly combines two separate systems of units; the absolute and the gravitational systems. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit of mass. However, the use of balances and scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.8 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this test method.

1.8.1 For purposes of comparing a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal of significant digits in the specified limit.

1.8.2 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope

[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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*A Summary of Changes section appears at the end of this standard of these test methods to consider significant digits used in analysis methods for engineering design.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

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))

D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes

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

D2435/D2435M 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 Procedures)

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/D4220M Practices for Preserving and Transporting Soil Samples (Withdrawn 2023)[3]

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 and Data Records in Geotechnical Data

D6027/D6027M Practice for Calibrating Linear Displacement Transducers for Geotechnical Purposes

D6913/D6913M Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

3. Terminology

3.1 *Definitions:*

3.1.1 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 *fabricated slurry specimen*—laboratory reconstituted specimen formed by consolidating a slurry to a specified water content.

3.2.2 *failure criterion*—(Generically defined in Terminology D653.) For this standard, *failure criterion* 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.

3.2.3 *nominal normal stress—in the direct shear test*, the applied normal (vertical) force divided by the area of the shear box.

3.2.3.1 *Discussion*—The contact area of the specimen on the imposed shear plane decreases during shear and hence the true normal stress is unknown.

3.2.4 *nominal shear stress—in the direct shear test*, the applied shear force divided by the area of the shear box.

3.2.4.1 *Discussion*—The contact area of the specimen on the imposed shear plane decreases during shear and hence the true shear stress is unknown.

3.2.5 *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.

3.2.6 *pre-shear—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.

3.2.7 *relative lateral displacement*—the displacement between the top and bottom shear box halves.

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.

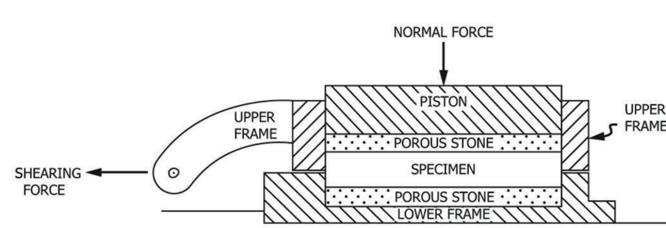

FIG. 1 Test Specimen in Single Shear Apparatus

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

5. Significance and Use

5.1 The direct shear test is suited to the relatively rapid determination of the drained friction angle of soils under consolidated drained conditions because the drainage paths through the test specimen are short, allowing excess pore pressure to dissipate more rapidly than other drained strength tests. It is applicable for testing intact, or reconstituted specimens. There is, however, a limitation on the maximum particle size (see 6.2.1 and 6.2.2).

5.2 The testing protocols represent a field situation where complete consolidation has occurred under the existing normal stresses. Failure is reached slowly under drained conditions to allow excess pore pressure dissipation during shear. The shear rate must meet the requirements of 9.10. The results from several tests may be used to express the relationship between normal stress on the failure plane 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 and 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 There are some limitations of the test, such as nonuniformity of shear stress on the failure plane and possibilities of nonuniformity of the failure plane due to nonuniformities within the soil and applied forces (moments caused by top half of shear box movement either up or down during shearing, and the like). Furthermore, when testing intact stiff clays, which are highly overconsolidated, there might be fissures or other discontinuities to cause excessive tilting, vertical movement (up or down) while shearing, and the like, and which, would nullify the use of the direct shear test.

5.5 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—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 test method 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 *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 height 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 fail 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 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, and the like. The use of dissimilar metals, which may cause galvanic action, is 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 shall 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 height shall be 0.75 in. [20 mm], and not less than six (6) times the maximum particle diameter.

6.2.3 The minimum specimen diameter or width to height ratio shall be 2.0 or greater.

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 porous insert shall be substantially greater than that of the soil, but shall be textured fine enough to prevent excessive intrusion of the soil into the pores of the insert; see Note 4. The diameter or width of the top porous insert or plate shall be 0.01 to 0.02 in. [0.25 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 shall not be so irregular as to cause substantial stress concentrations in the soil. Porous inserts shall be checked for clogging on a regular basis.

NOTE 4—Exact criteria for porous insert texture and hydraulic conductivity have not been established. The inserts have to be porous enough to allow drainage and make sure water can flow into the specimen to remove any capillary stresses within the test specimen. 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 shall be checked on a regular schedule to verify the mass of individual weights and the functionality of the lever mechanism. All systems with adjustable force application (for example, 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 by 9.10 may produce partially drained shear results that will differ from the drained strength of the material.

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 will be sheared under a greater applied normal force. In addition, the top half of the shear box has to be supported in such a manner that it is free to move up and down during shearing without changing the normal stress on the shear plane greater than 1 percent of the 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 the height (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. [0.025 mm]. D6027/D6027M 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 inserts 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 may 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 during trimming.

6.12 *Balances*—A balance or scale conforming to the requirements of Specification D4753 readable 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, spatulas, knives, straightedge, wire saws, and the like, 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/D1587M, or other intact tube sampling procedures. Intact samples shall be preserved and transported as outlined for Group C or D samples in Practice D4220/D4220M. 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 shall be sufficiently large so that a test series 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 shall 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. Perform one or more water content determinations on material trimmed from the specimen in accordance with Test Method D2216.

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

NOTE 7—A controlled high-humidity room or laboratory glove box provides an appropriate atmosphere for trimming the specimen.

7.2 *Laboratory Fabricated Slurry Specimens*—Shear testing of fine-grained soils from reconstituted slurries are used, in part, to measure anticipated normally consolidated field conditions where obtaining quality intact field samples proves difficult or not cost effective. Acquire enough material to conduct the required series of tests. Air drying the specimen prior to disaggregation or sieving is allowed. Highly plastic soils, tropical soils and organic soils shall not be air dried. Blend the material to produce a uniform slurry and if necessary, divide into appropriate quantities for each required water content. Allow the moist material to stand prior to specimen preparation in accordance with Table 1.

7.2.1 Take a representative portion of the test batch for water content determination in accordance with D2216. After the water content specimen is secured, immediately place the remainder of the test batch in a sealed container and store in a humidity room or moisture cabinet.

7.2.2 Using the water content of the slurry and the lower desired water content of the fabricated slurry specimen, determine the mass of the slurry that will result in a final height within the direct shear cavity such that the height of the specimen is in accordance with 6.2.2 and its mid-height is at the shear plane within 0.008-in. [2-mm].

7.2.3 To facilitate placing the material into the shear box, reduce the water content of the slurry to 3-5 percentage points above the desired water content. Reduce the water content of the slurry using one of the methods described in 11.1.2.4 of D4318.

7.2.4 Secure the two halves of the shear box with the alignment screws. Place a moist porous insert in the bottom of the shear box. Place saturated filter paper, as prescribed in 6.4 of Standard D2435/D2435M, on the porous insert.

7.2.5 Place all of the test material into the shear box taking care not to leave voids. Level the surface by tapping the shear box with a rubber mallet or using a close-fitting block or screeding tool to level the surface.

7.2.6 Place moist porous insert with saturated filter paper on top of the test specimen. Complete assembling the shear box in the load frame and mount the vertical deformation indicator. Apply a seating load in accordance with 9.6 to take the slack out of the assembly. Zero or record the vertical deformation indicator. Add water or moist cotton to the shear box's reservoir.

TABLE 1 Required Standing Times of Moisturized Specimens

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

7.2.7 Apply incremental loads to achieve the desired specimen height. Allow each load to remain until primary consolidation has been achieved. The number and magnitude of individual loads will vary according to amount of vertical movement required to achieve the desired height and therefore the desired water content. The final height shall be at least ±0.01-in. [0.3-mm] of the desired height.

7.2.8 Remove the alignment screws and set the shear gap using the gap screws and a feeler gauge to achieve a uniform gap.

7.2.9 Proceed with shearing in accordance with 9.9 through 9.13.

7.3 *Reconstituted Specimens*—Specimens shall be prepared using the compaction method, water content, and dry density prescribed by the individual assigning the test. Specimens may be molded by using either kneading or tamping method. One layer of the soil is placed in the shear box and compacted/reconstituted to a known volume by adjusting the number of tamps and the force per tamp to meet the initial specimen height. 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 one-half the area or the shear box. Test specimens may also be prepared by compacting soil using the procedures and equipment used to determine compaction characteristics 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 shall not be aligned with any of the compaction lift interfaces.

7.3.1 Secure the halves of the shear box together and assemble in the shear box bowl. Place a moist porous insert in the bottom of the shear box. Determine total mass of the 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. Perform one or more water content determinations on material representative of the material used to form the specimen in accordance with Test Method D2216.

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.

8. Calibration

8.1 *Apparatus Deformation*—Calibration is needed 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 whenever the equipment deformation exceeds 0.1 % of the initial specimen height. Therefore, only deformation due to specimen consolidation will be reported for completed tests. The following series of steps provide one method of calibrating the apparatus. Other methods of proven accuracy for calibrating the apparatus are acceptable.

8.1.1 Assemble the direct shear device with a copper, aluminum, or steel disk or plate of approximately the same height as the test specimen and at least 0.04 in. [1 mm], but no more than 0.2 in. [5 mm] smaller in diameter or width than the direct shear box. Moisten the porous inserts.

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

8.1.3 Position the normal displacement indicator. Adjust the indicator so that it can measure the change in height of the calibration disk or plate. Record the zero or "no load" reading.

8.1.4 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 height of the test specimen and compression within the test apparatus itself. Recalibration shall be done on an annual basis, or after replacement of major apparatus components.

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

8.3 The metal disk or plate will also deform; however, modification of the apparatus deformation due to this deformation will be negligible for all but extremely large stress levels. If necessary, the compression of the metal disk or plate can be computed and subtracted to the corrections.

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 8—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. It is recommended that the dry mounting method be used for soils that swell when in contact with water. Soils with high swell potential usually require special provisions for the consolidation and shear phase of testing not addressed in this standard.

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

NOTE 9—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 place 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 10—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/D2435M (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.

NOTE 11—An initial load producing a normal stress of approximately 100 lbf/ft^2 [5 kPa] is recommended for specimens reconstituted to a water content close to or less than the liquid limit to avoid extrusion of soil during the first consolidation load. After that, a load increment ratio of one (that is, the load is doubled) is recommended until the desired consolidation stress is reached. Test specimens prepared at a liquidity index of 1.5 or above might require an initial normal stress of around 50 lbf/ft^2 [2.5 kPa] to prevent extrusion.

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 may be filled with potable tap water.

NOTE 12—Flooding the specimen with water eliminates negative pore pressure due to surface tension and also prevents evaporative drying of the specimen 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. In the absence of a specification, performing the test using potable tap water is acceptable.

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 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/D2435M provides details of the loading procedure and suggestions for appropriate time recording schedules. For this load increment, 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. Test Method D2435/D2435M 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 shall be maintained for at least one log 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 pre-shear 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 13—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 shall be used to compute the required shear rate. Subsections 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 over-consolidation ratio. Subsection 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 shall be interpreted as in Test Method D2435/D2435M and the time to failure shall be computed using the following equation:

$$t_f = 50t_{50} \quad (1)$$

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 shall be interpreted as in Test Method D2435/D2435M and the time to failure shall be computed using the following equation:

$$t_f = 11.6t_{90} \quad (2)$$

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 over consolidated (OCR greater than about 2) under the maximum consolidation stress, default values for the time to failure shall be computed based on a normally consolidated coefficient of consolidation for the soil. In the absence of soil specific consolidation data the time shall be based on the soil type. Table 2 provides these default values.

NOTE 14—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 over consolidated 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 versus 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, select a d_f = 0.5 in. of 10 to 20 % of the specimen's shear plane length if the material is normally or lightly over consolidated fine-grained soil, but at least d_f = 0.2 in. [5 mm].

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

$$R_d = \frac{d_f}{t_f} \quad (3)$$

TABLE 2 Minimum Time to Failure of Testing Specimens

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

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 (or set the measurement device to indicate zero), 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, normal and shear forces at the desired interval of displacement or time. Data readings shall be taken often enough to accurately define a shear stress-displacement curve. At a minimum, data should be recorded at relative lateral displacements in in. [mm] of about 0.1, 0.2, 0.3, 0.4, 0.5, 1, 1.5, 2, 2.5, 3, and then every 2 percent of initial specimen height until test completion.

NOTE 15—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 shall be checked periodically to confirm that a gap persists throughout the shearing phase of the test.

9.11.5 The specimen shall be sheared to at least 10 percent relative lateral displacement (3.2.5) unless specific termination criteria are provided by the specifying agency. Stop the motor drive to terminate shearing.

NOTE 16—The shape of the shear force versus displacement curve will depend on the soil type, stress history, and the like. 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.

NOTE 17—If large particles (greater than the requirements listed in 6.2.1 and 6.2.2) are found in the soil after testing, it is recommended that a particle size analysis be performed in accordance with Method D6913/D6913M to confirm the visual observations, and the result provided with the test report.

10. Calculation

10.1 *General*—Typical units are shown for both Imperial 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 1.7 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 total density, initial water content, initial total mass, and initial volume of the total specimen. Specimen volume is determined by measurements of the shear box lengths or diameter and the measured height of the specimen.

10.4 Compute the pre-shear total density based on the values used in 10.3 plus the measured pre-shear normal deformation in 9.9 after consolidation of the last increment is completed.

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 1.8 and Practice D6026.

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

11.2.1 Identification of the material being tested, such as the project identification, boring number, sample number, and depth.

11.2.2 Test number, if any, testing dates and the initials of the person(s) who performed the test.

11.2.3 Description of type of shear device and apparatus identification 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 D6913/D6913M), if obtained (see 7.2).

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

11.3 Record as a minimum the following test specimen data:

11.3.1 Initial height and diameter (width for square shear boxes).

11.3.2 Initial total mass of test specimen.

11.3.3 Initial water content.

11.3.4 Initial and pre-shear total density and pre-shear specimen height.

11.3.5 Initial dry density, see Note 19.

11.4 Record as a minimum the following test data:

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

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

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

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

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

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

11.4.7 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) cannot be determined with any degree of reliability. Therefore these values are not required in the test report.

12. Precision and Bias

12.1 *Precision*—Test data on precision is not presented due to the nature of the soil tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. Also, 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.

12.1.1 Subcommittee D18.05 is seeking any data from users of this test method that might be used to make a limited statement on precision.

12.2 *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; reconstituted specimens; shear strength

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D3080–11, that may impact the use of this test method. (Approved November 1, 2023)

(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) Updated 1.8, 1.9 and added 1.11 to current D18 format.
(3) Section 2 deleted D422 and added D6913/D6913M.
(4) Figure 1 added missing "S" to complete the label as "Shearing Force."
(5) Updated Note 2 to current D18 format.
(6) Subsection 6.15 added for required equipment.
(7) Revised 7.2 and 7.3, and deleted 7.4. Remove Note 9.
(8) Revised 8.1 refer to D2435/D2435M and added 8.3.
(9) Added Note 13 followed by 9.8.
(10) Updated Section 11 to current D18 format.