Designation: D 6467 – 06

Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils[1]

This standard is issued under the fixed designation D 6467; 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 provides a procedure for performing a torsional ring shear test under a drained condition to determine the residual shear strength of cohesive soils. An undisturbed specimen can be used for testing. However, obtaining a natural slip surface specimen, determining the direction of field shearing, and trimming and properly aligning the usually non-horizontal shear surface in the ring shear apparatus is difficult. As a result, this test method focuses on the use of a remolded specimen to measure the residual strength. This test method is performed by deforming a presheared, remolded specimen at a controlled displacement rate until the constant minimum drained shear resistance is offered on a single shear plane determined by the configuration of the apparatus. An unlimited amount of continuous shear displacement can be achieved to obtain a residual strength condition. Generally, three or more normal stresses are applied to a test specimen to determine the drained residual failure envelope. A separate test specimen may be used for each normal stress.

1.2 A shear stress-displacement relationship may be obtained from this test method. However, a shear stress-strain relationship or any associated quantity, such as modulus, cannot be determined from this test method because possible soil extrusion and volume change prevents defining the height needed in the shear strain calculations. As a result, shear strain cannot be calculated but shear displacement can be calculated.

1.3 The selection of normal stresses and final determination of the shear strength envelope for design analyses and the criteria to interpret and evaluate the test results are the responsibility of the engineer or office requesting the test.

1.4 The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximated. All measured and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D 6026.

1.5 *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]

D 422 Test Method for Particle-Size Analysis of Soils

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

D 2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D 2435 Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

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

D 4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

D 6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *consolidated*—soil specimen condition after primary consolidation under a specific normal stress.

3.2.2 *presheared*—soil specimen condition after shearing at least one revolution of the ring in the direction of shear to create a failure surface prior to drained shearing.

3.2.3 *residual shear force*—the shear force being applied to the specimen when the shear resistance neither increases nor decreases with continued shear displacement.

3.2.4 *residual shear strength*—the constant minimum resistance of soil to shear along a fully developed failure surface

[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.

and equals the residual shear force divided by the cross-sectional area of the specimen.

4. Summary of Test Method

4.1 This test method consists of placing the specimen in the annular specimen container, applying a predetermined normal stress through the top loading platen, providing for wetting and draining of the specimen (optional); consolidating the specimen under the normal stress; decreasing the normal stress to yield an overconsolidated specimen; preshearing the specimen by rotating the specimen container against the top loading platen for one revolution; applying a constant rate of shear deformation; and measuring the shearing force and displacement until a constant minimum resistance is reached.

5. Significance and Use

5.1 The apparatus keeps the cross-sectional area of the shear surface constant during shear and shears the specimen continuously in one rotational direction for any magnitude of displacement. This allows clay particles to become oriented parallel to the direction of shear and a residual strength condition to develop.

5.2 The apparatus allows a remolded specimen to be overconsolidated and presheared prior to drained shearing. This simulates the field conditions that lead to a preexisting shear surface along which the drained residual strength can be mobilized.

5.3 The ring shear test is suited to the relatively rapid determination of drained residual shear strength because of the short drainage path through the thin specimen, and the capability of testing one specimen under different normal stresses to quickly obtain a shear strength envelope.

5.4 The test results are primarily applicable to assess the shear strength in slopes that contain a preexisting shear surface, such as old landslides, and sheared bedding planes, joints, or faults.

NOTE 1—Notwithstanding the statements on precision and bias contained in this test method: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent testing. Users of this test method are cautioned that compliance with Practice D 3740 does not ensure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Shear Device*, to hold the specimen securely between two porous inserts. The shear device shall provide a means for applying a normal stress to the faces of the specimen, for measuring changes 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 torque to the specimen along a shear plane parallel to the faces of the specimen. A number of different ring shear devices are commercially available, in practice, or are being developed so a general description of a ring shear device is presented without schematic diagrams. The location of the shear plane depends on the configuration of the apparatus. As a result, the shear plane may be located near a soil/porous insert interface or at the mid-height of the specimen if an upper ring can be separated from a bottom ring as is done in a direct shear box. The device shall have low friction along the inner and outer walls of the specimen container developed during shearing. Friction may be reduced by having the shear plane occur at the top of the specimen container, modifying the specimen container walls with low-friction material, or exposing the shear plane by separating the top and bottom portions of the specimen container. 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 a material such as stainless steel, bronze, or coated aluminum that is not subject to corrosion by moisture or substances within the soil. Dissimilar metals, which may cause galvanic action, are not permitted.

6.2 *Specimen Container*, a device containing an annular cavity for the soil specimen with an inside diameter not less than 50 mm (2 in.) and an inside to outside diameter ratio not less than 0.6. The container has provisions for drainage through the top and bottom. The initial specimen depth, before consolidation and preshearing, is not less than 5 mm (0.2 in.). The maximum particle size is limited to 10 % of the initial specimen height as stated in the test specimen description. Soil extrusion and changes in specimen volume during shear preclude use of the device for undrained testing unless the device can provide a constant volume or undrained condition.

6.3 *Torque Arm/Loading Platen Assembly*, may have different bearing stops for the proving rings, load cells, or force or torque transducers to provide different options for the torque measurement.

6.4 *Porous Inserts*, two bronze or stainless steel porous inserts mounted on the top loading platen and the bottom of the specimen container cavity to allow drainage from the soil specimen along the top and bottom boundaries. The inserts aid in transfer of shear stress to the top and bottom boundaries of the specimen. The inserts must be sufficiently serrated to develop a strong interlock with the soil specimen. The permeability of the inserts 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. The outer and inner diameters of the inserts shall be 0.1 mm (0.004 in.) less, and greater than those of the specimen annular cavity, respectively. The serration should have a depth of between 10 and 15 % of the initial specimen height.

NOTE 2—Exact criteria for porous insert texture and permeability have not been established. For normal soil testing, medium-grade inserts with a permeability of about 5.0×10^{-4} to 1.0×10^{-3} cm/s (0.5 to 1.0×10^{3} ft/year) are appropriate for testing silts and clays. It is important that the permeability of the porous insert is not reduced by the collection of soil particles in the pores of the insert; hence frequent checking and cleaning (by flushing and boiling, or by ultrasonic cleaning) are required to ensure the necessary permeability.

6.5 *Loading Devices*:

6.5.1 *Device for Applying and Measuring the Normal Force*—Normal force is usually applied by a lever-loading yoke that is activated by dead weights (masses). The device shall be capable of rapidly applying and maintaining the normal force to within ±1 % of the specified force.

6.5.2 *Device for Shearing the Specimen*—This device shall be capable of shearing the specimen at a uniform rate of displacement, with less than ±5 % deviation. The rate to be applied depends upon the consolidation characteristics of the soil (see 9.5.1). The rate is usually maintained with an electric motor and gear box arrangement.

6.6 *Shear Force Measurement Device*, two proving rings, load cells, or a torque transducer accurate to measure a force of 0.2 N (0.05 lbf).

6.7 *Water Bath*, container for the shear device and water needed to inundate the specimen.

6.8 *Controlled High-Humidity Room*—If required, for preparing the specimen, such that the water content gain or loss during specimen rehydration is minimized.

6.9 *Deformation Indicators*, dial gage, or other suitable device, capable of measuring the change in thickness of the specimen, with a sensitivity of at least 0.0025 mm (0.0001 in.). Etched scale on circumference of the ring base to measure the degrees traveled, and thus the shear displacement, or other methods capable of obtaining a sensitivity of at least 2°.

6.10 *Equipment for Determination of Water Content*, in accordance in Test Method D 2216.

6.11 *Miscellaneous Equipment*, including timing device with a second hand, site-specific, distilled or demineralized water, mortar, pestle, spatulas, razor blades, straightedge, and so forth.

7. Test Specimen

7.1 The sample used for specimen preparation is to be sufficiently large so that a ring shear specimen and specimens for index property tests can be prepared.

7.2 If an undisturbed specimen is desired, the shear surface sample should be trimmed to produce an annular specimen. This can be accomplished using an annular trimming ring to facilitate trimming and insertion of the specimen into the annular specimen container. A field shear surface may consist of small seams of clayey material surrounded by material with a coarser gradation. If so, only the clayey shear zone material should be tested and not the coarser surrounding material to simulate field shearing conditions. The undisturbed specimen should be trimmed in a controlled temperature and humidity environment to minimize moisture loss or gain.

7.3 Reconstituted silt and clay specimens may be prepared by crushing an air-dried representative sample and passing it through the appropriate sieve, for example, opening size less than or equal to 10 % of the initial specimen height.

7.4 Reconstituted specimens of heavily overconsolidated clays, mudstones, claystones, and shales may be prepared by ball-milling an air-dried representative sample and passing it through the U.S. Standard sieve #200. The ball-milling facilitates disaggregation of the clay particles and reduces the shear displacement required to achieve a residual strength condition. If ball-milling is not used, greater shear displacement will be required to disaggregate the clay particles and achieve a residual strength condition in the apparatus. The additional shear displacement can be large and create testing problems such as significant soil extrusion and wall friction.

7.5 Another technique for obtaining a reconstituted specimen is pushing a representative sample, at the as-received water content, through the appropriate sieve. Soil with more than 25 % organic content is to be reconstituted without drying.

7.6 The reconstituted specimens should be prepared in a controlled temperature and humidity environment to minimize moisture loss or gain.

7.7 After processing, the reconstituted sample should be mixed with site specific water/fluid or distilled water until a water content near the liquid limit is obtained. Using this water content minimizes the amount of air trapped during placement of the soil paste into the annular cavity by increasing the degree of saturation. A water content between the liquid and plastic limits can be used if air will not be trapped in the annular cavity. The sample should then be allowed to rehydrate for 24 h in a high-humidity room.

7.8 Care is to be taken during crushing and mixing operations to avoid introducing impurities into the sample.

7.9 A spatula is used to place the remolded soil paste into the annular specimen cavity. The top of the specimen is planed flush with the top of the specimen container.

7.10 The liquid limit, plastic limit, and clay-size fraction of the specimens are measured using the ball-milled or sieved soil samples that are used to create the test specimen.

8. Calibration

8.1 The calibration is to determine the deformation of the apparatus, exclusive from the specimen, when subjected to the consolidation load. The apparatus deformation at each consolidation load should be subtracted from the observed deformations during a test. Therefore, only deformation caused by specimen consolidation will be reported for complete tests.

8.2 Assemble the ring-shear device with the porous inserts and a metal calibration disk or plate of a thickness approximately equal to the desired test specimen and slightly smaller in width. The metal calibration disk shall have parallel end surfaces finished to a high degree of precision, and be clean without any grit. Similarly, the sample holder shall be clean without any grit. Record the zero or "no load" reading.

8.3 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. Plot the load-deformation relationship 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.

8.4 Remove the calibration disk or plate.

8.5 Calibration for the equipment load-deformation characteristics needs to be performed on the apparatus when first placed in service, or when apparatus parts are changed.

NOTE 3—Other methods of proven accuracy for calibrating the apparatus are acceptable.

9. Procedure

9.1 Assemble the specimen container.

9.2 *Preconsolidation*: