Designation: D6467 – 21$^{\varepsilon 1}$

# Standard Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Fine-Grained Soils[1]

This standard is issued under the fixed designation D6467; 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.

$\varepsilon^1$ NOTE—The standard was editorially updated in January 2022.

## 1. Scope*

1.1 Fine-grained soils in this Test Method are restricted to soils containing no more than 15 % fine sand (100 % passing the 425 µm (No. 40) sieve and no more than 15 % retained on the 75 µm (No. 200) sieve).

1.2 This test method provides a procedure for performing a torsional ring shear test under a drained condition to determine the residual shear strength of fine-grained soils. This test method is performed by shearing a reconstituted, overconsolidated, presheared specimen at a controlled displacement rate until the constant drained shear resistance is established on a single shear surface determined by the configuration of the apparatus.

1.3 In this test, the specimen rotates in one direction until the constant or residual shear resistance is established. The amount of rotation is converted to displacement using the average radius of the specimen and multiplying it by numbers of degrees traveled and 0.0174.

1.4 An intact specimen or a specimen with a natural shear surface can be used for testing. However, obtaining a natural slip surface specimen, determining the direction of field shearing, and trimming and 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 reconstituted specimen to determine the residual strength. An unlimited amount of continuous shear displacement can be achieved to obtain a residual strength condition in a ring shear device.

1.5 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 the height of the shear zone unknown, so an accurate or representative shear strain cannot be determined.

1.6 The selection of effective normal stresses and determination of the shear strength parameters for design analyses are the responsibility of the professional or office requesting the test. Generally, three or more effective normal stresses are applied to a test specimen in a multi-stage test or a new specimen can be used for each effective normal stress to determine the drained residual failure envelope.

1.7 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only and are not considered standard. The values given in parentheses are mathematical conversions to inch-pound units. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.8 All measured and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026 unless superseded by this standard.

1.8.1 The procedures used to specify how data are collected/recorded or 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 of this standard 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.*

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[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**

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

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 Procedures)

D2974 Test Methods for Determining the Water (Moisture) Content, Ash Content, and Organic Material of Peat and Other Organic Soils

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

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

D7928 Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

## 3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

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

3.2.2 *presheared, adj*—soil specimen condition after shearing to 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, n*—the residual shear force is the average 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, n*—the minimum constant resistance of soil to shear along a fully developed failure surface and equals the residual shear force divided by the cross-sectional area of the specimen.

3.2.5 *drained residual strength state, n*—the state at which a soil exhibits residual shear strength and shear stress – shear displacement relationship becomes almost horizontal.

3.2.6 *indurated sediments, n*—sediments hardened by significant pressure and/or cementing agent to create a sedimentary rock such as shale.

## 4. Summary of Test Method

4.1 This test method consists of a consolidation and shear phase. The consolidation phase is accomplished by placing a specimen in the annular specimen container, applying a predetermined effective normal stress, usually in stages, through the top loading platen, providing for wetting and draining of the specimen; consolidating the specimen under each of the effective normal stresses; decreasing the effective normal stress to yield an overconsolidated specimen prior to preshearing for both single and multi-stage tests. The shear phase is accomplished by preshearing the specimen by rotating the specimen container at a slow and constant rate of shear deformation rotation against the top loading platen for at least one revolution; allowing the specimen to equilibrate before drained shearing, applying a slow and constant rate of shear deformation rotation during shearing; and measuring the torque/shearing force, vertical displacement, and rotation displacement until a constant value of shearing resistance is reached.

## 5. Significance and Use

5.1 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, the constant cross-sectional area of the shear surface during shear, unlimited rotational displacement in one direction, and the capability of testing one specimen under different effective normal stresses to obtain clay particles that are oriented parallel to the direction of shear to obtain residual shear strength envelope.

5.2 The apparatus allows a reconstituted specimen to be overconsolidated and presheared prior to drained shearing. Overconsolidation and preshearing of the reconstituted specimen significantly reduces the horizontal displacement required to reach a residual condition, and therefore, reduces soil extrusion, wall friction, and other problems (Stark and Eid, 1993)[3]. This simulates a preexisting shear surface along which the drained residual strength can be mobilized.

5.3 The ring shear test specimen is annular so the angular displacement differs from the inner edge to the outer edge. At the residual condition, the shear strength is constant across the specimen so the difference in shear stress between the inner and outer edges of the specimen is negligible.

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 D3740 are generally considered capable of competent testing. Users of this test method are cautioned that compliance with Practice D3740 does not ensure reliable testing. Reliable testing depends on several factors; Practice D3740 provides a means of evaluating some of those factors.

## 6. Apparatus

6.1 *Shear Device,* to hold the specimen securely between two porous discs. The shear device provides a mean for

[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] Stark, T.D. and Eid, H.T. (1993). "Modified Bromhead Ring Shear Apparatus," *Geotechnical Testing Journal*, ASTM, Vol. 16, No. 1, March, 1993, pp. 100-107.

applying an effective normal stress to the faces of the specimen, for measuring changes in thickness of the specimen, for permitting drainage of water through the porous discs at the top and bottom boundaries of the specimen, and for submerging the specimen in water. The device is capable of applying a torque to the specimen along a shear surface 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 surface depends on the configuration of the specimen container and/or apparatus. As a result, the shear surface may be located near a soil/porous disc 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 surface occur at the top of the specimen container and modifying the specimen container walls with low-friction material. The frames that hold the specimen shall be sufficiently rigid to prevent their distortion during consolidation and 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 thickness, before consolidation and preshearing, is not less than 5 mm (0.2 in.). The maximum particle size for non-indurated soils is limited to 10 % of the initial specimen height as stated in the test specimen description.

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 Discs,* two porous metal discs such as, bronze, stainless steel, carborundum, or corundum, 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 outer and inner diameters of the discs shall be 0.1 mm (0.004 in.) less, and greater than those of the specimen annular cavity, respectively.

6.4.1 The porous discs must have good contact between the disc and the soil and a surface or pattern that develops a strong interlock with the soil specimen to aid in transfer of shear stress to the top and bottom boundaries of the specimen. The discs must be sufficiently serrated to develop a strong interlock with the soil specimen so shearing occurs in the soil and not at the soil-disc interface. If failure occurs at the soil-disc interface, the resulting resistance will be extremely low. This interlock can be accomplished by minimizing the disc surface area in contact with the soil and having part of the disc penetrate into the specimen. The serration must have a depth of between 10 and 15 % of the specimen height before shearing.

6.4.2 The hydraulic conductivity of the discs 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 disc. The porous discs shall be clean and free from cracks, chips, and nonuniformities. New porous discs should be boiled for at least 10 minutes and left in the water to cool to ambient temperature before use. Immediately after each use, clean the porous discs with a nonabrasive brush and boil to remove clay particles that may reduce their permeability. Alternatively, ultrasonic cleaning could be used to clean the porous disc.

NOTE 2—Exact criteria for porous disc texture and hydraulic conductivity have not been established. For normal soil testing, medium-grade discs with a hydraulic conductivity of about $5.0 \times 10^{-4}$ to $1.0 \times 10^{-3}$ cm/s (0.5 to $1.0 \times 10^{3}$ ft/year) are appropriate for testing fine-grained soils.

6.5 *Loading Devices:*

6.5.1 *Device for Applying and Measuring the Normal Force*—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 rotation, without difference in shear displacement rate due to friction. The rate to be applied depends upon the consolidation characteristics of the soil (see 9.6.1). The rate is usually maintained with an electric motor and gear box arrangement.

6.6 *Shear Force Measurement Device,* two proving rings, load cells, in combination with a lever arm or a torque transducer accurate to measure a force of 0.1 N (0.03 lbf).

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

6.8 *Controlled High-Humidity Environment*—For preparing the specimen, such that the water (moisture) content gain or loss during specimen rehydration is minimized.

6.9 *Vertical Deformation Indicators*—Dial gauge, or other suitable device, capable of measuring the change in thickness of the specimen, with a sensitivity of 0.0025 mm (0.0001 in.).

6.10 *Rotational Horizontal Deformation Indicator*—Ring shear device having gauge or 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 1.0 mm or 1.5°.

6.11 *Equipment for Determination of Water Content,* in accordance with Test Method D2216.

6.12 *Sieves*—425 µm (No. 40) and 75 µm (No. 200) sieves conforming with Specification E11.

6.13 *Miscellaneous Equipment,* including timing device that can be read to seconds, site-specific, distilled or demineralized water, mortar, pestle, spatulas, razor blades, straightedge, data sheet or acquisition system to monitor the test, and so forth.

6.14 *Wall Friction Reduction*—Wall friction may be significant during the shearing process causing an overestimate of the residual strength, therefore, minimization of wall friction is necessary. For example, if the specimen container consists of a single piece of metal, the amount of wall friction depends on