Designation: D7608 – 18$^{\varepsilon 1}$

Standard Test Method for Torsional Ring Shear Test to Measure Drained Fully Softened Shear Strength and Stress Dependent Strength Envelope of Fine-Grained Soils[1]

This standard is issued under the fixed designation D7608; 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.

ε[1] NOTE—The standard was editorially updated in January 2022.

1. Scope

1.1 This test method provides a procedure for performing a torsional ring shear test under a drained condition to measure the fully softened shear strength and stress dependent strength envelope of fine-grained soils (using a reconstituted normally consolidated specimen). The fully softened strength and the corresponding stress dependent effective stress strength envelope are used to evaluate the stability of slopes that do not have a pre-existing shear surface but have been subjected to environmental conditions and shear stresses that lead to soil softening, deterioration of the soil fabric, and strength loss. It has been shown (Skempton 1970[2] and 1977[3]) that under these conditions and within the depth zones that have undergone softening, first-time slope failures can occur at effective stress levels that correspond to a fully softened strength envelope. It has also been shown empirically (Skempton 1970[2] and 1977[3]) that fully softened strength of fine grained soils can be approximated by the peak strength of a reconstituted and normally consolidated specimen. In this test method, reconstituted and normally consolidated specimens are sheared at a controlled and constant displacement rate until the peak shear resistance has been obtained. Generally, the drained fully softened failure envelope is determined at three or more effective normal stresses. A separate test specimen must be used for each normal stress to measure the fully softened strength otherwise a post-peak or even drained residual strength will be measured if the same specimen is used at the same or at another effective normal stress because of the existence of a prior shear surface.

1.2 The ring shear apparatus allows a reconstituted specimen to be normally consolidated at the desired normal stress prior to drained shearing. The test results closely simulate the fully softened strength of stiff natural fine-grained soils (Skempton 1970[2] and 1977[3]) and compacted fills of fine-grained soils (Gamez and Stark 2014[4]). This simulates the mobilized shear strength in overconsolidated clays, claystones, mudstones, and shales in natural slopes and compacted fill in manmade slopes, such as, dams, levees, and highway embankments, after the soil has fully softened and attained the fully softened strength condition.

1.3 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 defining the height of the shear zone is difficult and needed in the shear strain calculations. As a result, the height of this shear zone is unknown, so an accurate or representative shear strain can therefore not be determined.

1.4 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 entity requesting the test.

1.5 *Units*—The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.6 *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.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[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] Skempton, A. (1970). "First-time slides in over-consolidated clays." Géotechnique, 20(3), 320–324.

[3] Skempton, A. (1977). "Slope stability of cutting in brown London clay." Proc. 9th Int. Conf. on Soil Mechanics and Foundation Engineering, Society of Soil Mechanics and Foundation Engineering, Tokyo, 261–270.

[4] Gamez, J. and Stark, T.D. (2014). "Fully Softened Shear Strength at Low Stresses for Levee and Embankment Design" ASCE Journal of Geotechnical and Geoenvironmental Engineering, June, 140(9), 06014010-1-06014010-6.

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:*[5]

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
D6467 Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Fine-Grained Soils
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 technical terms used in this test method, refer to Terminology D653.

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 *fully softened shear force*—the shear force being applied to the specimen when the shear resistance begins to decrease with continued shear displacement.

3.2.3 *fully softened shear strength*—the maximum shear resistance of normally consolidated and not presheared soil and equals the fully softened shear force divided by the cross-sectional area of the annular specimen.

4. Summary of Test Method

4.1 This test method consists of placing the soft reconstituted specimen (paste) in the annular specimen container of a ring shear device, applying a predetermined normal stress through the top loading platen, providing for wetting and drainage of the specimen; consolidating the specimen under the applied normal stress; applying a constant rate of shear deformation for fully drained condition; and measuring the shearing force and angular shear displacement until a maximum shear resistance is reached.

5. Significance and Use

5.1 The ring shear apparatus maintains the cross-sectional area of the shear surface constant during shear and shears the specimen continuously in one rotational direction for any magnitude of shear displacement and along the entire specimen cross-sectional area.

5.2 The ring shear apparatus allows a reconstituted specimen to be consolidated at the desired normal stress prior to drained shearing. This simulates the field conditions under which complete softening develops in overconsolidated clays, claystones, mudstones, and shales that do not have a pre-existing shear surface, sheared bedding planes, joints, or faults as described by Skempton (1970[2] and 1977[3]) and unfailed compacted fill slopes (Gamez and Stark 2014[4]) because the fully softened strength corresponds to the peak shear strength of a normally consolidated fine-grained soil. The fully softened strength is only applicable to the soil zones that are subject to the environmental deterioration and applied shear stresses that lead to soil softening, deterioration of soil fabric, and strength loss, which may not be relevant to all slopes and all depths. The fully softened strength should be used in an effective stress/drained stability analysis using a stress dependent strength envelope for slopes with no prior shearing.

5.3 The ring shear test is suited to the determination of the drained fully softened shear strength because of the short drainage path through the thin specimen, small post-peak strength loss in a normally consolidated specimen, and the constant cross-sectional area.

5.4 The ring shear test specimen is annular so the angular displacement differs from the inner radius to the outer radius. This is not significant because a normally consolidated specimen does not exhibit a large post-peak strength loss so the difference in peak shear resistance at the inner radius and outer radius at different displacements is not significant and the ratio of the inner to outer radii of the ring is greater than 0.5 in accordance with Hvorslev (1936)[6].

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;

[5] 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.

[6] Hvorslev, M. J. (1936). "A ring shear apparatus for the determination of the shearing resistance and plastic flow of soils." Proceedings of the 1st International Conference on Soil Mechanics and Foundation Engineering, 2, 125–129.

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 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 discs 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 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 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 during shearing. Friction may be reduced by having the shear surface occur at the top of the specimen container, modifying the specimen container walls with low-friction material, or exposing the shear surface 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 0.5. 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.) when shearing occurs at the top soil/porous disc interface. The maximum particle size 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 bronze or stainless steel porous discs 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 discs should have good contact between the porous 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 porous 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, which will result in too low shear resistances. This can be accomplished by minimizing the porous disc surface area in contact with the soil and having part of the porous disc penetrate into the specimen. 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 porous disc. 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. The serration should have a depth of between 10 and 15% of the specimen height before shearing.

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 5.0×10^{-4} to 1.0×10^{-3} cm/s (0.5 to 1.0×10^{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 displacement, without differences in shear displacement rate due to friction. The rate to be applied depends upon the consolidation characteristics of the soil (see 8.5.1). 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 force or torque transducer with a readability/sensitivity of 0.1 N-m (0.03 lbf-ft).

6.7 *Water Bath,* container for the specimen container 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 *Vertical Deformation Indicators,* dial gauge, 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.).

6.10 *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 in Test Method D2216.

6.12 *Miscellaneous Equipment,* including timing device that can be read to seconds, site-specific, distilled, or demineralized water, mortar, pestle, spatulas, spatula, razor blades, straightedge, data sheet or acquisition system to monitor the test, 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, for example, Atterberg Limits (Test Method D4318) and clay-size fraction (Test Method D7928), can be prepared.