Designation: D7608 – 10

Standard Test Method for Torsional Ring Shear Test to Determine Drained Fully Softened Shear Strength and Nonlinear Strength Envelope of Cohesive Soils (Using Normally Consolidated Specimen) for Slopes with No Preexisting Shear Surfaces[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.

1. Scope

1.1 This test method provides a procedure for performing a torsional ring shear test under a drained condition to determine the fully softened shear strength and nonlinear strength envelope of cohesive soils. The fully softened strength is used to evaluate the stability of slopes that do not have a preexisting shear surface. In addition, the fully softened shear strength corresponds to the peak shear strength of a normally consolidated specimen. This test method focuses on the use of a reconstituted specimen to measure the fully softened strength. This test method is performed by shearing a normally consolidated, reconstituted specimen at a controlled 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 residual strength will be measured if the same specimen is used because of the existence of a 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. This simulates the field conditions under which the fully softened strength develops in overconsolidated clays, claystones, mudstones, and shales.

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 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.

1.4 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 office requesting the test.

1.5 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D422 Test Method for Particle-Size Analysis of Soils
D653 Terminology Relating to Soil, Rock, and Contained Fluids
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)
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 in Geotechnical Data
D6467 Test Method for Torsional Ring Shear Test to Determine Drained Residual Shear Strength of Cohesive Soils

[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.

Current edition approved May 15, 2010. Published July 2010. DOI: 10.1520/D7608–10.

[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. 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 to shear and equals the fully softened shear force divided by the cross-sectional area of the specimen. The fully softened shear strength should be used in an effective stress stability analysis of slopes in overconsolidated clays with no pre-existing shear surface. The shear strength can be represented by a failure envelope and the strength parameters of c' and Φ'.

4. Summary of Test Method

4.1 This test method consists of placing the reconstituted specimen (slurry or paste) 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; applying a constant rate of shear deformation; and measuring the shearing force and 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 displacement and along entire 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 the fully softened strength develops in overconsolidated clays, claystones, mudstones, and shales because the fully softened strength corresponds to the peak shear strength of a normally consolidated clay.

5.3 The ring shear test is suited to the relatively rapid determination of drained fully softened shear strength because of the short drainage path through the thin specimen and failure occurring near the top porous stone.

5.4 The ring shear test minimizes the effect of initial disturbance that may result from adjusting/creating a gap before starting shearing, especially in the direct shear device.

5.5 The test results are primarily applicable to assess the shear strength of overconsolidated soils for drained analysis in slopes that do not have a pre-existing shear surface, 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 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 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.

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 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 operated 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, without stick slip. 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 with a readability/sensitivity 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 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.). 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 D2216.

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 A reconstituted specimen can be obtained by 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.

7.3 Reconstituted 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. Air dried method should not be used for highly plastic soils, tropical soils, and organic soils.

7.4 After sieving, the processed sample is 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 processed sample should be allowed to rehydrate for at least 24 h in a high-humidity room.

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

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

7.7 The liquid limit, plastic limit, and clay-size fraction of the specimens are measured using the soil used to create the test specimen.

8. Procedure

8.1 Assemble the specimen container.

8.2 *Consolidation:*

8.2.1 Place and secure the specimen container (containing the reconstituted specimen) into the empty water bath that is attached to the apparatus. Place the top platen with the moist porous insert over the top of the specimen.

8.2.2 Place a small seating load so that the normal stress applied to the specimen (from the seating load and the top platen) is approximately 3.0 kPa (0.4 psi).

8.2.3 Attach and adjust the vertical displacement measurement device and obtain the initial time and vertical displacement reading.

8.2.4 Fill the water bath with site specific distilled or demineralized water, and keep it full for the duration of the consolidation phase.

8.2.5 Consolidate the specimen to the desired normal stress at which the fully softened strength will be measured using a load increment ratio of unity. For each load increment, verify completion of primary consolidation before proceeding (see Test Method D2435).

8.3 *Wall Friction Reduction:* To reduce the effect of wall friction on the measured shear stress. Wall friction may be significant during the shearing process causing an overestimate of the fully softened shear strength. If the specimen container consists of a single piece of metal, the amount of wall friction depends on the magnitude of top platen settlement into the specimen container, type of soil, and material lining the specimen container walls. In this type of specimen container, the thickness of soil trapped between the inner and outer walls of the specimen container and the upper porous insert should be minimized. If the specimen container can be separated into two pieces, the opening between the upper and lower halves should be wide enough to prevent particles from being trapped in the opening and to ensure that shearing occurs at this opening. Other techniques also can be used to reduce wall friction. Document the wall friction reduction method utilized, if any, in the report.

8.4 *Shearing:*

8.4.1 Select the appropriate displacement rate to minimize shear-induced pore water pressure. The following equation is used as a guide to estimate an appropriate rate of shear:

$$d_r = \frac{d_f}{t_f} \quad (1)$$

where:

d_r = displacement rate, mm/min (in./min),
d_f = estimated shear displacement at failure, mm (in.), and
t_f = estimated total elapsed time to failure, min.

NOTE 3—Rapid shearing of the test specimen may produce partially drained shear results that differ from the drained strength of the material. As a guide, a displacement rate of 0.02 mm/min (0.0008 in./min) is usually required for a clay of high plasticity with an initial specimen height of 5 mm (0.2 in.). This slow displacement rate can be used for other soils if better information to estimate shear rate is unavailable.

NOTE 4—The magnitude of the estimated displacement at failure is dependent on many factors including the type of soil. As a guide, use d_f = 5 mm (0.2 in.) for a clay of high plasticity (CH), and use d_f = 2.5 mm (0.1 in.) for clay of low plasticity (CL).

NOTE 5—The preceding equation is being used to estimate the displacement rate for shearing an intact soil specimen in which the shear displacement required to reach the drained peak strength, or structure failure, can be easily defined.

NOTE 6—Elapsed time to failure can be estimated by the following equation:

$$t_f = 50 \times t_{50} \quad (2)$$

where:

t_{50} = time required for the specimen to achieve 50 % consolidation under the specified normal stress (or increments thereof), min.

8.4.2 Set the displacement rate.

8.4.3 Swing the two proving rings or load cell assemblies toward the torque arm so that the two bearing adjustment rods create a right angle with the bearing stops on the torque arm. Secure the proving ring or load cell assemblies into place using clamps. A torque transducer assembly may not require this step.

NOTE 7—The proving ring, load cell, or force transducer rods must be at a right angle to the torque arm. This produces a force couple at the top of specimen, which facilitates calculation of the shear stress. A small set square is useful in establishing right angles. A torque transducer may not require this procedure.

8.4.4 Record the initial time; vertical and shear displacements; and proving ring, load cell, or force or torque transducer readings. All data must be recorded at significant digits which can be possibly and accurately read from the dials.

8.4.5 Start the apparatus and initiate shear.

8.4.6 Obtain data readings of time, vertical and shear displacement, and shear force at desired intervals of displacement.

8.4.7 After the soil has exhibited a well-defined maximum or peak shear resistance, stop the apparatus. The fully softened strength state has been achieved when the peak shear stress has been reached and the shear resistance begins to decrease, which usually requires a shear displacement of at least 2.5 mm (0.1 in.). This can be verified using the plotting technique in accordance with 10.2.1.

8.4.8 Deactivate shear stress measurement system.

8.4.9 Remove the normal force and swing the proving ring or load cell assemblies away from the torque arm. A torque transducer assembly may not require this step.

8.4.10 Separate the top platen from the specimen container with a sliding motion along the failure plane. Do not pull the top platen perpendicular to the failure surface, because it would damage the specimen. Photograph, sketch, or describe in writing the failure surface.

8.4.11 Remove the specimen so another specimen can be tested. The same specimen cannot be used for a test at another normal stress because the existence of a shear surface will preclude measurement of the fully softened strength.

9. Calculation

9.1 Calculate the following:

9.1.1 Calculate shear stress that resists slippage between the two surfaces of the failure plane as follows:

$$\tau = \frac{3(F_1+F_2)L}{4\pi(R_2^3 - R_1^3)} \quad (3)$$

where:

τ = shear stress, MPa (lbf/in.^{2})
F_1, F_2 = load on the proving rings, load cells, or force transducer, N (lbf)
R_1, R_2 = inner and outer specimen radii, mm (in.), and
L = torque arm length, mm (in.)

9.1.2 Calculate normal stress acting on the failure plane as follows:

$$\sigma'n = \frac{P}{\pi(R_2^2 - R_1^2)} \quad (4)$$

where:

$\sigma'n$ = normal stress, MPa (lbf/in.^{2}), and
P = normal vertical force acting on the specimen, N (lbf).

9.1.3 *Displacement Rate*—Calculate the actual displacement rate by dividing the shear displacement by the elapsed time, or report the rate used for the test.

$$d_r = \frac{d_h}{t_e} \quad (5)$$

where:

d_r = shear displacement rate, mm/min (in./min),
dh = shear displacement, mm (in.) =

$$(\textit{degrees traveled})\left(\frac{\pi}{180°}\right)\left(\frac{R_1+R_2}{2}\right)$$, and

t_e = elapsed time of test, min.

9.2 *Shear Stress—Displacement and Shear Stress—Normal Stress Graphs:*

9.2.1 For each normal stress, prepare a graph of shear stress versus shear displacement. From these graphs, select the value of fully softened shear strength for each normal stress by determining the maximum or peak shear stress value. The maximum shear stress occurs at the peak of the shear stress-shear displacement relationship or where the shear resistance begins to decrease.

9.2.2 Prepare a graph of normal stress versus shear stress using the same scale for each axis. Plot the values of fully softened shear strength determined in 10.2.1 and construct the shear strength envelope to define the fully softened shear strength of the soil as a function of normal stress. The shear strength envelope may be nonlinear, that is, stress dependent, and should pass through the origin.

10. Report and Data

10.1 Report the following information:

10.1.1 Sample identification, project, and location.

10.1.2 Description of ring shear device used in this test method.

10.1.3 Description of soil in the specimen, based on Classification D2487, liquid and plastic limits (Test Method D4318), and grain size data (Test Method D422).

10.1.4 Record specific gravity of soils (Test Method D854).

10.1.5 Initial thickness and radii of soil specimen.

10.1.6 Initial water content of the prepared specimen as it is placed in the test apparatus (Test Method D2216).

10.1.7 Initial percent saturation and final percent saturation of the specimen.

10.1.8 Liquid limit, plastic limit, and clay-size fraction of the test specimen.

10.1.9 Sample preparation procedure used for the reconstituted test specimen.

10.1.10 What technique, if any, was used to minimize wall friction.

10.1.11 Normal stress, rate of shear displacement, and corresponding fully softened shear strength value and specimen thickness changes conforming to the guidelines for significant digits and rounding established in Practice D6026. For example:

10.1.11.1 Normal and shear stresses (kPa)—one significant digit.

10.1.11.2 Displacement rate (mm/min)—three significant digits.

10.1.11.3 Specimen thickness changes (mm)—two significant digits.

10.1.12 Completed test data for each test on a standard form.

10.1.13 For each normal stress, a graph of shear stress versus shear displacement and a graph of shear displacement versus vertical displacement.

10.1.14 A graph of normal stress versus shear stress showing the fully softened shear strength values and the constructed failure envelope.

11. Precision and Bias

11.1 *Precision*—It is not feasible to specify the precision of this test method at this time because no material having an acceptable reference value is available.

11.2 *Bias*—No information can be presented on the bias of this test method because no material having an acceptable reference value is available.

12. Keywords

12.1 consolidated; drained test conditions; fully softened shear strength; reconstituted specimens; ring-shear test; strength envelope