



Designation: D6243/D6243M – 20

# Standard Test Method for Determining the Internal and Interface Shear Strength of Geosynthetic Clay Liner by the Direct Shear Method<sup>1</sup>

This standard is issued under the fixed designation D6243/D6243M; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This test method covers a procedure for determining the internal shear resistance of a geosynthetic clay liner (GCL) or the interface shear resistance between the GCL and an adjacent material under a constant rate of deformation.

1.2 This test method is intended to indicate the performance of the selected specimen by attempting to model certain field conditions.

1.3 This test method is applicable to all GCLs. Remolded or undisturbed soil samples can be used in the test device. See Test Method [D5321/D5321M](#) for interface shear testing of non-GCL geosynthetics. See Guide [D7702/D7702M](#) for a summary of available information related to the evaluation of direct shear results obtained using this test method.

1.4 This test method is not suited for the development of exact stress-strain relationships within the test specimen due to the nonuniform distribution of shearing forces and displacement.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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*

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee [D35](#) on Geosynthetics and is the direct responsibility of Subcommittee [D35.04](#) on Geosynthetic Clay Liners.

Current edition approved March 15, 2020. Published March 2020. Originally approved in 1998. Last previous edition approved in 2016 as D6243/D6243M – 16. DOI: 10.1520/D6243\_D6243M-20.

*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:<sup>2</sup>

[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<sup>3</sup> (600 kN-m/m<sup>3</sup>))

[D1557](#) Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft<sup>3</sup> (2,700 kN-m/m<sup>3</sup>))

[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)

[D3080/D3080M](#) Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions

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

[D4439](#) Terminology for Geosynthetics

[D5321/D5321M](#) Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

[D6072/D6072M](#) Practice for Obtaining Samples of Geosynthetic Clay Liners

[D6496/D6496M](#) Test Method for Determining Average Bonding Peel Strength Between Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners

[D7005/D7005M](#) Test Method for Determining the Bond Strength (Ply Adhesion) of Geocomposites

[D7466/D7466M](#) Test Method for Measuring Asperity Height of Textured Geomembranes

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



## D7702/D7702M Guide for Considerations When Evaluating Direct Shear Results Involving Geosynthetics

### 3. Terminology

3.1 *Definitions*—For definitions of terms relating to soil and rock, refer to Terminology D653. For definitions of terms relating to GCLs, refer to Terminology D4439.

#### 3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adhesion,  $c_a$ ,  $n$* —the y-intercept of the Mohr-Coulomb strength envelope.

3.2.2 *atmosphere for testing geosynthetics,  $n$* —air maintained at a relative humidity of between 50 and 70 % and temperature of  $21 \pm 2^\circ\text{C}$  [ $70 \pm 4^\circ\text{F}$ ].

3.2.3 *GCL,  $n$* —a manufactured hydraulic barrier consisting of clay bonded to a layer, or layers, of geosynthetic materials.

3.2.4 *Mohr-Coulomb friction angle,  $\delta$ ,  $n$* —(angle of friction of a material or between two materials, degrees) the angle defined by the least-squares, “best-fit” straight line through a defined section of the shear strength-normal stress failure envelope; the component of the shear strength indicated by the term  $\delta$ , in Coulomb’s equation,  $\tau = C_a + \sigma_n * \tan(\delta)$  (see 13.6).

3.2.4.1 *Discussion*—The end user is cautioned that some organizations (for example, FHWA, AASHTO, along with state agencies who use these documents) are currently using the Greek letter, Delta ( $\delta$ ), to designate wall-backfill interface friction angle and the Greek letter, Rho ( $\rho$ ), to designate the interface friction angle between geosynthetics and soil.<sup>3,4</sup>

3.2.5 *Mohr-Coulomb shear strength envelope,  $n$* —(angle of friction between two materials) (degrees) the angle whose tangent is the slope of the line relating limiting value of the shear stress that resists slippage between two solid bodies and the normal stress across the contact surface of the two bodies. Limiting value may be at the peak shear stress or at some other failure condition defined by the user of the test results. This is commonly referred to as interface friction angle. **D653**

3.2.6 *secant friction angle,  $\delta_{sec}$ ,  $n$* —(angle of friction of a material or between two materials, °) the angle defined by a line drawn from the origin to a data point on the shear strength-normal stress failure envelope. Intended to be used only for the normal stress on the shearing plane for which it is defined.

3.2.7 *shear strength,  $\tau$ ,  $n$* —the shear force on a given failure plane. In the direct shear test it is always stated in relation to the normal stress acting on the failure plane. Two different types of shear strengths are often estimated and used in standard practice:

3.2.7.1 *peak shear strength*—the largest value of shear resistance experienced during the test under a given normal stress.

3.2.7.2 *post-peak shear strength*—the minimum, or steady-state value of shear resistance that occurs after the peak shear strength is experienced.

3.2.7.3 *Discussion*—The end user is cautioned that the reported value of post-peak shear strength (regardless how defined) is not necessarily the residual shear strength. In some instances, a post-peak shear strength may not be defined before the limit of horizontal displacement is reached.

3.2.8 *shear strength envelope,  $n$* —curvilinear line on the shear stress-normal stress plot representing the combination of shear and normal stresses that define a selected shear failure mode (for example, peak and post-peak).

### 4. Summary of Test Method

4.1 The shear resistance internal to the GCL or between a GCL and adjacent material, or between any GCL combination selected by the user, is determined by placing the GCL and one or more contact surfaces, such as soil, within a direct shear box. A constant normal stress representative of design stresses is applied to the specimen, and a tangential (shear) force is applied to the apparatus so that one section of the box moves in relation to the other section. The shear force is recorded as a function of the horizontal displacement of the moving section of the shear box.

4.2 To define a Mohr-Coulomb shear strength envelope, it is recommended that test points be performed at different normal stresses, selected by the user, to model appropriate field conditions. However, there may be instances where fewer test points are desired (see Note 1). The peak shear stresses, or shear stresses at some post-peak displacement, or both, are plotted against the applied normal stresses used for testing. The test data are generally represented by a best-fit straight line through the peak strength whose slope is the Mohr-Coulomb friction angle for peak strength between the two materials where the shearing occurred, or within the GCL. The y-intercept of the straight line is the cohesion intercept for internal shearing or adhesion intercept for interface shearing. A straight line fit for shear stresses at some post-peak displacement is the post-peak interface strength between the two materials where the shearing occurred, or the post-peak internal strength within the GCL. If the post-peak shear stresses have reached a constant value less than the peak strength, the post-peak strength is the interface residual strength or the internal residual strength.

NOTE 1—There may be some investigative cases where only a single test point is desired. If the field design conditions will experience a range of normal stresses, it is standard industry practice to bracket the normal stress range with tests on both sides of the range, as it is unconservative to extrapolate results outside of the normal stress range tested. When defining a Mohr-Coulomb shear strength envelope over a range of normal stresses, standard industry practice is to use a minimum of three test points. Attempting to define a single linear Mohr-Coulomb shear strength envelope over too large of a normal stress range may prove to be problematic in many cases because most failure envelopes exhibit significant curvature over such a large range, particularly at low normal stresses on the shearing plane.

### 5. Significance and Use

5.1 The procedure described in this test method for determination of the shear resistance for the GCL or the GCL

<sup>3</sup> *LRFD Bridge Design Specifications*, 5th Edition, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2010.

<sup>4</sup> “Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines,” *FHWA GEC 011*, FHWA-NHI-10-024, Vol 1 and FHWA-NHI-10-025, Vol II, U.S. Department of Transportation, Federal Highway Administration (FHWA), Washington, D.C., 2009.

interface is intended as a performance test to provide the user with a set of design values for the test conditions examined. The test specimens and conditions, including normal stresses, are generally selected by the user.

5.2 This test method may be used for acceptance testing of commercial shipments of GCLs, but caution is advised as outlined in 5.2.1.

5.2.1 The shear resistance can be expressed only in terms of actual test conditions (see Notes 2 and 3). The determined value may be a function of the applied normal stress, material characteristics (for example, of the geosynthetic), soil properties, size of sample, moisture content, drainage conditions, displacement rate, magnitude of displacement, and other parameters.

NOTE 2—In the case of acceptance testing requiring the use of soil, the user must furnish the soil sample, soil parameters, and direct shear test parameters. The method of test data interpretation for purposes of acceptance should be mutually agreed to by the users of this standard.

NOTE 3—Testing under this test method should be performed by laboratories qualified in the direct shear testing of soils and meeting the requirements of Practice D3740, especially since the test results may depend on site-specific and test conditions.

5.2.2 This test method measures the total resistance to shear within a GCL or between a GCL and adjacent material. The total shear resistance may be a combination of sliding, rolling, and interlocking of material components.

5.2.3 This test method does not distinguish between individual mechanisms, which may be a function of the soil and GCL used, method of material placement and hydration, normal and shear stresses applied, means used to hold the GCL in place, rate of horizontal displacement, and other factors. Every effort should be made to identify, as closely as is practicable, the sheared area and failure mode of the specimen. Care should be taken, including close visual inspection of the specimen after testing, to ensure that the testing conditions are representative of those being investigated.

5.2.4 Information on precision between laboratories is incomplete. In cases of dispute, comparative tests to determine whether a statistical bias exists between laboratories may be advisable.

5.3 The test results can be used in the design of GCL applications, including but not limited to, the design of liners and caps for landfills, cutoffs for dams, and other hydraulic barriers.

5.4 The displacement at which peak strength and post-peak strength occur and the shape of the shear stress versus shear displacement curve may differ considerably from one test device to another due to differences in specimen mounting, gripping surfaces, and material preparation. The user of results from this standard is cautioned that results at a specified displacement may not be reproducible across laboratories and that the relative horizontal displacement measured in this test at peak strength may not match relative shear displacement at peak strength in a field condition.

## 6. Apparatus

6.1 *Shear Device*—A rigid device to hold the specimen securely and in such a manner that a uniform shear force

without torque can be applied to the tested interface. The device consists of both a stationary and moving container, each of which is capable of containing dry or wet soil and is rigid enough to not distort during shearing of the specimen. The traveling container must be placed on firm bearings and rack to ensure that the movement of the container is only in a direction parallel to that of the applied shear force.

NOTE 4—The position of one of the containers should be adjustable in the normal direction to compensate for vertical deformation of the GCL, soil, and adjacent materials.

6.1.1 Square or rectangular containers are recommended. They should have a minimum dimension that is the greatest of 300 mm [12 in.], 15 times the  $d_{85}$  of the coarser soil used in the test, or a minimum of five times the maximum opening size (in plane) of the geosynthetic tested. The depth of each container should be at least 50 mm [2 in.] or six times the maximum particle size of the coarser soil tested, whichever is greater.

NOTE 5—The minimum container dimensions given in 6.1.1 are guidelines based on requirements for testing most combinations of GCLs and adjacent materials. Containers smaller than those specified in 6.1.1 can be used if it can be shown that data generated by the smaller devices contain no bias from scale or edge effects when compared to the minimum size devices specified in 6.1.1 for specific materials being tested. The user should conduct comparative testing prior to the acceptance of data produced on smaller devices. For direct shear testing involving soils, competent geotechnical review is recommended to evaluate the compatibility of the minimum and smaller direct shear devices.

6.2 *Normal Stress Loading Device*, capable of applying and maintaining a constant uniform normal stress on the specimen for the duration of the test. Careful control and accuracy ( $\pm 2\%$ ) of normal stress is important. Normal force loading devices include, but are not limited to, weights, pneumatic or hydraulic bellows, or piston-applied stresses. For jacking systems, the tilting of loading plates must be limited to  $2^\circ$  from the shear direction during shearing. The device must be calibrated to determine the normal force delivered to the shear plane.

6.3 *Shear Force Loading Device*, capable of applying a shearing force to the specimen at a constant rate of displacement. The horizontal force measurement system must be calibrated, including provisions to measure and correct for the effects of friction and tilting of the loading system. The rate of displacement should be controlled to an accuracy of  $\pm 10\%$  over a range of at least 6.35 mm/min [0.25 in./min] to 0.025 mm/min [0.001 in./min]. The system must allow constant measurement and readout of the applied shear force. An electronic load cell or proving ring arrangement is generally used. The shear force loading device should be connected to the test apparatus in such a fashion that the point of the load application to the traveling container is in the plane of the shearing interface and remains the same for all tests. (See Note 6).

NOTE 6—The operating range of normal and horizontal shear stresses for a device should be limited to between 10 and 90 % of its calibrated range. If a device is used outside this range, the report shall so state and give a discussion of the potential effect of uncertainties in normal stress on the measured results.

6.4 *Displacement Indicators*, for providing continuous readout of the horizontal shear displacement, and if desired, vertical

displacement of the specimen during the consolidation or shear phase, or both. Displacement indicators, such as dial indicators, or linear variable differential transformers (LVDTs), capable of measuring a displacement of at least 75 mm [3 in.] for shear displacement and 25 mm [1 in.] for vertical displacement are recommended. The sensitivity of displacement indicators should be at least 0.02 mm [0.001 in.] for measuring shear displacement and 0.002 mm [0.0001 in.] for measuring vertical displacement.

6.5 *GCL Clamping Devices*, required for fixing GCL specimens to the stationary section or container, the traveling container, or both, during shearing of the specimen. Clamps and grips shall not interfere with the shearing surfaces within the shear box and must keep the GCL specimens flat during testing. Gripping surfaces must develop sufficient shear resistance to prevent nonuniform displacement of the GCL and adjacent geosynthetics. Gripping surfaces must develop sufficient shear resistance to prevent tensile failure within any geosynthetics material outside the specimen area subjected to normal stress. Flat, jaw-like clamping devices are normally sufficient. Textured surfaces or soil must be used to support the top, bottom, or both of the geosynthetic. Where the internal shear resistance of the GCL is to be measured, rough (textured) surfaces must be used on the top and bottom of the GCL to force internal shearing within the GCL. These surfaces must permit flow of water into and out of the test specimen. Work is still in progress to define the best type of textured surfaces. Selection of the type of texture surface should be based on the following criteria:

6.5.1 The gripping surface should be able to fully mobilize the friction between the gripping surface and the outside surfaces of the GCL. The rough surfaces must be able to prevent slip between the GCL and the gripping surface to prevent tensile failure in the geotextile. This requirement also applies to any geosynthetics used to determine interface shear strength of the GCL.

6.5.2 The gripping surface must be able to completely transfer the applied shear force through the outside surfaces into the inside of the GCL. A textured steel gripping surface made of rasps, truss plates, nail boards, or machined angled spikes 1 to 2 mm tall mounted on a rigid substrate have been found to work. Indicate the gripping surface type, spacing, and height on the test report. Gluing of the GCL to a substrate may influence the strength behavior of the GCL and may not be used.

6.5.3 The gripping surface must not extend into the failure plane for internal shear of the GCL. The resulting failure surface for internal shear of GCL should be entirely within the GCL.

NOTE 7—The selection of specimen substrate may influence the test results. For instance, a test performed using a rigid substrate, such as a wood or metal plate, may not simulate field conditions as accurately as that using a soil substrate. However, use of compressible soils as a substrate is not recommended due to the possibility that these soils may compress under the applied normal load to the extent that the intended shear plane is no longer level with the gap between the two halves of the shear box. The user should be aware of the influence of substrate on direct shear resistance data. Accuracy, reproducibility, and relevance to field conditions should be considered when selecting a substrate for testing.

NOTE 8—Gripping and clamping systems vary widely and can be different based on the geosynthetic material being tested. Several authors have successfully used a multitude of systems.<sup>5</sup>

6.6 *Soil Preparation Equipment*, for preparing or compacting bulk soil samples, as outlined in Test Method **D698**, **D1557**, or **D3080/D3080M**.

6.7 *Miscellaneous Equipment*, as required for preparing specimens. A timing device and equipment required for maintaining saturation of the geosynthetic or soil samples, if desired.

## 7. GCL Sampling

7.1 *Lot Sample*—Divide the product into lots, and for any lot to be tested, take the lot sample as directed in Practice **D6072/D6072M** (see **Notes 6 and 7**).

7.2 *Laboratory Sample*—Consider the units in the lot sample as the units in the laboratory sample for the lot to be tested. For a laboratory sample, take a sample extending the full width of the GCL production unit and of sufficient length so that the requirements of **7.3** can be met. Take a sample that will exclude material from the outer edge.

7.3 *Test Specimens*—From each unit in the laboratory sample, remove the three specimens (or fewer if specified by the user) as outlined in **7.3.1**.

7.3.1 Remove specimens for shearing in a direction parallel to the machine, or roll, direction of the laboratory sample and three specimens for shearing in a direction parallel to the cross-machine, or cross-roll direction, if required (see **Notes 9 and 10**). All the specimens should be sufficiently large to fit snugly in the container described in **6.1.1**, and they should be of sufficient size to facilitate clamping. All specimens should be free of surface defects, etc., that are not typical of the laboratory sample. Space the specimens along a diagonal of the unit of the laboratory sample. Take no specimens nearer the edge of the GCL production unit than  $\frac{1}{10}$  the width of the unit.

NOTE 9—Lots for GCLs usually are designated by the producer during manufacturing. While this test method does not attempt to establish a frequency of testing for the determination of design-oriented data, the lot number of the laboratory sample should be identified. The lot number should be unique to the raw material and manufacturing process for a specific number of units, for example, rolls, panels, etc., designated by the producer.

NOTE 10—The shear strength characteristics of some GCLs may depend on the direction tested. In many applications, it is necessary to perform shear tests in only one direction that matches the direction of shear in the installation. In addition, it is often necessary to perform shear tests against a specific side of the geosynthetic that matches the installation. The direction of shear and the side of the GCL specimen(s) must be noted clearly in these cases.

NOTE 11—To understand the shear characteristics of the GCL specimen(s), it may be useful to conduct peel strength tests on the material adjacent to the location the shear test specimen was taken from the laboratory sample. Peel strength testing should be conducted in general accordance with Test Method **D6496/D6496M**, but the number of test specimens is at the discretion of the user.

NOTE 12—To understand the shear characteristics of the geocomposite specimen(s), it may be useful to conduct ply adhesion tests on the material

<sup>5</sup> Fox et al., 1997; Pavlik, 1997; Trauger et al., 1997; Fox et al., 1998; Zanzinger and Alexiew, 2000; Olsta and Swan, 2001; Triplett and Fox, 2001; Marr, 2002; Koerner and Lacy, 2005; Fox et al., 2006; and Allen and Fox, 2007.

adjacent to the location the shear test specimen was taken from the laboratory sample. Ply adhesion testing should be conducted in general accordance with Test Method **D7005/D7005M**, but the number of test specimens is at the discretion of the user.

NOTE 13—To understand the shear characteristics of the textured geomembrane specimen(s), it may be useful to conduct asperity height tests of the shear test specimen(s) prior to shearing (and potentially after shearing). Asperity height testing should be conducted in general accordance with Test Method **D7466/D7466M**, but the number of measurements taken is at the discretion of the user.

## 8. Shear Device Calibration

8.1 The direct shear device must be calibrated to measure the internal resistance to shear inherent to the device. The inherent shear resistance is a function of the geometry and mass of the traveling container, type and condition of the bearings, and type of shear loading system, and the applied normal stress. The calibration procedure described in this section is applicable to certain devices. Other procedures may be required for specific devices. Refer to the manufacturer's literature for recommended calibration procedures. (See **Note 14**).

NOTE 14—Calibration of electronic equipment used in this method and calibration for device friction should be performed at least once per year using traceable reference materials.

8.2 Assemble the shear device completely without placing a specimen inside it. If the device permits, apply a normal stress equal to that for which friction is being measured. If applying a normal stress, some low-friction mechanism such as rollers must be used to resist the normal stress without creating a shear resistance. Some boxes do not permit calibration with a normal stress. Adjust the gap between the upper and lower box to the value used in shear testing. Apply the shear force to the traveling container at a rate of 6.35 mm/min [0.25 in./min]. Record the shear force required to sustain movement of the traveling container for at least 75 mm [3 in.] total shear displacement. Record the applied shear force at 1 mm [0.05 in.] intervals. Determine the average shear force over 75 mm [3 in.] of displacement. Variations in shear force of more than 25 % of the average value may indicate damaged or misaligned bearings, an eccentric application of the shear force, or a misaligned box. The equipment must be repaired if the measured shear force varies by more than 25 % of the average value.

8.3 The maximum shear force recorded is the internal shear correction to be applied to shear force data after the testing of the specimens. The internal shear correction for device friction should not exceed 10 % of the measured peak strength.

## 9. Conditioning

9.1 Maintain samples at the as-received moisture content until ready to cut specimens for testing.

9.2 For tests on GCL without soil, test specimens at the temperature specified in the standard atmosphere for testing geosynthetics. Humidity control normally is not required for direct shear testing.

9.3 When soil is included in the test specimen, the method of conditioning is selected by the user or mutually agreed upon by the user and the testing agency. Material required for the

specimen shall be batched by thoroughly mixing soil with sufficient water to produce the desired water content. Allow the soil to stand prior to compaction in accordance with the following guide:

Classification (by Practice <b>D2487</b> )	Minimum Standing Time, h
SW, SP	No Requirement
SM	3
SC, ML, CL	18
MH, CH	36

9.3.1 In the absence of specified conditioning criteria, as described in **9.4**, the test should be performed at the temperature specified in the standard atmosphere for testing GCLs. Relative humidity control should be performed when specified by the user.

9.4 The minimum user-specified test conditioning criteria include the following:

9.4.1 The test configuration, including all components from the top to bottom (supporting substrates, soil, geosynthetics, GCLs, and gripping surfaces).

9.4.2 Type of clamping, and gripping surfaces, or both.

9.4.3 Compaction criteria for soil(s), including dry unit weight, moisture content, and conditions for compacting the soil adjacent to the GCL or other geosynthetics.

9.4.4 Sample conditioning, such as wetting, soaking/hydration, and consolidation of GCL separately or with entire test section. Wetting should be defined by either pouring water onto the sample or by spraying GCL or other geosynthetic with water. Conditions must be defined during soaking/hydration for the type of fluid, duration of soaking, criteria to define completion of consolidation during soaking, normal stress to be applied during soaking, and whether GCL is to be hydrated by itself or with other interface components assembled. The GCL should be hydrated sufficiently long to come to full hydration unless otherwise specified. Hydration may be performed outside of the shear box under the required conditions and the hydrated specimen then transferred to the shear box, provided (1) the GCL is not damaged by the transfer, (2) the hydrating conditions have not caused bentonite to extrude to the outer faces of the geotextile, and (3) transfer time is kept to a minimum and the specimen is not allowed to dry.

9.4.5 Normal stresses during the shear phase.

9.4.6 Rate of shearing or the procedure for the lab to follow to establish the shear rate must be given (see **10.7** and **11.6**).

## 10. Procedure A – GCL Internal Shear Strength

10.1 Adjust the lower roughened surface so that it is one half the thickness of the GCL below the top of the lower box. Place the GCL over the lower roughened surface in the shear box. The lower roughened surface must be sufficiently rough to prevent slippage between the surface and the bottom of the GCL. The specimen must cover the entire substrate. Half the thickness of the GCL should extend above the top of the lower box. If clamps are used, the GCL should be sufficiently long to permit the bottom geotextile to be clamped to one side of the bottom shear box and the top geotextile to be clamped to the opposite side of the top shear box. The GCL must be flat, free of folds and wrinkles, and in complete contact with the roughened substrate.



10.2 Slide the two halves of the shear box together and fix them in the start position.

10.3 Place a top roughened surface over the GCL specimen. The top plate must be sufficiently rough to prevent slippage between the top of the GCL and the plate. Fix the loading plate and apply the normal stress to the specimen. Gripping and clamping systems currently available may not shear GCL specimens internally under some test conditions, such as tests under low normal loads.

10.4 Apply a normal seating load. If the test is for a wet condition, inundate the specimen and monitor vertical displacements until the sample comes to equilibrium. (See **Note 15.**)

**NOTE 15**—The acceptance sequence for the seating load, normal load, and wetting will depend on the application, as described in 9.4. Insufficient information exists at this time to provide a single application sequence. Tailor the test sequence to application conditions. Use methods described in Test Method **D2435/D2435M** to determine when primary consolidation is complete. Use a degree of primary consolidation of 90 % or more as the equilibrium condition. Avoid applying a single load increment sufficiently large to cause bentonite to squeeze through the geotextile, unless that load increment simulates an actual field condition as requested by the user.

10.5 If the seating load does not equal the normal load for shearing, increase the normal load in steps to avoid squeeze-out of bentonite from the GCL. When the normal load for the shear test is reached, monitor vertical displacements until the sample comes to equilibrium. Verify equilibrium (see **Note 15**) before proceeding. If the GCL has been hydrated in a separate apparatus and transferred to the shear box, apply the same load used in hydration in the shear box and verify equilibrium, or wait for a time period not less than twice the time taken to removal of the seating load in the hydrating box until its reapplication in the shear box. The normal load may have to be applied in increments with time for consolidation allowed in each increment to avoid extrusion of bentonite outside the GCL geotextiles. The GCL should be allowed to fully consolidate under the final increment so that excess pore pressures are essentially zero prior to the start of shear.

10.6 Place and zero the shear displacement indicators onto the traveling container. Assemble the shear force loading device such that the loading ram is in contact with the traveling container, but no shear force is applied. If necessary, adjust the location of the loading ram to minimize the induced moment. Create a gap between the upper box and the lower box. The gap should be just large enough to prevent friction between the boxes during shear.

10.7 Apply the shear force using a constant rate of displacement. The rate of displacement should be specified by the user. The displacement rate should normally be relatively slow so that insignificant excess pore pressures exist at failure, unless the application requires rapid loading to simulate field conditions.

**NOTE 16**—The appropriate rate of horizontal loading for GCLs depends on several factors, including the GCL, the materials on both sides of the GCL, the normal stress level, the hydrating conditions, and the field drainage conditions. Research has shown that rates of 1 mm/min for interface shear and 0.1 mm/min for internal shear provide appropriate shear strengths for design purposes provided the test specimens are fully

hydrated under a normal stress of at least 1 psi and consolidated under a normal stress of 10 psi. Other conditions may require determination of the appropriate hydrating conditions, consolidation conditions, and strain rates to simulate actual field conditions. Some of the older shear boxes for this test cannot displace slower than 0.125 mm/min. This rate is an acceptable substitute for 0.1 mm/min.

**NOTE 17**—Direct shear tests also may be conducted using a constant shear stress approach. This approach can be achieved by three different methods:

- (I) *Controlled Stress Rate Method*, where the shear force is applied to the test specimen under a uniform rate of horizontal force increase until slipping or failure of the test specimen occurs;
- (II) *Incremental Stress Method*, where the shear force is applied in uniform or doubling increments and held for a specific time before proceeding to the next increment, until slipping or failure of the test specimen occurs;
- (III) *Constant Stress (Creep) Method*, where the shear force is applied using Method (I) or (II) until the specified constant shear stress is reached. The constant shear stress is then maintained and the test monitored for the specified duration.

The user shall specify the desired loading conditions for the constant shear stress approach. The laboratory shall clearly indicate the type of test and rates of load application for test run with the constant shear stress approach.

10.8 Record the shear force as a function of displacement. A minimum of 50 data points should be obtained per test.

10.9 Run the test until the shear displacement exceeds 75 mm [3 in.] or other value specified by the user (see **Note 18**). The test may be stopped sooner if the shear force has reached steady state (see **Note 19**).

**NOTE 18**—Some interfaces may require displacement larger than 3 in. to reach a steady-state strength value. Other methods such as reset tests, reversal tests, and drum shear apparatus may be required in these instances.

**NOTE 19**—Shear force may be considered to have reached steady state once it has peaked and exhibits no significant increase or decrease for 12.7 mm [0.5 in.] of shear displacement after reaching peak.

10.10 At the end of the test, remove the normal stress from the specimen and disassemble the device carefully. Inspect the failure surface and clamp area carefully in order to identify the failure mechanisms involved. Note evidence of tensile shear strains within the specimen or at the clamps.

10.11 Evidence of shear strains from testing a specimen that is not typical of other specimens tested may result in discarding of the specimen and retesting. If excessive strains in the specimen or slipping occurs, the test may have to be rerun at a lower normal stress, or the substrate-GCL interface made rougher to prevent slippage.

10.12 At the end of the test, take a sample from the center of the GCL and determine its moisture content.

10.13 Repeat the test at a new normal stress with a new GCL specimen. Test a minimum of three specimens (or less if specified by the user), each at a different normal stress selected by the user.

10.14 Plot the test data as a graph of applied shear force versus shear displacement. For this plot, identify the peak shear force and the post-peak shear force, if reached. Determine the shear displacements for these shear forces. Subtract the internal shear correction determined in 8.3 from these forces to obtain the corrected shear forces for peak and post-peak conditions.