Designation: D 5321 – 02

# Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method[1]

This standard is issued under the fixed designation D 5321; 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 covers a procedure for determining the shear resistance of a geosynthetic against soil, or a geosynthetic against another geosynthetic, under a constant rate of deformation.

1.1.1 The test method is intended to indicate the performance of the selected specimen by attempting to model certain field conditions. Results obtained from this method may be limited in their applicability to the specific conditions considered in the testing.

1.2 The test method is applicable for all geosynthetics.

1.3 The test method is not suited for the development of exact stress-strain relationships for the test specimen due to the non-uniform distribution of shearing forces and displacement.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all 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:*

D 653 Terminology Relating to Soil, Rock and Contained Fluids[2]

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft/lbf/ft$^3$(600 kN/m/m$^3$))[2]

D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56 000 ft-lbf/ft$^3$(2700 kN/m/m$^3$)[2]

D 2435 Test Method for One-Dimensional Consolidation Properties of Soils[2]

D 3080 Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions[2]

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[2]

D 4354 Practice for Sampling of Geotextiles for Testing[3]

D 4439 Terminology for Geotextiles[3]

D 6243 Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method[3]

## 3. Terminology

3.1 Definitions—For definitions of terms relating to soil and rock, refer to Terminology D 653. For definitions of terms relating to geosynthetics, refer to Terminology D 4439.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *adhesion*, $c_a$ *n*—the shearing resistance between two adjacent materials under zero normal stress. Practically, this is determined as the y-intercept of a straight line relating the limiting value of shear stress that resist slippage between two materials and the normal stress across the contact surface of the two materials. **(D 653, D-18)**

3.2.2 *angle of friction*, *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. **(D 653, D-18)**

3.2.3 *atmosphere for testing geosynthetics*, *n*—air maintained at a relative humidity of 65 ± 5 % and temperature of 21 ± 2°C (70 ± 4°F). **(D 4439)**

3.2.4 *coefficient of friction*, *n*—The slope of the line relating limiting value of the shear stress that resists slippage between two materials 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. **(D 653, D-18)**

[1] This test method is under the jurisdiction of ASTM Committee D35 on Geosynthetics and is the direct responsibility of Subcommittee D35.01 on Mechanical Properties.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.13.

3.2.5 *direct shear friction test*, *n—for geosynthetics*, a procedure in which the interface between a geosynthetic and any other surface, under a range of normal stresses specified by the user, is stressed to failure by the horizontal movement of one surface against the other.

3.2.6 *geosynthetic*, *n*—a planar synthetic product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering-related material as an integral part of a man-made project, structure, or system. **(D 4439)**

3.2.7 *limiting value*, *n*—the value of shear stress at some condition, such as the peak value, the ultimate value, or the value at some prescribed displacement.

## 4. Summary of Test Method

4.1 The shear resistance between a geosynthetic and a soil, or other material selected by the user, is determined by placing the geosynthetic and one or more contact surfaces, such as soil, within a direct shear box. A constant normal force 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 The test is performed at a minimum of three different normal stresses, selected by the user, to model appropriate field conditions. The limiting values of shear stresses are plotted against the applied normal compressive stresses used for testing. The test data are generally represented by a best fit straight line whose slope is the coefficient of friction between the two materials where the shearing occurred. The y-intercept of the straight line is the adhesion.

## 5. Significance and Use

5.1 The procedure described in this test method for determination of the coefficient of soil and geosynthetic or geosynthetic and geosynthetic friction by the direct shear method 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 geosynthetics, but caution is advised as outlined below.

5.2.1 The coefficient of soil and geosynthetic friction can be expressed only in terms of the soil used in testing (see Note 1and Note 2). The determined value may be a function of the applied normal stress, geosynthetic material characteristics, soil gradation, soil plasticity, density, moisture content, size of sample, drainage conditions, displacement rate, magnitude of displacement, and other parameters.

NOTE 1—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.

NOTE 2—Testing under this standard should be performed by laboratories experienced in the direct shear testing of soils and meeting the requirements of Practice D 3740

5.2.2 This test method measures the total resistance to shear between a geosynthetic and a supporting material (substratum) or a geosynthetic and an overlying material (superstratum). Total sliding resistance may be a combination of sliding, rolling, interlocking of soil particles and geosynthetic surfaces, and shear strain within the geosynthetic specimen. Shearing resistance may be different on the two faces of a geosynthetic and may vary with direction of shearing relative to orientation of the geosynthetic.

5.2.3 The test method does not distinguish between individual mechanisms, which may be a function of the soil used, method of soil placement, normal and shear stresses applied, rate of horizontal displacement, and other factors. Every effort should be made to identify and record with a sketch, 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 method produces test data that can be used in the design of geosyntheic applications, including but not limited to: the design of geosynthetic-reinforced retaining walls, embankments, and base courses; in applications in which the geosynthetic is placed on a slope; for determination of geosynthetic overlap requirements; or in other applications in which sliding may occur between soil and a geosynthetic or between two geosynthetic materials.

## 6. Apparatus

6.1 *Shear Device*—A rigid device to hold the specimen securely and in such a manner that a shear force without torque can be applied to the specimen. The device consists of both a stationary and moving container, both of which are capable of containing dry or wet soil and are rigid enough to not distort during shearing of the specimen. The traveling container must be placed on firm bearings and rack, or other mechanism, to ensure that the movement of the container encounters low friction and is only in a direction parallel to that of the applied shear force.

NOTE 3—The position of one of the containers should be adjustable in the normal direction to compensate for deformation of the substrate and geosynthetic. Thecontainer should also be aligned to minimize any moment produced by non-colinear forces on the containers.

6.1.1 Square or rectangular containers are recommended and they should have a minimum dimension that is the greater 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 plan) of the geosynthetic tested. The depth of each container that contains soil must be a minimum of 50 mm (2 in.) or six times the maximum particle size of the coarser soil tested, whichever is greater.

NOTE 4—The minimum container dimensions given in 6.1.1 are guidelines based on requirements for testing most combinations of geosynthetics and soils. 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 when compared to the minimum size devices specified in 6.1.1. 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 (±2 %) of the normal stress is important. Normal stress 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° from the shear direction during shearing. The device must be calibrated to determine the normal stress 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 in a direction parallel to the direction of travel of the moving container. The horizontal force measurement system must be calibrated, includng provisions to measure and correct for the effects of friction and tilting of the loading system. The rate of displacement must be controlled to an accuracy of ±10 % over a displacement range of of at least 6.35mm/min (0.25 in/min) to 0.025 mm/min (0.001 in/min). The system must allow constant measurement and readout of the shear force applied. 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 force application to the traveling container is in the plane of the shearing interface and remains the same for all tests.

NOTE 5—The operating range for normal and horizontal stresses for a device must 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 measured forces on the reported results.

6.4 *Displacement Indicators*, for providing readout of the horizontal shear displacement and, if desired, vertical displacement of the specimen during the consolidation or shear phase. Displacement indicatorus such as dial indicators, or linear variable differential transformers (LVDT), capable of measuring a displacement of at least 75 mm (3 in.) for horizontal displacement and 25 mm (1 in.) for vertical displacement are recommended. The sensitivity of displacement indicators should be 0.02 mm (0.001 in.) for measuring horizontal displacement.

6.5 *Geosynthetic Clamping Devices*, required for fixing geosynthetic specimens to the stationary section or container, the traveling container, or both, during shear. Clamps shall not interfere with the shearing surfaces within the shear box and must keep the geosynthetic specimens flat during testing. Flat jaw-like clamping devices are normally sufficient. Textured surfaces or soil must be used to support the top and/or bottom of the geosynthetic. These surfaces must permit flow of water into and out of the test speciment.Work is still in progress to define the best type or textured surfaces. Selection of the type of texture surface should be based on the following criteria:

6.5.1 The gripping surface must be able to prevent the outside surface of the geosynthetic being sheared from slipping to the extent that the geosynthetic fails.

6.5.2 The gripping surface must be able to completely transfer the shear stress through the outside surfaces into the geosynthetic.

6.5.3 The gripping surface must not damage the geosynthetic and should not influence the shear strength behavior of the geosynthetic.

NOTE 6—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. The user should be aware of the influence of substrate on direct shear friction data. Accuracy and reproducibility should be considered when selecting a substrate for testing.

6.6 *Soil Preparation Equipment*, for preparing or compacting bulk soil samples, as outlined in Test Methods D 698 or D 1557 or Method D 3080.

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

## 7. Geosynthetic 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 D 4354 (Note 7 and Note 8).

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 geosynthetic production unit and of sufficient length along the selvage or edge from each sample roll so that the requirements of 7.3 can be met.

7.3 *Test Specimens*—From each unit in the laboratory sample, remove the required number of specimens as outlined below.

7.3.1 Remove a minimum of three 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 (cross-roll) direction, if required (Note 7). 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 selvage or edge of the geosynthetic production unit than 1⁄10 the width of the unit.

NOTE 7—Lots for geosynthetics are usually designated by the producer during manufacturer. While the 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 8—The frictional characteristics of some geosynthetics may depend on the direction tested. In many applications, it is necessary to perform shear test in only one direction. The direction of shear in the geosynthetic specimen(s) must be noted clearly in these cases.

## 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, 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.

8.2 Assemble the shear device completely without placing a specimen inside it. If the design 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 50 mm (2 in.) total horizontal displacement. Record the applied shear force at 2.5 mm (0.1 in) intervals. Determine the average shear force over the 50 mm 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 average shear force recorded is the internal shear correction to be applied to shear force data after the testing of geosynthetics or soil specimens.

## 9. Conditioning

9.1 For geosynthetic friction tests without soil, test specimens must be at the temperature specified in the atmosphere for testing geosynthetics, except that humidity control is normally not required for direct shear testing.

9.2 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. In the absence of specified conditioning criteria, as described in 10, the test should be performed at the temperature specified in the standard atmosphere for testing geosynthetics. Relative humidity control should be performed when specified by the user.

9.3 When the geosynthetic is to be tested in the wet condition, soak the specimen in water for a minimum of 24 h prior to testing (Note 9).

9.4 The minimum user specified test conditions include the following:

9.4.1 The test configuration, including all components, for example, supporting substrates, soil, geosynthetics, and gripping surfaces.

9.4.2 Type of clamping and/or gripping surfaces.

9.4.3 Compaction criteria for soils (S), including dry unit weight, moisture content and conditions for compacting the soil adjacent to the geosynthetic material.

9.4.4 Sample conditioning, such as, wetting and soaking/hydration of the geosynthetic separately or with the entire test setup. Wetting should be defined as either pouring water onto the sample or spraying the surfaces with water. Conditions must be defined during soaking/hydration for the type of fluid, duration of soaking, criteria to define completion of soaking, normal stress to be applied during soaking, and whether the geosynthetic is to be hydrated by itself or with other interface components assembled.

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 rate of shearing (See 10.8and 11.6).

NOTE 9—Geosynthetics that do not absorb measurable quantities of water may not require a 24-h soaking period for this test. Test involving soils may require more or less than 24h of soaking to achieve moisture equilibrium within the entire specimen.

## 10. Procedure A—Geosynthetic on Geosynthetic Interface Friction

10.1 Place the lower geosynthetic specimen flat over a rigid substrate in the lower container of the direct shear apparatus. The substrate may consist of soil, wood, roughened steel plates, or other rigid media. The specimen must cover the entire substrate, and the upper surface of the specimen must extend above the edges of the lower container.

10.1.1 If the test is to be performed using wet specimens, remove the wetted specimen from the conditioning chamber and blot the upper surface of the specimen free of excess surface moisture. Begin the test as soon as possible after removing the specimen from the conditioning chamber.

10.2 Slide the two containers halves of the shear box together and fix them in the start position. Place the upper geosynthetic specimen over the previously placed lower specimen so that both specimens are flat, free of folds, wrinkles, etc., and in complete contact within the test area. The specimen must protrude below the lower surface of the upper container. Only the two specimens are to be in contact within the test area.

10.3 Place the superstratum (soil or textured surface) over the upper specimen so that a uniform stress may be applied over the entire specimen within the test area. Fix the loading plate and apply the normal compressive stress to the specimen.

10.4 Clamp the specimen to constrain failure to the interface between the upper and lower geosynthetic specimens.

10.5 Apply a normal seating load. If the test is for a wet condition, inundate the specimen and monitori vertical displacements until the sample comes to equilibrium. (See Note 10).

NOTE 10—The application sequence for the seating load, normal load, and wetting will depend on the field application as described in 6.5.3. Tailor the test sequence to the application conditions.

10.5.1 If the seating load does not equal the normal load for testing, apply the normal load and monitor vertical displacements until the sample comes to equilibrium. Verify equilibrium (Note 10) before proceeding.

10.6 Place and zero the 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. Create a gap between the upper box and the lower box. The gap should be large enough to prevent friction between the boxes during shear. If necessary, adjust the location of the horizontal loading ram to minimize the induced moment.

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 be sufficiently slow that insignificant excess pore pressures exist at failure. Some applications may require rapid loading to simulate field conditions. In the absence of any material specifications, use a maximum displacement rate of 5 mm/min (0.2 in./min).

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

10.9 Run the test until the applied shear force remains constant with increasing displacement. Displacements ranging from 25 to 75 mm (1 to 3 in.) are generally required to generate a constant shear force for shearing between geosynthetic interfaces. (SeeNote 11).

NOTE 11—Some interfaces may require displacement larger than 3 in. to reach an ultimate or residual strength value. Other methods such as reset tests, reversal tests and drum shear apparatus may be required in these instances if the ultimate or residual strength is required.

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 shear strains within the specimen or at the clamps.

10.10.1 Evidence of shear strains from testing of 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 occur, the test may have to be rerun at a lower normal compressive stress.

10.11 Repeat the test at different normal stresses using new geosynthetic specimens. Test a minimum of three specimens, each at a different normal stress selected by the user.

10.12 Plot the test data as a graph of applied shear force versus horizontal displacement. For this plot, identify the limiting force(s). Determine the horizontal displacements for these shear forces.

## 11. Procedure B—Soil on Geosynthetic Friction

11.1 Place soil or rigid substrate in the lower container, as required. Compact the soil at the specific moisture content to the density desired. If soil is used. fill the lower container with soil so that the surface of the soil specimen protrudes a distance equal to one-half of the $d_{85}$ of the soil, as described in Method D 3080. A protrusion of 1 mm is sufficient for fine-grained soils. Level the soil surface carefully.

11.2 Place the geosynthetic specimen loosely over the substrate. Remove all folds and wrinkles in the geosynthetic. Clamp or otherwise fix the end of the specimen temporarily, and reset it to ensure that the geosynthetic specimen is in complete contact with the soil. Verify that the protrusion of the soil substrate is suitable as outlined in 11.1.

NOTE 12—Some devices permit the soil to be placed on top of the geosynthetic. Similar procedures for placing the soil should be used as described herein with the necessary modifications to place the soil in the upper box.

11.3 Fix the two halves of the shear box in the start position. Clamp or fix the upper half of the shear box so that it cannot move during the next step of preparation.

11.4 Place the upper substrate or soil at the desired density and moisture content in a manner that minimizes damage to the geosynthetic specimen. Apply the seating normal stress. (See Note 13).

NOTE 13—Sections 11.1 through 11.3 apply to commonly occuring test conditions of soil against geosynthetic. Other interface conditions, test conditions and material combinations may be desired to model specific conditions. The test report should describe specific variations made from this standard.

11.4.1 Apply the normal seating load. If the test is for a wet condition, inundate the specimen and monitor the vertical displacements until the sample comes to equilibrium. (See Note 10).

11.4.2 If the seating load does not equal the normal load for testing, apply the normal load for testing and monitor the vertical displacements until the sample comes to equilibrium. Verify that equilibrium is reached before proceeding. (See Note 10).

11.4.3 After the consolidation period, reclamp the geosynthetic speciment to th upper or lower container, as required.

11.5 Place the displacement indicators and assemble the shear loading device as described in 10.5. Create a gap between the upper box and lower box. The gap should be large enough to prevent friction between the boxes during shear but small enough to prevent soil particles from entering into the gap and creating friction. If necessary, adjust the location of the horizontal loading ram to minimize the induced moment.

11.6 Apply the shear force using a constant rate of displacement that is slow enough to dissipate soil pore pressures, as described in Method D 3080 (See Note 14 and Note 15). The rate of shearing should be specified by the user of the test results. If excess pore pressures are not anticipated, and in the absence of a requirement from the user of the test results, apply the shear force at a rate of 1 mm/min (0.04 in./min).

NOTE 14—The appropriate rate of shearing depends on several factors, including the geosynthetic, the materials on both sides of the geosynthetic, the soil, the normal stress level, the hydrating conditions and the drainage conditions. For drained shearing the following equation can be used as a guide to determine the maximum rate of horizontal displacement.

$$R = d_f/50 * t_{50} * 0$$

where:

| | | |
|---|---|---|
| $R$= | = | rate of horizontal displacement, mm/min, |
| $d_f$= | = | estimated horizontal displacement at peak shear stress, |
| $t_{50}$= | = | time required for specimen to reach 50% consolidation under the current normal stress increment. This time is determined from methods described in Test Method D2435 assuming double drainage, min, and |
| $0$= | = | factor to account for drainage conditions on the shear plane. |

Use a value of 4 shear where the geosynthetic has low permitivity or the soil has low permeability. Use a value of 0.002 for shear between a geosynthetic with high permitivity and a pervious soil. At some values of normal stress, the specimen will not exhibit well defined time-displacement curves from which to determine $t_{50}$. In those instances, use a $t_{50}$ determined for a higher normal stress that is sufficient to cause measurable consolidation of the soil. If an alternate value of $t_{50}$ is selected, the rationale for the selection shall be explained with the test results.

NOTE 15—Direct shear test may also 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.

11.7 Record the shear force as a function of horizontal displacement. Record a minimum of 50 data points per test.

11.8 Run the test until the applied shear force remains constant with increasing displacement. Displacements ranging from 25 to 75 mm (1 to 3 in.) are generally required to generate a constant shear force for shearing between geosynthetic and soil interfaces. (See Note 12).

11.9 Remove the normal stress and disassemble the device at the end of the test. Carefully inspect and identify the failure surface and the area of the clamp. Failures should be consistent for all tests in order for the test data to be comparable.

11.10 At the end of the test, remove the soil specimen (if used) to determine the density and moisture content.

11.11 Repeat the procedure for a minimum of two additional normal compressive stresses.

11.12 Plot the test data as a graph of applied shear force versus horizontal displacement. For this plot, identify the limiting value(s) of shear force. Determine the horizontal displacements for these shear forces.

## 12. Calculation

12.1 For tests using soil, calculate the initial and final water content, unit weight, and degree of saturation, if required.

12.2 Calculate the apparent shear stress applied to the specimen for each recorded shear force as follows:

$$T=(F_S–F_{cor}/A_C$$

where:
$T$ = shear stress (kPa),
$F_S$ = shear force (kN),
$F_{cor}$ = correction to shear force for friction (kN), and
$A_C$ = corrected area ($m^2$).

12.2.1 For tests in which the area of specimen contact decreases with increased displacement, a corrected area must be calculated. This will occur in test devices in which the stationary and traveling containers have the same overall plan dimensions. In this case, the actual contact area will decrease as a function of horizontal displacement of the traveling container. For square or rectangular containers, the corrected area is calculated for each displacement reading using the following equation:

$$A_C=A_O-(d\,XW)$$

where:
$A_C$ = corrected area ($m^2$),
$A_O$ = initial specimen contact area ($m^2$),
$d$ = horizontal displacement of the traveling container (m), and
$W$ = specimen contact width in a direction perpendicular to that of shear force application (m).

12.2.2 No area correction may be required for tests in which the stationary container is larger than the traveling container, provided that the horizontal displacement of the traveling container does not result in a decrease in specimen contact area. See Note 16.

NOTE 16—For devices which apply the normal stress to the interface as a constant force, for example by dead weights, any area correction applied to the shear force must also be applied ot the normal force.

12.3 Plot the limiting values of shear stress versus applied normal stress for each test conducted. Limiting values are typically at peak shear stress and at the end of the test. Other limiting values may be specified by the user. The shear stress and normal stress axes must be drawn to the same scale.

12.4 Connect the data points with a straight line. Some judgment and experience may be required to construct this line, which is referred to as the strength envelope. The slope of the failure envelope is the coefficient of friction. The angle of friction is determined using the following equation:

$$\delta_p=\tan^{-1}(\omega_p)$$

where:
$\delta_p$ = angle of friction corresponding to the limiting shear stress (degrees), and
$\omega_p$ = the coefficient of friction corresponding to the limiting shear stress.

Friction angle and adhesion intercept are typically reported for the peak shear stress condition.

12.5 Additionally, the coefficient of friction may be calculated at some condition other than peak horizontal force, such at a specific value of shear displacement or at the end of the test. The procedures in 12.4 can be used to determine a friction angle and adhesion intercept, using the shear stress and normal stress for this other condition. Parameters obtained for a condition other than peak horizontal force should be clearly defined and the condition for which they apply defined.

## 13. Report

13.1 In the report of test results by the direct shear method, include the following information:

13.1.1 Project, name, test number and description of geosynthetic specimens tested and direction of material tested.

13.1.2 Complete information on any soils used in testing, including soil preparation, compaction, moisture, gradation, classification, etc., and the methods used to prepare the soils..

13.1.3 Description of the test apparatus, including container dimensions, loading apparatus, and measuring devices used.

13.1.4 All test conditions, including normal stresses selected, rate of shear loading, soaking condtitions, and clamping methods used. A sketch of the test setup is recommended.

13.1.5 Statement of any departures from the suggested test procedure, including use of the test device outside of its calibrated operating range, as required for special studies, so that the results can be evaluated and used.

13.2 Complete test data, including plots of shear force versus horizontal displacement and a plot of shear stress versus normal stress for the tests conducted. Clearly mark all data points, the failure envelope, and the adhesion and coefficient of friction or friction angle values.

## 14. Precision and Bias

14.1 The precision of this test method is being established.

14.2 *Bias*—The value of the coefficient of friction between a soil and a geosynthetic friction can be defined only in terms of the soil and conditions used during testing. Because of the many variables involved and the lack of a superior standard or referee method, there are no direct data to determine bias.

14.2.1 The value of the coefficient of friction between a geosynthetic and another geosynthetic friction can be defined only in terms of a test method. When this test method is the determining test method, measurements of the coefficient of geosynthetic/soil and geosynthetic/geosynthetic friction have no bias.

14.3 Tests are underway to determine precision for this test method.

## 15. Keywords

15.1 coefficient of friction; direct shear; geosynthetics; performance test