



Designation: D 5321 – 02

Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method¹

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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 Fluids²

D 698 Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft³ (600 kN/m/m³))²

D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56 000 ft-lbf/ft³ (2700 kN/m/m³))²

D 2435 Test Method for One-Dimensional Consolidation Properties of Soils²

D 3080 Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions²

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 Construction²

D 4354 Practice for Sampling of Geotextiles for Testing³

D 4439 Terminology for Geotextiles³

D 6243 Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method³

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* —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 $65 \pm 5\%$ and temperature of $21 \pm 2^\circ\text{C}$ ($70 \pm 4^\circ\text{F}$). (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 1 and 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 geosynthetic 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. The container 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 of 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 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, including 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 $\pm 10\%$ over a displacement 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 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 indicators 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 specimen. 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 $\frac{1}{10}$ the width of the unit.

NOTE 7—Lots for geosynthetics are usually designated by the producer during manufacture. 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