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Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method[1]

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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 displacement or constant stress.

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.

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

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

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

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

D 4439 Terminology for Geosynthetics[3]

D 5321 Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method[3]

D 6072 Guide for Obtaining Samples of Geosynthetic Clay Liners[3]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adhesion, c_a, n*—the shearing resistance between two unlike materials under zero normal stress.

3.2.2 *angle of friction, n*—(angle of friction between solid bodies, °,) the angle whose tangent is the ratio between the limiting value of the shear stress that resists slippage between two solid bodies at rest with respect to each other and the normal stress across the contact surface.

3.2.2.1 *Discussion*—Limiting values may be at the peak shear stress or at some other failure condition defined by the user.

3.2.3 *atmosphere for testing geosynthetics*, *n*—air maintained at a relative humidity of between 50 and 70 % and temperature of 21 ± 2°C (70 ± 4°F).

3.2.4 *coefficient of friction*, *n*—a constant proportionality factor relating normal stress and the corresponding critical shear stress for a defined failure condition.

3.2.5 *cohesion*, *c*, *n*—the portion of the internal shear strength indicated by the term *c*, in Coulomb's equation $\tau = c + \sigma_n \tan(\phi)$.

3.2.6 *direct shear friction test*, *n*—for GCLs, a procedure in which the internal GCL or the interface between a GCL and any other surface, under a range of normal stresses specified by the user, is stressed to failure by the relative movement of one surface against the other.

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

[1] This test method is under the jurisdiction of ASTM Committee D-35 on Geosynthetics and is the direct responsibility of Subcommittee D35.04 on Geosynthetic Clay Liners.

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

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

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 field 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 for a minimum of three different normal stresses, selected by the user, to model appropriate field conditions. 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 generally are represented by a best fit straight line whose slope is the coefficient of friction 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.

5. Significance and Use

5.1 The procedure described in this test method for the shear resistance for the GCL or the GCL 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, generally are 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 Note 1 and Note 2). The determined value may be a function of the applied normal stress, material characteristics, size of sample, moisture content, 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 test method should be performed by laboratories qualified in the direct shear testing of soils, especially since the test results may be dependent 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. Total shear resistance may be a combination of sliding, rolling, interlocking of soil particles, or adjacent surfaces, and shear strain, or a combination thereof, within the GCL specimen.

5.2.3 This 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, 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.

6. Apparatus

6.1 *Shear Device*—A rigid device to hold the specimen securely and in such a manner that a uniform force without torque can be applied to the specimen. The device consists of both a stationary and moving container, each of which is 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 to ensure that the movement of the container 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 GCL and adjacent materials.

6.1.1 Square or rectangular containers are recommended. They should have a minimum dimension that is greater of 300 mm (12 in.), 15 times the d_{35} 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 should be 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 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. 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 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 less than 2° from horizontal during shearing.

NOTE 5—Due to the potential inaccuracies in the normal stress applied by some test devices, the operating range of normal 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.

6.3 *Shear Force Loading Device*, capable of applying a shearing force to the specimen at a constant rate of horizontal displacement (strain controlled), or at a constant horizontal stress (stress controlled) in a direction parallel to the direction of travel of the soil container, or both. The rate of displacement should be controlled to an accuracy of ±10 % over a range of at least 6.35 mm/min (0.25 in./min) to 0.025 mm/min (0.001 in./min). In a constant stress test, the horizontal stress shall be maintained to an accuracy of ±2 % of the normal stress. 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.

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. Dial indicators, or linear variable differential transformers (LVDTs), 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 at least 0.02 mm (0.001 in.) for measuring horizontal 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 shall not interfere with the shearing surfaces within the shear box and must keep the GCL specimens flat during testing. Flat jaw-like clamping devices normally are sufficient for interface testing. Where the internal shear resistance is to be measured, rough (textured) surfaces must be used on the top and bottom of the GCL to cause 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 rough surfaces.

6.5.1 Selection of the type of rough (textured) surface should be based on the flowing criteria:

6.5.1.1 The gripping surface should be able to mobilize fully the friction between the gripping surface and the outside surfaces of the GCL:

6.5.1.2 The gripping surface should be able to transfer completely the shear stress through the outside surfaces into the inside of the GCL:

6.5.1.3 No slippage should occur between the gripping surfaces and the outside surfaces of the GCL, such that a tensile failure occurs within one or both of these surfaces of the GCL:

6.5.1.4 The gripping surface should not damage the outside surfaces of the GCL and should not influence the shear strength behavior of the GCL:

6.5.1.5 The resulting failure surface should be entirely within the GCL.

6.5.2 A textured steel gripping surface made of wood working rasps mounted on a rigid substrate has been found to work. Gluing of the GCL to a substrate may influence the strength behavior of the GCL and should not be used.

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 resistance 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, D 1557, or D 3080.

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 Guide D 6072 (see Note 5 and Note 6).

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 required number of specimens as outlined in 7.3.1.

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 (see Note 7 and Note 8). The specimens should be slightly larger than the inside dimensions in all directions of the soil 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 1⁄10 the width of the unit.

NOTE 7—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 8—The 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. The direction of shear in the GCL specimen(s) must be noted clearly in these cases.

8. Shear Device Calibration

8.1 The direct shear device is 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.

8.2 Assemble the shear device completely without placing a specimen inside it. Do not apply a normal stress. 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.)