INTERNATIONAL

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Standard Guide for Considerations When Evaluating Direct Shear Results Involving Geosynthetics[1]

This standard is issued under the fixed designation D7702/D7702M; 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 guide presents a summary of available information related to the evaluation of direct shear test results involving geosynthetic materials.

1.2 This guide is intended to assist designers and users of geosynthetics. This guide is not intended to replace education or experience and should only be used in conjunction with professional judgment. This guide is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. Not all aspects of this practice may be applicable in all circumstances. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.3 This guide is applicable to soil-geosynthetic and geosynthetic-geosynthetic direct shear test results, obtained using either Test Method D5321/D5321M or D6243/D6243M.

1.4 This guide does not address selection of peak or large-displacement shear strength values for design. References on this topic include Thiel (**1**),[2] Gilbert (**2**), Koerner and Bowman (**3**), and Stark and Choi (**4**).

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 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:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D4439 Terminology for Geosynthetics

D5321/D5321M Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

D6243/D6243M Test Method for Determining the Internal and Interface Shear Strength of Geosynthetic Clay Liner by the Direct Shear Method

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *adhesion,* c_a or *c, n*—the y-intercept of the Mohr-Coulomb shear strength envelope; the component of shear strength indicated by the term c_a, in Coulomb's equation, $\tau = c_a + \sigma \tan \delta$.

3.2.2 *failure envelope, n*—curvi-linear line on the shear stress-normal stress plot representing the combination of shear and normal stresses that define a selected shear failure criterion (for example, peak and post-peak). Also referred to as shear strength envelope.

3.2.3 *Mohr-Coulomb friction angle δ, 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

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[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

defined section of the shear strength-normal stress failure envelope; the component of the shear strength indicated by the term δ, in Coulomb's equation, $\tau = c + \sigma \tan \delta$.

3.2.4 *Mohr-Coulomb shear strength envelope, n*—the least-squares, "best-fit" straight line through a defined section of the shear strength-normal stress failure envelope described in the equation $\tau = c_a + \sigma \tan \delta$. The envelope can be described for any chosen shear failure criteria (for example, peak, post-peak, or residual).

3.2.5 *secant friction angle, δ_{sec}, n*—(degrees) 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 at the shearing normal stress for which it is defined.

3.2.6 *shear strength, τ, 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:

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

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

3.2.6.3 *Discussion*—Due to horizontal displacement limitations of many commercially available shear boxes used to determine interface shear strength, the post-peak shear strength is often specified and reported as the value of shear resistance that occurs at 75 mm [3 in.] of displacement. 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.

4. Significance and Use

4.1 The shear strength of soil-geosynthetic interfaces and geosynthetic-geosynthetic interfaces is a critical design parameter for many civil engineering projects, including, but not limited to: waste containment systems, mining applications, dam designs involving geosynthetics, mechanically stabilized earth structures, reinforced soil slopes, and liquid impoundments. Since geosynthetic interfaces often serve as a weak plane on which sliding may occur, shear strengths of these interfaces are needed to assess the stability of earth materials resting on these interfaces, such as a waste mass or ore body over a lining system or the ability of a final cover to remain on a slope. Accordingly, project-specific shear testing using representative materials under conditions similar to those expected in the field is recommended for final design. Shear strengths of geosynthetic interfaces are obtained by either Test Method D5321/D5321M (geosynthetics) or D6243/D6243M (geosynthetic clay liners). This guide touches upon some of the issues that should be considered when evaluating shear strength data. Because of the large number of potential conditions that could exist, there may be other conditions not identified in this guide that could affect interpretation of the results. The seemingly infinite combinations of soils, geosynthetics, hydration and wetting conditions, normal load distributions, strain rates, creep, pore pressures, etc., will always require individual engineering evaluations by qualified practitioners. Along the same lines, the list of references provided in this guide is not exhaustive, nor are the findings and suggestions of any particular reference meant to be considered conclusive. The references and their related findings are presented herein only as examples available in the literature of the types of considerations that others have found useful when evaluating direct shear test results.

4.2 The figures included in this guide are only examples intended to demonstrate selected concepts related to direct shear testing of geosynthetics. The values shown in the figures may not be representative and should not be used for design purposes. Site-specific and material-specific tests should always be performed.

5. Shear Strength Fundamentals

5.1 Mohr first presented a theory for shear failure, showing that a material experiences failure at a critical combination of normal and shear stress, and not through some maximum normal or shear stress alone. In other words, the shear stress on a given failure plane was shown to be a function of the normal stress acting on that plane (**5**):

$$\tau = f(\sigma) \tag{1}$$

If a series of shear tests at different values of normal stress is performed, and the stress circle corresponding to failure is plotted for each test, at least one point on each circle must represent the normal and shear stress combination associated with failure (**6**). As the number of tests increases, a failure envelope (line tangent to the failure circles) for the material becomes apparent (Fig. 1).

5.2 In general, the failure envelope described by Eq 1 is a curved line for many materials (**5**). For most geotechnical engineering problems, the shear stress on the failure plane is approximated as a linear function of the total or effective normal stress within a selected normal stress range, as shown in Fig. 1. This linear approximation is known as the Mohr-Coulomb shear strength envelope. In the case of total stresses, the Mohr-Coulomb shear strength envelope is expressed as:

$$\tau = c_a + \sigma \tan \delta \tag{2}$$

where:

τ = shear stress,
σ = normal stress,
δ = friction angle (degrees), and
c_a = adhesion.

In the case of effective stresses, the linear failure envelope is:

$$\tau = c'_a + (\sigma - u) \tan \delta \tag{3}$$

or

$$\tau = c'_a + \sigma' \tan \delta'$$