Designation: D 6706 – 01

Standard Test Method for Measuring Geosynthetic Pullout Resistance in Soil[1]

This standard is issued under the fixed designation D 6706; 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 Resistance of a geosynthetic to pullout from soil is determined using a laboratory pullout box.

1.2 The test method is intended to be a performance test conducted as closely as possible to replicate design or as-built conditions. It can also be used to compare different geosynthetics, soil types, etc., and thereby be used as a research and development test procedure.

1.3 The values stated in SI units are to be regarded as standard. The values stated in parentheses are provided for information only.

1.4 *This standard may involve hazardous materials, and equipment. 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 123 Definitions of Terms Relating to Textiles[2]

D 653 Terminology Relating to Soil, Rock and Contained Fluids[3]

D 2905 Statement on Number of Specimens Required to Determine the Average Quality of Textiles[2]

D 3080 Method for Direct Shear Test of Soils Under Consolidated Drained Conditions[3]

D 4354 Practice for the Sampling of Geotextiles[4]

D 4439 Terminology for Geotextiles[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *apertures*, *n*—the open spaces in geogrids which enable soil interlocking to occur.

3.1.2 *atmosphere for testing geosynthetics*, *n*—air maintained at a relative humidity of 60 ± 10 % and a temperature of 21 ± 2°C (70 ± 4°F).

3.1.3 *cross-machine direction*, *n*—the direction in the plane of the geosynthetic perpendicular to the direction of manufacture.

3.1.4 *failure*, *n*—a defined point at which a material ceases to be functionally capable of its intended use.

3.1.5 *geosynthetic*, *n*—a planar 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)**

3.1.6 *junction*, *n*—the point where geogrid ribs are interconnected in order to provide structure and dimensional stability.

3.1.7 *machine direction*, *n*—the direction in the plane of the geosynthetic parallel to the direction of manufacture.

3.1.8 *pullout*, *n*—the movement of a geosynthetic over its entire embedded length, with initial pullout occurring when the back of the specimen moves, and ultimate pullout occurring when the movement is uniform over the entire embedded length.

3.1.9 *pullout force,* (kN), *n*—force required to pull a geosynthetic out of the soil during a pullout test.

3.1.10 *pullout resistance,* (kN/m), *n*—the pullout force per width of geosynthetic measured at a specified condition of displacement.

3.1.11 *rib*, *n*—the continuous elements of a geogrid which are either in the machine or cross-machine direction as manufactured.

3.1.12 *ultimate pullout resistance,* (kN/m), *n*—the maximum pullout resistance measured during a pullout test.

3.1.13 *wire gage*, *n*—a displacement gage consisting of a non extensible wire attached to the geosynthetic and monitored by connection to a dial extensometer, or electronic displacement transducer.

3.2 For definitions of other terms used in this test method refer to Terminology D 123, D 653, and D 4439.

4. Summary of Test Method

4.1 In this method, a geosynthetic is embedded between two layers of soil, horizontal force is applied to the geosynthetic and the force required to pull the geosynthetic out of the soil is recorded.

4.2 Pullout resistance is obtained by dividing the maximum load by the test specimen width.

4.3 The test is performed while subjected to normal compressive stresses which are applied to the top soil layer.

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[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.

Current edition approved Sept. 10, 2001. Published October 2001.

[2] *Annual Book of ASTM Standards*, Vol 07.01.

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

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

4.4 A plot of maximum pullout resistance versus applied normal stress is obtained by conducting a series of such tests.

5. Significance and Use

5.1 The pullout test method is intended as a performance test to provide the user with a set of design values for the test conditions examined.

5.1.1 The test method is applicable to all geosynthetics and all soils.

5.1.2 This test method produces test data, which can be used in the design of geosynthetic-reinforced retaining walls, slopes, and embankments, or in other applications where resistance of a geosynthetic to pullout under simulated field conditions is important.

5.1.3 The test results may also provide information related to the in-soil stress-strain response of a geosynthetic under confined loading conditions.

5.2 The pullout resistance versus normal stress plot obtained from this test is a function of soil gradation, plasticity, as-placed dry unit weight, moisture content, length and surface characteristics of the geosynthetic and other test parameters. Therefore, results are expressed in terms of the actual test conditions. The test measures the net effect of a combination of pullout mechanisms, which may vary depending on type of geosynthetic specimen, embedment length, relative opening size, soil type, displacement rate, normal stress, and other factors.

5.3 Information between laboratories on precision is incomplete. In cases of dispute, comparative tests to determine if there is a statistical bias between laboratories may be advisable.

6. Apparatus

6.1 *Pullout Box*—An open rigid box consisting of two smooth parallel sides, a back wall, a horizontal split removable door, a bottom plate, and a load transfer sleeve. The door is at the front as defined by the direction of applied pullout force. A typical box is shown in Fig. 1.

6.1.1 The box should be square or rectangular with minimum dimensions 610 mm (24 in.) long by 460 mm (18 in.) wide by 305 mm (12 in.) deep, if sidewall friction is minimized, otherwise the minimum width should be 760 mm (30 in.). The dimensions should be increased, if necessary, so that minimum width is the greater of 20 times the D85 of the soil or 6 times the maximum soil particle size, and the minimum length greater than 5 times the maximum geosynthetic aperture size. The box shall allow for a minimum depth of 150 mm (6 in.) above and below the geosynthetic. The depth of the soil in the box above or below the geosynthetic shall be a minimum of 6 times the D85 of the soil or 3 times the maximum particle size of the soil, whichever is greater. The box must allow for at least 610 mm (24 in.) embedment length beyond the load transfer sleeve and a minimum specimen length to width ratio of 2.0. It should be understood that when testing large aperture geosynthetics the actual pullout box may have to be larger than the stated minimum dimensions.

NOTE 1—To remove side wall friction as much as possible a high density polyethylene (HDPE) geomembrane should be bonded to the inside surfaces of the pullout box. The sidewalls may also be covered with a layer of silk fabric, which has been shown to eliminate adhesion and has a very low friction value. Alternatively, a lubricant can be spread on the sidewalls of the box and thin sheets of polyethylene film used to minimize the side wall friction. It should be also noted that the effect of sidewall friction on the soil-geosynthetic interface can also be eliminated if a minimum distance is kept between the specimen and the side wall. This minimum distance is recommended to be 150 mm (6 in.).

6.1.2 The box shall be fitted with a metal sleeve at the entrance of the box to transfer the force into the soil to a sufficient horizontal distance so as to significantly reduce the stress on the door of the box. The sleeve, as shown in Fig. 2, shall consist of two thin plates (no more than 13 mm (0.5 in.) thick) extending the full width of the pullout box and into the

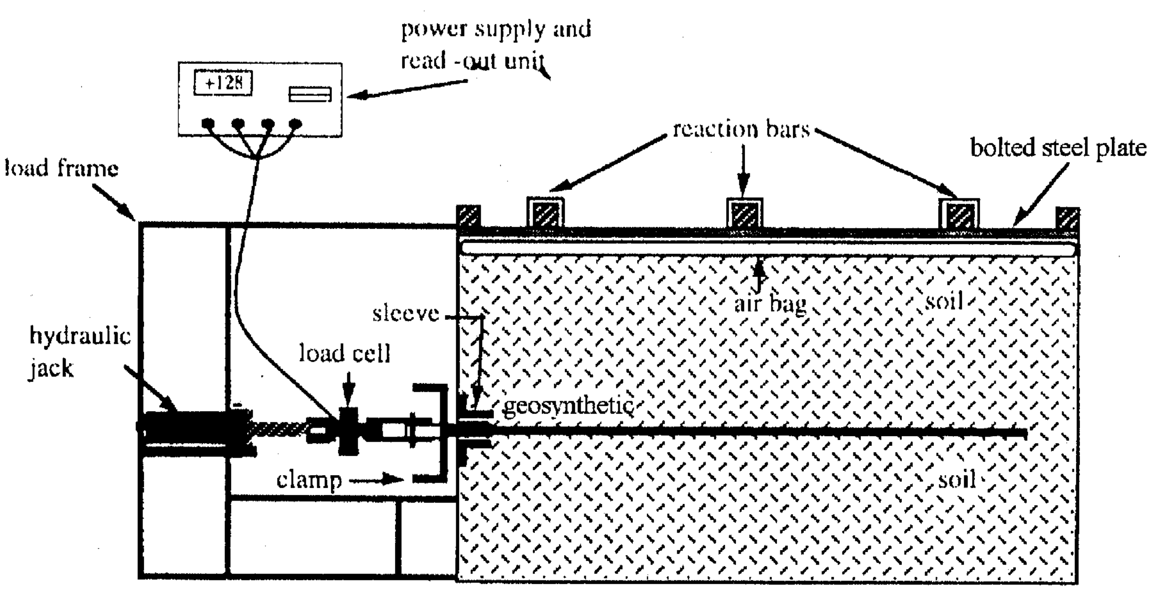

FIG. 1 Experimental Set-Up for Geosynthetic Pullout Testing

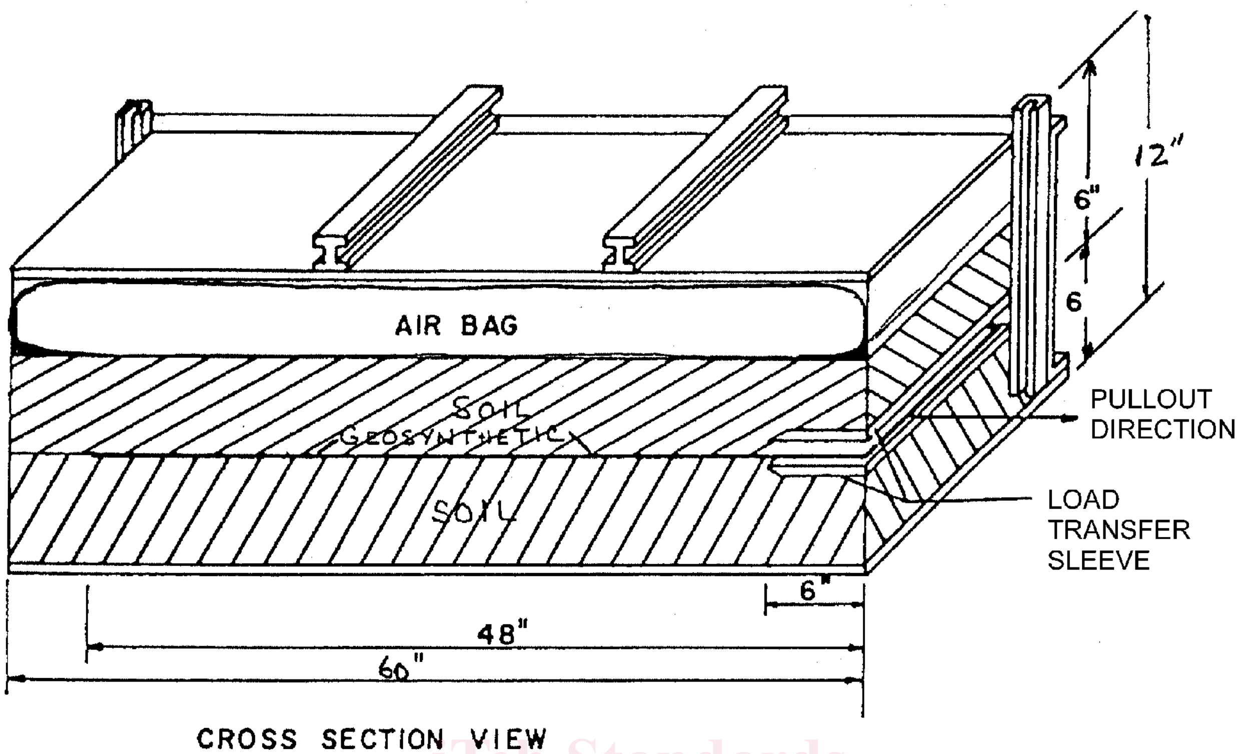

FIG. 2 Cross-Sectional Detail View for Geosynthetic Pullout Setup

pullout box a minimum distance of 150 mm (6 in.) but it is recommended that this distance equal the total soil depth above or below the geosynthetic. The plates shall be tapered as shown in Fig. 2, such that at the point of load application in the soil, the plates forming the sleeve are no more then 3 mm (0.12 in.) thick. The plates shall be rigidly separated at the sides with spacers and be sufficiently stiff such that normal stress is not transferred to the geosynthetic between the plates.

6.2 *Normal Stress Loading Device*—Normal stress applied to the upper layer of soil above the geosynthetic must be constant and uniform for the duration of the test. To maintain a uniform normal stress, a flexible pneumatic or hydraulic diaphragm-loading device which is continuous over the entire pullout box area should be used and capable of maintaining the applied normal stress within ±2 % of the required normal stress. Normal stresses utilized will depend on testing requirements, however, stresses up to 250 kPa (35 psi) should be anticipated. A recommended normal stress-loading device is an air bag is shown in Fig. 2.

6.3 *Pullout Force Loading Device*—Pullout force must be supplied by a device with the ability to pull the geosynthetic horizontally out of the pullout box. The force must be at the same level with the specimen. The pullout system must be able to apply the pullout force at a constant rate of displacement, slow enough to dissipate soil pore pressures as outlined in Test Method D 3080. If excess pore pressures are not anticipated and in the absence of a material specification, apply the pullout force at a rate of 1 mm/min ±10 percent, and the pullout rate should be monitored during testing, see Note 2. Also, a device to measure the pullout force such as a load cell or proving ring must be incorporated into the system and shall be accurate within ±0.5 % of its full-scale range.

NOTE 2—Pullout tests may also be conducted using a constant stress loading approach. This approach can be achieved using one of the three methods described: (*1*) Controlled Stress Rate Method (short-term loading condition) where the pullout force is applied to the geosynthetic under a uniform rate of load application, not exceeding 2 kN/m/min until pullout or failure of the geosynthetic is achieved; (*2*) Incremental Stress Method (short-term loading condition) where the pullout force is applied in uniform or doubling increments and held for a specific time before proceeding to the next increment, as agreed to by the parties involved until pullout or failure of the geosynthetic is achieved; and (*3*) Constant Stress (Creep) Method (long-term loading condition) where the pullout force is applied using one of the first two methods mentioned above to achieve the required constant stress for the test. The constant stress is maintained and the test specimen is monitored over time for the duration of time agreed to by the parties involved (i.e., typically 100 to 10,000 h depending on application). It should be noted that the constant stress procedures described above, have not been widely researched and comparisons with the constant strain method have not been determined.

6.4 *Displacement Indicators*—Horizontal displacement of the geosynthetic is measured at the entrance of the pullout box and at several locations on the embedded portion of the specimen. Measurements outside the door at the pullout box entrance are made by a dial extensometer or electronic displacement transducers (e.g. liner variable differential transformers (LVDT's) can be used) mounted to the box frame to read against a plate attached to the specimen near the door.

6.4.1 Determine the displacement of the geosynthetic at a minimum of three equally spaced distances from the clamping plates. Displacement measurements within the box may employ any of several methods, which place sensors or gauge connectors directly on the geosynthetic and monitor their change in location remotely. One such device utilizes wire gages, which are protected from normal stress by a surrounding tube, which runs from a location mounted on the specimen to the outside of the box where displacements are measured by a dial indicator or electronic displacement transducer. A typical instrumentation setup is shown in Fig. 3.

6.4.2 All dial gauges or electronic measurement devices must be accurate to ± 0.10 mm. Locations of the devices must be accurately determined and recorded. Minimum extension capabilities of 50 mm (2 in.) are recommended.

6.5 *Geosynthetic Clamping Devices*—Clamps which connect the specimen to the pullout force system without slipping, causing clamp breaks or weakening the material may be used, see Note 3. The clamps shall be swiveled to allow the pulling forces to be distributed evenly through out the width of the sample. The clamps must allow the specimen to remain horizontal during loading and not interfere with the pullout/shear surface. Gluing, bonding, or otherwise molding of a geosynthetic within the clamp area is acceptable and recommended whenever slippage might occur.

NOTE 3—A suggested device is shown in Fig. 4 and includes a simple clamp consisting of two, 100 mm (4 in.) wide metal angle pieces with a series of bolts and nuts holding the material between them. One possible modification is the addition of a metal rod behind the back flange which allows looping of the material around the rod and back into the clamp. The use of epoxy bonding within the clamp is generally recommended when accurate measurement of the geosynthetic displacements within the soil are required.

6.6 *Soil Preparation Equipment*—Use equipment as necessary for the placement of soils at desired conditions. This may include compaction devices such as vibratory or "jumping-jack" type compaction, or hand compaction hammers. Soil container or hopper, leveling tools and soil placement/removal tools may be required.

6.7 *Miscellaneous Equipment*—Measurement and trimming equipment as necessary for geosynthetic preparation, a timing device and soil property testing equipment if desired.

7. Geosynthetic Sampling

7.1 *Lot Sample*—Divide the product into lots and for any lot to be tested, take the lot samples as directed in Practice D 4354, see Note 4.

NOTE 4—Lots of geosynthetics are usually designated by the producer during manufacture. While this test method does not attempt to establish a frequency of testing for 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, panel, etc.) designated by the producer.

7.2 *Laboratory Sample*—Consider the units in the lot sample as the units in the laboratory sample for the lot to be tested. Take for a laboratory sample, a sample extending the full width of the geosynthetic production unit, of sufficient length along the selvage or edge from each sample roll so that the requirement of 7.3 can be met. Take a sample that will exclude material from the outer wrap unless the sample is taken at the production site, at which point inner and outer wrap material may be used.

7.3 *Test Specimens*—For each unit in the laboratory sample, remove the required number of specimens. In the absence of a material specification, select a minimum of 3 specimens if pullout force versus normal stress relations are to be established.

7.3.1 Remove the minimum of specimens for pullout testing in a required direction, see Note 5. The minimum embedded

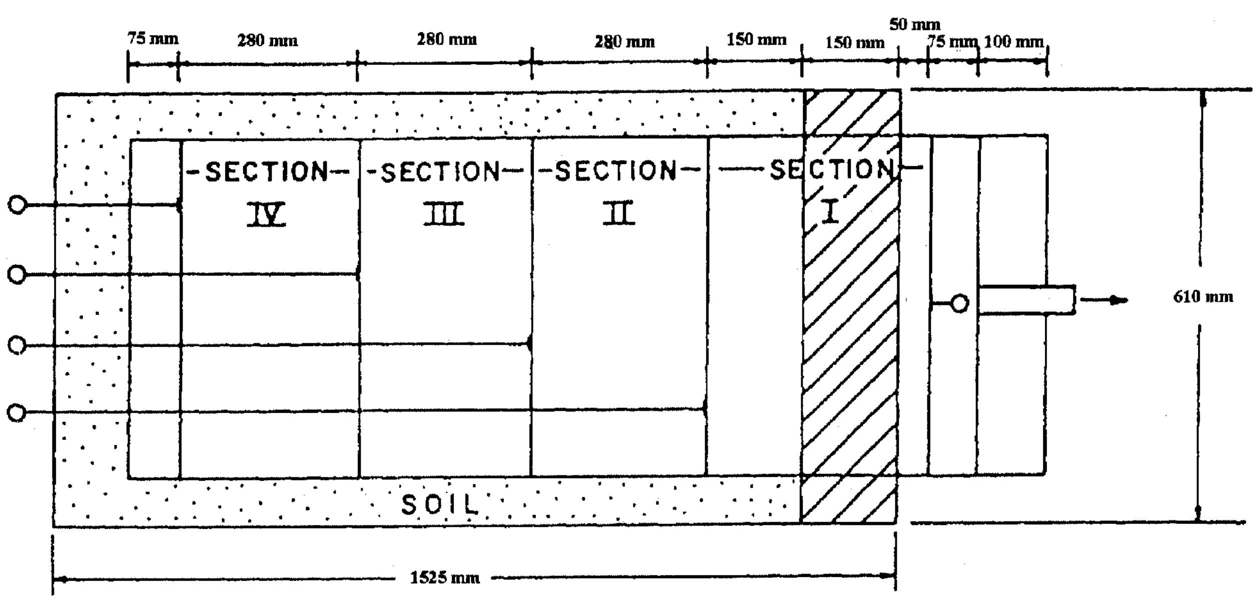

FIG. 3 Plan View and Typical "Tell-Tail" Gage Layout