Designation: D7864/D7864M – 15

Standard Test Method for Determining the Aperture Stability Modulus of Geogrids[1]

This standard is issued under the fixed designation D7864/D7864M; 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 the procedure for measuring the "Aperture Stability Modulus" of a geogrid. (The terms "Secant Aperture Stability Modulus," "Torsional Rigidity Modulus," "In-plane Shear Modulus," and "Torsional Stiffness Modulus" have been used in the literature to describe this same property.)

1.2 This test method is intended to determine the in-plane stability of a geogrid by clamping a center node and measuring the stiffness over an area of the geogrid. This test method is applicable for various types of geogrid.

1.3 This test method is intended to provide characteristic properties for design. The test method was developed for pavement and subgrade improvement calibrated design methods requiring input of aperture stability modulus.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 *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:*[2]

D4439 Terminology for Geosynthetics

D4354 Practice for Sampling of Geosynthetics and Rolled Erosion Control Products(RECPs) for Testing

2.2 *FHWA Document:*[3]

FHWA Geosynthetic Design and Construction Guidelines (2008)

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms used in this test method, refer to Terminology D4439.

3.1.2 *geogrid, n*—a geosynthetic formed by a regular network of integrally connected elements with apertures greater than 6.35 mm [¼ in.] to allow interlocking with surrounding soil, rock, earth, and other surrounding materials to primarily function as reinforcement.

3.1.3 *index test, n*—a test procedure which may contain a known bias but which may be used to establish an order for a set of specimens with respect to property of interest.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aperture*—the openings between adjacent ribs forming an angle which enable soil interlocking to occur.

3.2.2 *aperture stability modulus*—a measure of the in-plane torsional stiffness of a geogrid. This is defined as torque, divided by the rotation at that torque.

3.2.3 *geosynthetic, n*—a product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering material as integral part of a man made project, structure, or system.

3.2.4 *initial aperture stability modulus, n*—the change in moment at 0.5 and 1.0 N-m [4.4 and 8.8 lbf-in.], respectively, divided by the change in angular rotation at these two moment values.

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

3.2.6 *offset aperture stability modulus*—the change in moment at 2.0 and 2.5 N-m [17.7 and 22.1 lbf-in.], respectively, divided by the change in angular rotation at these two moment values.

3.2.7 *rib, n*—for geogrids, the continuous oriented elements of a geogrid which are interconnected to a node or junction.

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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.

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[2] 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.

[3] Available from U.S. Department of Transportation, Federal Highway Administration, 1200 New Jersey Ave., SE, Washington, DC 20590, http://www.fhwa.dot.gov.

4. Summary of Test Method

4.1 A geogrid sample is placed over a square, horizontal opening and the edges are anchored just outside the opening. A rod is clamped vertically on the single center node or junction. A torque is applied to the rod, which twists the clamped node or junction and the geogrid rib matrix, thereby applying a moment causing bending to each of the ribs that intersects the single clamped center node or junction. The torque divided by the angle of rotation is termed the Aperture Stability Modulus expressed in units of N-m/degree [lbf-in./degree].

5. Significance and Use

5.1 The Aperture Stability Modulus is a measure of the in-plane shear modulus, which is a function of other geogrid characteristics, most notably junction stability, flexural rib stiffness, and rib tensile modulus.

5.2 The test data can be used in conjunction with interpretive methods to evaluate the geogrid aperture stability at various traffic loads and base/subgrade conditions.

NOTE 1—Aperture stability modulus is referenced in the FHWA Geosynthetics Design and Construction Guidelines (2008) as an input parameter for the design of geogrid-reinforced unpaved roads using punched and drawn biaxial geogrids. Geogrids of different manufacturing process and material composition may use this property in calibration and validation of their material within the associated design.

5.3 This test method is not intended for routine acceptance testing of geogrid. This test method should be used to characterize geogrid intended for use in applications in which aperture stability is considered relevant.

6. Apparatus

6.1 The apparatus consists of a table, table clamps for the edges of the geogrid, a rod with a center clamp that attaches to the ribs around a node or junction, a loading mechanism, and a method of measuring the moment and the angle of rotation of the rod. A cross section of the apparatus used originally to develop the test method is shown in Figs. 1-4. Other methods of clamping, applying a moment, loading, and measuring have been used by others and are acceptable, subject to the constraints discussed in the following subsections. Details of each part follow.

6.1.1 *Table*—The table shall be constructed so that the geogrid can be laid over a 229-mm [9-in.]-square hole and anchored in place. The geogrid must be placed as it would be in the field, flat but not stretched. This requires a supporting plate beneath the geogrid and a loading plate over the geogrid to keep it flat while it is being laid over the table and clamped around the edges with table clamps. The plate must be large enough to support every node or junction and any part of the geogrid that tends to protrude above or below the planes of the

FIG. 1 Test Apparatus during Test (Loading Plates and Weights Not Shown)

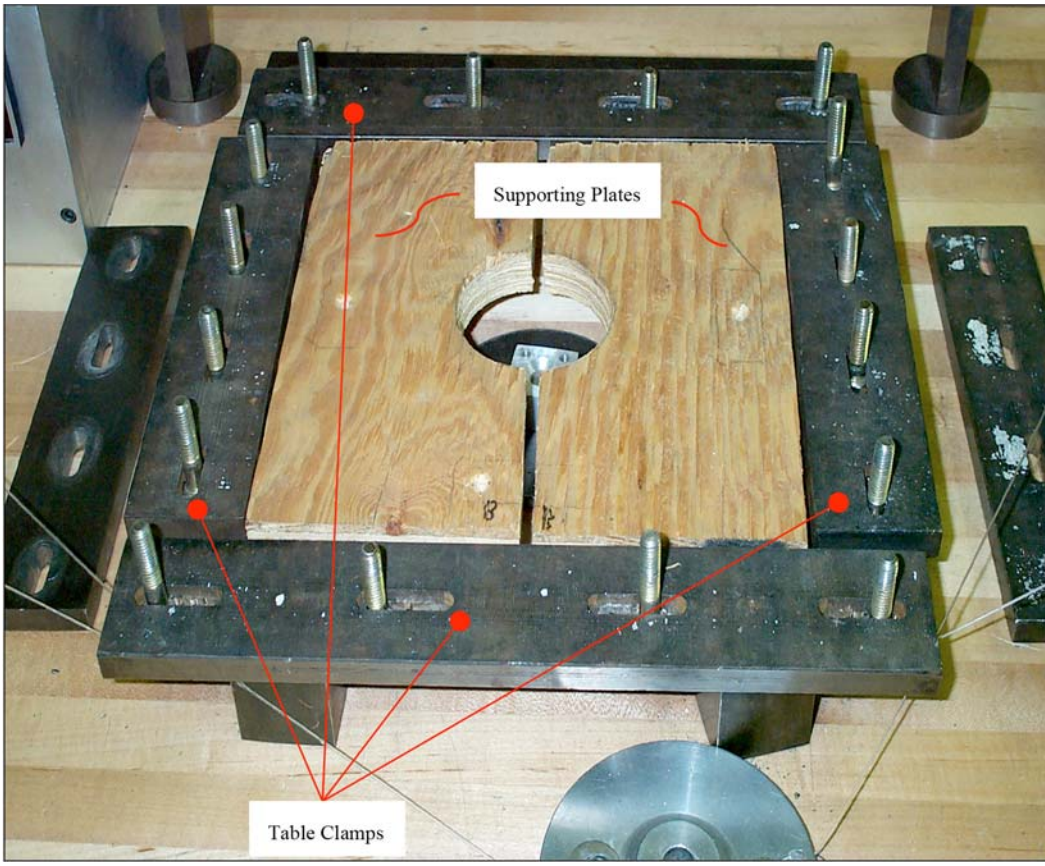

FIG. 2 Details of Table Clamps and Supporting Plates

tops and bottoms of the nodes or junction. The loading plate must cover the same nodes or junctions and be weighted with not less than 100 N [22.5 lbf] to sufficiently maintain the geogrid flat during clamping. These plates must be removed before test loads are applied and the sample inspected to insure that it is completely flat. No additional tensioning of the geogrid should be done.

6.1.2 *Table Clamps*—Clamps for the outside edges of the geogrid. The table clamps should have smooth surfaces and be rectangular in shape (Fig. 2). The table clamps hold the geogrid ribs firmly in place with respect to lateral movement at a distance of 8 mm [0.31 in.] ± 6 mm [0.24 in.] from the edge of the hole. If the node or junction is more than 12.7 mm [0.5 in.] outside the hole then the rib must be clamped between the node or junction and the edge of the hole. If the node or junction is within 12.7 mm [0.5 in.] of the edge of the hole, the node or junction must be clamped. Each rib must be held so that it does not move laterally more than 0.1 mm [0.004 in.] during the test. The tension in some ribs may be very high, perhaps on the order of several thousand N [several hundred lbf] for geogrids with high modulus values and large aperture sizes. The higher the Aperture Stability Modulus, the more important it is that the clamps do not allow lateral movement. The direction of maximum movement will be in the general direction of the rib. If the clamped point moves more than 0.1 mm [0.004 in.], the test should be discarded. Once confidence has been developed in a particular clamping technique with a particular geogrid, it will not be necessary to measure the potential movement in every test. However, while developing the clamping technique for a particular geogrid, the clamping efficiency must be checked. One method of doing this is to measure the distance from the edge of the clamp to a point close to the clamp on the rib. The clamping technique used to develop this test method was determined to be adequate for the geogrids tested and is shown in Figs. 1 and 2. The table clamps are made of steel bars with 9.5-mm [3/8-in.] bolts with 16 threads per 25 mm [1 in.] on about 50 mm [2 in.] spacing. The bolts were torqued to 13.5 N-m [120 lbf-in.].

6.1.3 *Torqueing Rod*—The torquing rod must have a clamp at one end to attach it to the ribs around the single center node or junction of the geogrid. The rod must be supported so that it does not apply a vertical force on the geogrid. In addition, the rod must be held in a vertical orientation to avoid applying an out-of-plane torque to the geogrid structure. The same displacement is required on each rib. The clamp that connects the torquing rod to the center node or junction is the center clamp. The center clamp is made of stainless steel and must apply a horizontal force to each intersecting rib at a uniform distance of 12.7 ± 1.0 mm [0.5 ± 0.04 in.] from the center of the center node or junction. The maximum torque expected is 2.5 N-m [22.1 lbf-in.]. Therefore, each contact point must be able to resist at least 250 N [55 lbf]. The clamping method used to develop the test method consists of two stainless steel metal blocks (center clamp) 35 ± 0.5 mm [1⅜ in.] in diameter, with a central hole to clear the geogrid node of 15.5 ± 0.5mm [⅜ in.] and with a clamp bolt circle diameter of 25.4 ± 0.5 mm

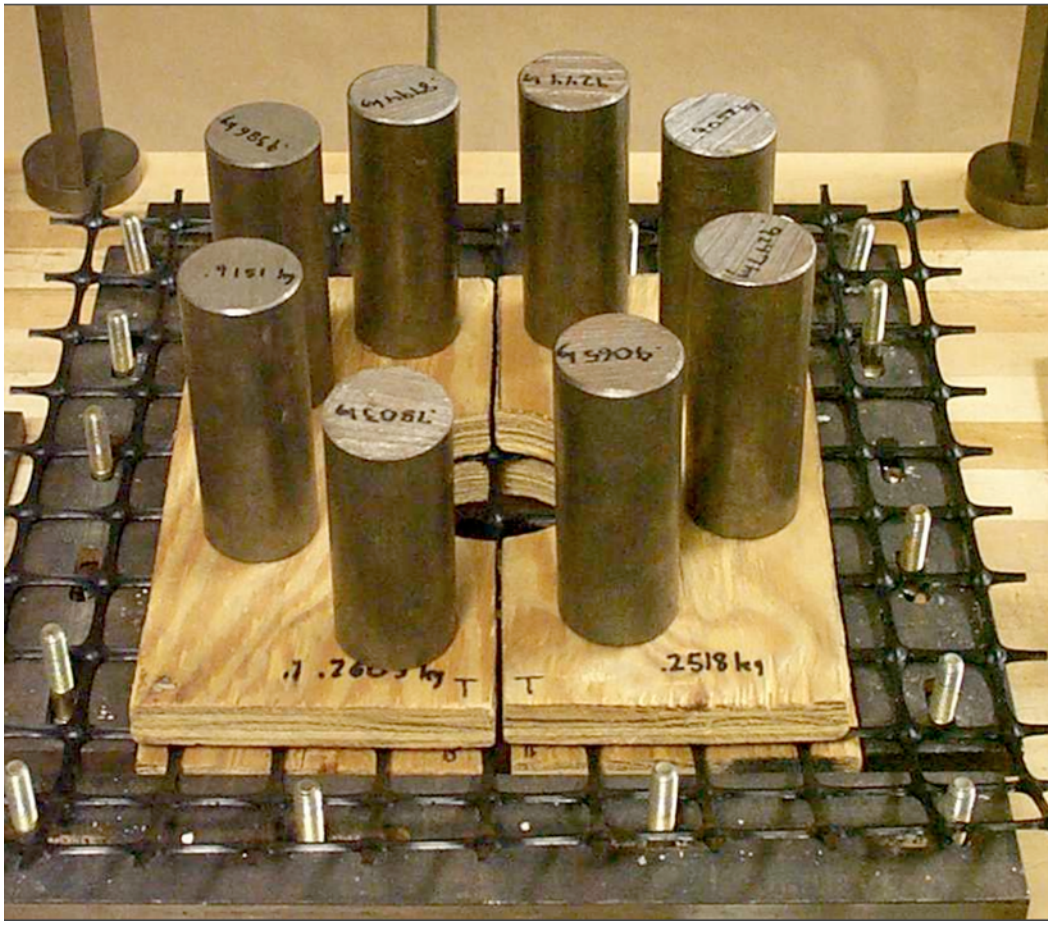

FIG. 3 Loading Plates and Weights Applied Prior to Clamping Specimens on Table Clamps

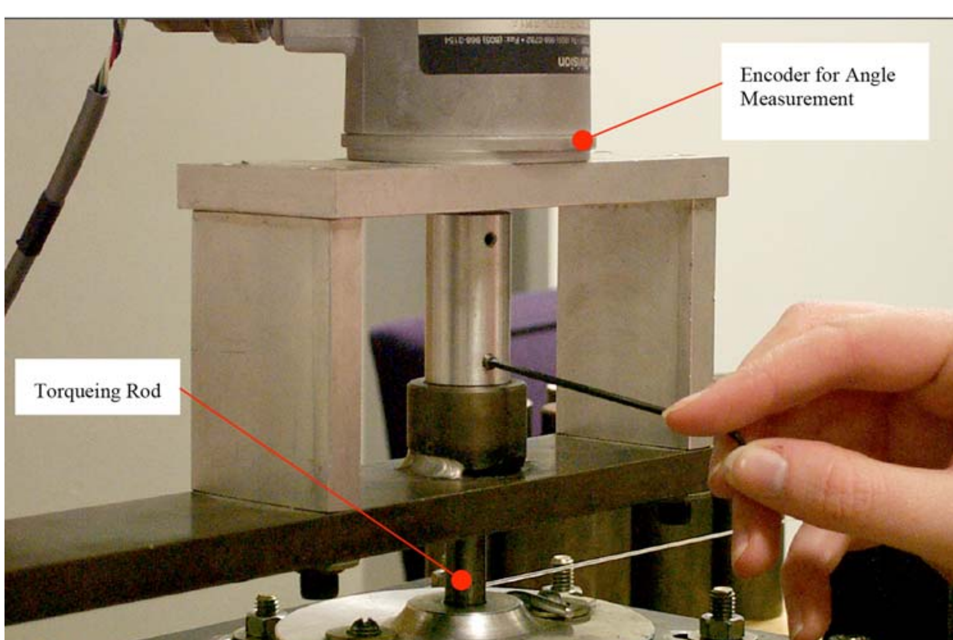

FIG. 4 Torqueing Rod with Encoder Being Lock In-Place

[½ in.]. The two blocks are held together with four or six sized 8-32 socket head cap screws, 4.2 mm [0.164 in.] bolts with 32 threads per 25.4 mm [1 in.] or 4-0.7 metric socket head cap screws, 4.0 mm diameter by 0.7 mm screw thread pitch. The number of bolts shall be equal to the number of ribs that radiate from the node or junction. The bolts are torqued to 0.5 N-m [4.5 lbf-in.]. This method provides reproducible results with no apparent slippage. If the ribs are of a different thickness, length, special clamping mechanisms may have to be used. If insufficient clamping force is used, or the ribs are not seated against the four or six clamping bolts prior to tightening the clamping bolts, then the ribs may slip in the clamp, which will negate the test results. Clamps should not slip or damage the single center node or junction and the intersecting ribs.

NOTE 2—The bolts must be placed directly against the intersecting ribs in the direction that the torque will be applied. The bolts should bear against the ribs immediately as the torque is applied. The node or junction must be centered within the center clamp.

6.1.4 *Torqueing Mechanism*—The torquing mechanism must be such that it can apply a clockwise torque (as viewed from the top of the device) of at least 2.5 N-m [22.1 lbf-in.]. The mechanism must be capable of applying the torque in increments so that the torque can be held and readings taken at several torque levels between the minimum and maximum values. The torque must be accurate to within ±2 % of the reading. The loading method used to develop the test is shown in Fig. 4. It consists of attaching a sheave to the torquing rod and running a 0.9 mm [0.035 in.] nylon-monofilament line around the sheave and over pulleys to a dead-load bar under the table. The total weight of the pulley assembly shall be 200 ± 5 g [7 oz]. The sheave shall be approximately 100 mm [4.00 in.] in diameter, and a total of five 10 N [2.25 lbf] weights shall be applied to create the incremental loads.

6.1.4.1 If the sheave is not exactly 100 mm in diameter the weights shall be adjusted to give torque increments of 0.5 ± 0.01 N-m [4.4 ± 0.09 lbf-in.].

6.2 *Method of Measuring the Angle or Rotation*—The angle of rotation of the vertical rod must be measured to within ±0.05 degree. There are many ways to measure the angle, including both mechanical and electrical devices. The measurement may be made on the rod or an extension of the rod, or it may be made on the movement of the loading mechanism or an extension of the loading mechanism. The result must be a measurement of the rotation of the rod. If there is significant deformation between the points where the measurement is taken and the rotation of the rod, that deformation must be accounted for by calibration and correction. One obvious example of this is that it would be possible to measure the movement of the weights in the loading system shown in Fig. 1. If the nylon-monofilament line stretch or creep, there would be an error created that must be considered in the calculation of the angle. Several methods of measuring the angles have been used in the development of this test; each seemed to give adequate results.

7. Sampling, Test Specimens, and Test Units

7.1 The test specimen shall be a representative sample of geogrid prepared as follows:

7.1.1 Cut a square sample of geogrid with a node or junction at the center. The size of the sample depends on the clamping mechanism used. It must be large enough to be properly clamped, and yet not so large that the extra geogrid interferes with the other parts of the testing apparatus. With the test apparatus used to develop the test, the samples were cut 330 mm [13 in.] square.

7.1.2 Lab or field sampling of geogrid test specimens, or both, should be performed in accordance with Practice D4354. All samples should be conditioned to standard laboratory temperature of 20 ± 2°C [68 ± 2°F].

8. Procedure

8.1 *Test Setup:*

8.1.1 Install the supporting plate so that it keeps the geogrid flat during clamping.

8.1.2 Place the sample over the supporting plate with one node or junction at the center of the location of the clamping mechanism.

8.1.3 Place the 229-mm [9-in.] loading plate and weights on the sample.

8.1.4 Clamp the sample onto the table using the table clamps.

NOTE 3—It is very important that the sample be flat and not stretched when clamped to the table. Violating this requirement appears to be the single greatest cause of test variability. The clamping efficiency is very important. Small movements of the clamped points make significant differences in the measured results.

8.1.5 Remove the loading plate.

8.1.6 Clamp the torqueing rod onto the center node or junction. Do not compress the node or junction within the center clamp.

NOTE 4—The four or six ribs of the samples must make contact with the 4-mm sized clamping bolts before these bolts are tightened. This can be ensured by gently torqueing the loosely assembled center clamp against the sample just prior to tightening the bolts. A "T-handle" affixed to the lower center clamp rod (located below the table) has been found effective to accomplish this task.

8.1.7 Connect the loading apparatus and the angle measuring apparatus if necessary.

8.2 *Test Procedure:*

8.2.1 Test the conditioned specimens in the standard atmosphere for testing geosynthetics, which is 20 ± 2°C [68 ± 4°F] and 50 to 70 % relative humidity, unless otherwise directed in a material specification or contract order.

8.2.2 Set the angle measuring instrumentation.

8.2.3 Immediately apply an initial torque increment of approximately 0.5 N-m [4.42 lbf-in.] for 1 min and measure the resulting angle of rotation. If the rotation has not stabilized, keep the load until the rate of rotation is less than 0.1 degree per minute.

8.2.4 Apply additional torque increments of the same magnitude [0.5 N-m] in a similar manner until the maximum torque of 2.5 N-m [22.1 lbf-in.] is reached.

8.2.5 Dismantle the test in the reverse order to the way it was set up without taking rotation readings.

8.2.6 After removing the last load, let the sample sit for 1 min and reset rotation reading of the angle measuring instrumentation. Start the next loading cycle immediately at the 1 min mark.

8.2.7 If necessary, make measurements to see if the geogrid has moved and record the measurements for the report.

8.2.8 Record any noticeable damage in the report.

8.2.9 Repeat the above steps on the same geogrid specimen for four complete load/unload cycles.

NOTE 5—There are four complete cycles for the five torque (loading) increments (0.5, 1.0, 1.5, 2.0, 2.5 N-m). That is, the sample is torqued through the application of five different loads, then unloaded and reloaded through the five loads for another three times (total of four cycles × five loads).

NOTE 6—In general, it has been found that the aperture stability modulus increases with successive load cycles. When a single sample is loaded and unloaded several times the results are most reproducible after the third or fourth cycle.

9. Data Presentation and Analysis

9.1 Determine if the geogrid performed "normally" in the test apparatus. Torque versus rotation curves must be smooth without a point of inflection, the geogrids must not be damaged, and the geogrids must not have moved under the clamps. If the curve has a point of inflection or is not smooth, it could indicate that the clamps slipped or the test loads exceeded the capacity of the geogrid. If there is any question as to the normality of a test, the test should be repeated.

9.2 Calculate the Aperture Stability Modulus at each level of rotation for the four load/unload cycles. The Aperture Stability Modulus is defined as torque, divided by the rotation at that torque. The units are N-m/degree [lbf-in./degree].

9.3 Calculate the Initial Aperture Stability Modulus as the change in moment of 0.5 and 1.0 N-m [4.4 and 8.8 lbf-in.], respectively divided by the change in angular rotation at these two moment values.

9.4 Calculate the Offset Aperture Stability Modulus as the change in moment at 2.0 and 2.5 N-m [17.7 and 22.1 lbf-in.], respectively, divided by the change in angular rotation at these two moment values.

9.5 Repeat the entire process for three different geogrid test specimens and average the modulus values calculated in 9.3 and 9.4.

10. Report

10.1 Report the following information:

10.1.1 Complete description of geogrid (manufacturer, product code, date of manufacture, roll, and lot number, etc.).

10.1.2 A table listing the average Aperture Stability Modulus at each load level with a note stating that the test terminated prior to application of full torque, if applicable. In addition, report the average value for the initial and offset aperture stability modulus for each test of three specimens. Fig. 5 has been included for guidance in reporting test data.

10.1.3 A description of any anomalies in the test or behavior of the sample.

11. Precision and Bias

11.1 The precision and bias of this test method is being established.

12. Keywords

12.1 aperture stability modulus; geogrids; index test; laboratory test

Aperture Stability Modulus Test Form

Client: ____________________ Product: ________________

Sample ID: ____________________ Date: ________________

Applied Moment (N-m)	Rotation (degrees)				Rotation	Aperture Stability Modulus (N-m/degree)		
Specimen 1	Load Cycle 1	Load Cycle 2	Load Cycle 3	Load Cycle 4	Average (degrees)	Average	Initial	Offset
0.5								
1.0								
1.5								
2.0								
2.5								
	Rotation (degrees)							
Specimen 2	1	2	3	4				
0.5								
1.0								
1.5								
2.0								
2.5								
	Rotation (degrees)							
Specimen 3	1	2	3	4				
0.5								
1.0								
1.5								
2.0								
2.5								
Average Aperture Stability Modulus (N-m/degree)								

FIG. 5 Example Data Collection Form