Designation: D 6638 – 01

Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks)[1]

This standard is issued under the fixed designation D 6638; 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 is used to determine the connection properties between a layer of geosynthetic reinforcement and segmental concrete block units used in construction of reinforced soil retaining walls. The test is carried out under conditions determined by the user that reproduce the connection system at full-scale. The results of a series of tests are used to define a relationship between connection strength for a segmental unit-geosynthetic connection system and normal load.

1.2 This is a performance test used to determine properties for design of retaining wall systems utilizing segmental concrete units and soil reinforcing geosynthetics, either geotextiles or geogrids. The test is performed on a full-scale construction of the connection and may be run in a laboratory or the field.

1.3 The values stated in SI units are regarded as the standard. The values stated in inch-pound units are provided for information only.

1.4 *This standard may involve hazardous materials, operations, 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 448 Classification for Sizes of Aggregate for Road and Bridge Construction[2]

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

D 4439 Terminology for Geosynthetics[3]

D 4595 Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *displacement criteria*, *n*—a user prescribed maximum movement, mm (in.), of the geosynthetic reinforcement out from the back of segmental concrete units.

3.1.2 *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)**

3.1.3 *granular infill*, *n*—coarse grained soil aggregate used to fill the voids in and between segmental concrete units.

3.1.4 *peak connection strength*, *n*—the maximum tensile capacity of the connection between geosynthetic reinforcement and segmental concrete units.

3.1.5 *segmental concrete unit (modular concrete block)*, *n*—a concrete unit manufactured specifically for mortarless, dry-stack retaining wall construction.

3.1.6 *segmental concrete unit width*, *n*—the segmental concrete unit dimension parallel to the wall face and coincident with the geosynthetic reinforcement test specimen width.

3.1.7 *service state connection strength*, *n*— the connection tensile capacity at a service state displacement criterion between geosynthetic reinforcement and segmental concrete units.

3.2 For definition of other terms relating to geosynthetics, refer to Terminology D 4439.

4. Summary of Test Method

4.1 One end of a wide geosynthetic reinforcement test specimen is attached to dry stacked segmental concrete block units assembled as specified by the user. The other end of the test specimen is attached to a clamp, which is part of a constant rate of extension tensile loading machine. The top course of segmental concrete block units is then loaded vertically to a constant normal load and the geosynthetic is then tensioned under constant rate of displacement until a sustained loss of connection capacity and/or excessive movement (greater than 150 mm) of the reinforcement out from the connection.

4.1.1 Peak connection capacity, and tensile capacity after a user prescribed displacement criteria has occurred, is used to

[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 04.03.

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

define connection strength based on peak and service state criteria respectively. Both these values may be obtained from each test that measures geosynthetic displacement. Tensile loads and strengths are reported per unit width of geosynthetic sample, kN/m (lb /ft). Generally a series of tests are performed to establish a mathematical relationship between connection strength and normal load on the connection.

5. Significance and Use

5.1 The connection strength between geosynthetic reinforcement and segmental concrete block units is used in design of reinforced soil retaining walls.

5.2 This test is used to determine the connection strength for the design of the connection system formed by segmental concrete block units and geosynthetic reinforcement layers in reinforced soil retaining walls. Performing a series of these connection tests at varying normal loads permits development of a relationship between connection strength and normal load. This relationship may be linear, bi-linear, or some other complex mathematical expression.

5.3 This connection strength test is meant to be a performance test (laboratory or field), therefore, it should be conducted using full-scale system components. The conditions for the test are selected by the user and are not for routine testing.

5.4 As a performance test on full-scale system components it accounts for some of the variables in construction procedures and materials tolerance normally present for these types of retaining wall systems.

6. Apparatus

6.1 *Testing System*—An example of a test apparatus and setup is illustrated in Figs. 1 and 2. The principal components of the test apparatus are:

6.1.1 *loading frame,*

6.1.2 *normal load piston/actuator,*

6.1.3 *vertical loading platen,* with stiff rubber mat or airbag to apply uniform vertical pressure to top of concrete blocks

6.1.4 *vertical load cell,* to measure normal load

6.1.5 *geosynthetic loading clamp,*

6.1.6 *horizontal piston/actuator,* to load geosynthetic reinforcement in tension

6.1.7 *horizontal load cell* to measure geosynthetic tensile force, and

6.1.8 *two (2) horizontal displacement measurement devices,*to record displacement of the geosynthetic at the back of the segmental concrete blocks.

6.2 *Loading Frame*—The loading frame shall have sufficient capacity to resist the forces developed by the horizontal and vertical loading pistons/actuators.

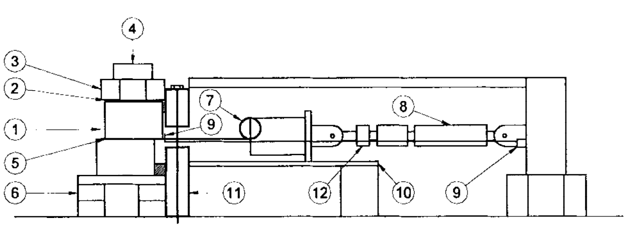

FIG. 1 Connection Strength Test System

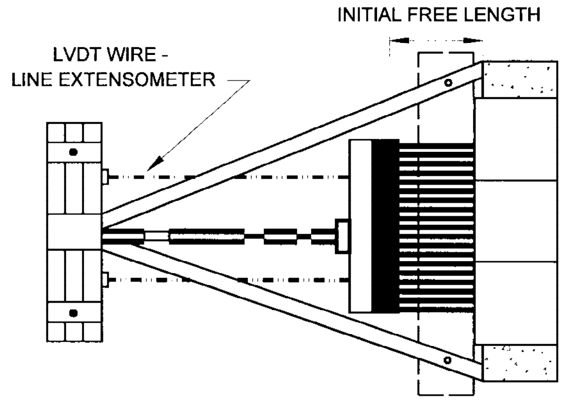

FIG. 2 Connection Test Apparatus (Plan View)

6.3 *Tensile Loading Clamp and Loading Assemblies*—The geosynthetic is gripped at its free end with a clamp extending the full width of the specimen. The clamp shall be capable of applying a uniform force across the full width of the test specimen. A roller grip assembly may be used to apply the tensile load. For some geosynthetics it may be necessary to epoxy bond the geosynthetic to, or within, the clamp in order to obtain a uniform stress distribution across the entire width of the test specimen.

6.3.1 The tensile loading unit will generally be a constant rate of extension screw jack or hydraulic actuator that can be displacement rate controlled. The loading equipment shall have a capacity that is at least equal to 120 % of the wide strip tensile strength of the geosynthetic (Test Method D 4595) multiplied by the specimen width. The piston shall be capable of at least 150 mm (6 inches) of movement in order to facilitate test set up and to ensure that there is adequate stroke to achieve failure of geosynthetic reinforcement specimens.

NOTE 1—Some systems (that is, modular concrete units with a depth greater than 0.5 m) may need more than 150 mm of movement to achieve failure of the connection.

6.3.2 The orientation of the tensioning force shall be horizontal and perpendicular to the back of the segmental units and shall be applied at the elevation where the geosynthetic exits the back of the segmental units.

6.4 *Load Cells*—A calibrated load cell shall be used to measure the tensile connection force and normal load during the test. The load cell used for measuring tension shall have a capacity that is greater than or equal to 120 % of the wide strip tensile strength of the geosynthetic (Test Method D 4595) multiplied by the specimen width. The load cell used for measuring the normal surcharge load shall have a capacity that is greater than or equal to 100 % of the maximum anticipated normal load. The load cells shall be accurate within ± 0.5 % of its full-scale range.

6.5 *Displacement Measuring Devices*— Two linear variable displacement transducers (LVDTs) or similar electronic displacement measuring devices are recommended to continuously monitor the displacement of the geosynthetic out from the back of the concrete units. Alternatively, dial gauges may be read and recorded manually at regular intervals not greater than one minute. LVDTs, dial gauges or similar measuring devices shall be accurate to ± 0.1 mm (±0.005 in.).

7. Sampling

7.1 *Segmental Concrete Units*

7.1.1 Segmental concrete units shall be full-size blocks and meet the manufacturer's material and dimensional specifications. Model or prototype units shall not be used unless it can be demonstrated that they are equivalent to production units.

7.1.2 The user shall specify and/or collect a sufficient sample of representative segmental units, from a standard production lot, to construct the anticipated number of test configurations for the connection system within the testing agency's load frame and testing system.

7.1.3 The wall for connection testing shall be constructed using randomly selected full-size (that is, full width) segmental units from the users sampling of a standard production lot, see section 7.1.2. A maximum of two half width segmental concrete units may be used on only one course of the units being tested in a confined width test apparatus. Segmental concrete units may be re-used in testing if there is no cracking, abrasion or wearing of the concrete surfaces between tests.

7.1.4 *Wall Width*—The wall for testing shall be constructed to a minimum of 750 mm (29.5 in.) in width and contain at least one typical segmental concrete unit running bond joint. The segmental wall width for testing shall be at least as wide as the geosynthetic test specimen width (see 7.2.3). Testing of segmental concrete unit widths greater than 500 mm, may be represented in this test by limiting the test wall to 1000 mm (39.4 in.) in width.

NOTE 2—Narrower wall widths may be used for testing, provided the connection strength is proven to be unaffected by this reduction (see section 7.2.3).

7.1.5 *Conditioning*—The segmental concrete unit test specimen shall be brought to standard temperature and relative humidity conditions for testing in a laboratory. The temperature is to be 21 ± 2°C (70 ± 4°F) and the relative humidity of 65 ± 10 %. For field-testing the specimen shall be brought to ambient conditions for not less than one hour. The temperature and humidity at the start and end of the test shall be recorded for field-testing.

7.2 *Geosynthetic*

7.2.1 *Sampling Requirements*—The latest version of ASTM sampling protocol for geotextiles (Practice D 4354) shall be used for the geosynthetic reinforcement material.

7.2.2 *Conditioning*—The geosynthetic reinforcement test specimen shall be brought to standard temperature and relative humidity conditions for testing in a laboratory. The temperature is to be 21 ± 2°C (70 ± 4°F) and the relative humidity of 60 ± 10 %. For field-testing the specimen shall be brought to ambient conditions for not less than one hour. The temperature and humidity at the start and end of the test shall be recorded for field-testing.

7.2.3 *Specimen Width*—The geosynthetic reinforcement test specimen shall be a minimum of 750 mm (29.5 in.) in width. For tests that use two or more full segmental retaining wall units on the bottom course, the geosynthetic shall be an exact multiple of the segmental retaining wall unit width totaling closest to, but exceeding 750 mm (29.5 in.) in width. For segmental retaining wall unit widths greater than 500 mm (19.7 in.) a geosynthetic specimen width of 1000 mm (39.4 in.) may be used.

NOTE 3—Narrower geosynthetic reinforcement specimen widths may be used for a specific concrete unit, provided that sufficient testing demonstrates that narrower samples provide an evaluation of connection performance that is equivalent to the minimum 750 mm (29.5 in.) width sample. This procedure may be appropriate for wall connections that are primarily mechanical (non-frictional) in nature.

7.2.4 *Specimen Length*—The geosynthetic specimen shall have sufficient length to cover the interface surface as specified by the user. The specimen must be trimmed to provide sufficient anchorage at the geosynthetic loading clamp and a free length between the back of the concrete blocks and loading clamp ranging from a minimum of 200 mm (7.9 in.) to a maximum of 600 mm (23.6 in.), The geosynthetic reinforcement specimen shall be placed between the stacked segmental concrete units to cover the same area that will be used in field construction of the connection or as determined by the user.

7.2.5 A new geosynthetic reinforcement test specimen shall be used for each test.

7.2.6 *Number of Tests*—A sufficient number of tests shall be conducted to adequately define a relationship between connection strength and normal load applied to the connection. Tests shall be conducted at a minimum of three unique normal loads within the range of loads typical of wall design, as directed by the user. Additionally, at least two more tests at one normal load will be necessary to verify repeatability (see section 7.2.7).

7.2.7 *Repeatability of Test Results*—The testing agency shall provide evidence of test results repeatability by conducting at least three tests at one normal load level for a specific segmental concrete units and geosynthetic reinforcement system. The general range for repeatability of peak connection strength of these three nominally identical tests is ± 10 % from the mean of the three tests (see reference in X1.1). If the test results are outside of this range it shall be duly noted on the report.

8. Test Procedure

8.1 Install and brace lower course of concrete segmental units. Place the units such that a running joint will be coincident with the center of pull for the geosynthetic reinforcement test specimen, on either this course or the course above.

8.1.1 The connection shall be constructed using the geosynthetic reinforcement, granular infill, full-scale segmental concrete block units and connectors specified by the user. The number, type and arrangement of mechanical connectors shall also be specified by the user.

8.1.2 A single course of segmental units shall be placed on a rigid base. A second course of segmental units will later (see 8.5) be placed over the bottom course of units, with the geosynthetic reinforcement located and placed between these courses as described by the user or in the same manner anticipated for field construction. Both courses of segmental concrete units shall be rigidly braced to prevent lateral movement of the units during geosynthetic tension testing.

8.1.3 The minimum width of the bottom course of concrete units shall be at least the geosynthetic reinforcement specimen width (see 7.2.3) and it must fully support the top course of segmental concrete units. Small wall widths are permissible (see 7.1.4 and 7.2.3). Reducing the width of segmental concrete units by cutting with a concrete/masonry saw is permissible, provided that the cut (rough) edges are located beyond the edge of the geosynthetic sample.

8.1.4 Arrange the lower course units such that a minimum of one "as manufactured" running bond joint shall be located at the centerline of pull for the geosynthetic reinforcement test specimen on either the top or bottom course of segmental units.

8.2 Place and compact granular infill within (if required) and between the segmental concrete units to the density specified by the user.

8.2.1 The granular infill for testing shall be specified by the user.

NOTE 4—A typical granular infill would be crushed stone conforming to the size number 57 or 67 gradations in Classification D 448.

8.3 Center geosynthetic reinforcement with respect to the centerline of the horizontal tension loading piston/actuator. Place the geosynthetic reinforcement test specimen in the user-specified position with respect to concrete keys, mechanical connectors, and the wall face. Record the geosynthetic reinforcement test specimen width, length, and position on the concrete units.

8.4 For concrete segmental wall widths greater than the geosynthetic reinforcement specimen width, trim two pieces of the same geosynthetic reinforcement to cover the interface between courses of concrete units on either side of the geosynthetic test specimen width. These pieces are required to ensure that the top course of concrete units remain level to receive uniform distribution of the normal load. Leave 10 mm (0.4 in.) between these pieces of geosynthetic and the edge of the geosynthetic test specimen.

8.5 Place the top course of concrete segmental units over the geosynthetic sample using the drystack jointing arrangement as described by the user or in the same manner anticipated for field construction. The number, type and arrangement of mechanical connectors must also be specified by the user.

8.5.1 The top course of segmental concrete units shall be level and rigidly braced to prevent lateral movement of the units during geosynthetic tension testing.

8.5.2 The minimum width of the top course of segmental concrete units shall be 750 mm (29.5 in.) and shall be fully supported by the bottom course. Reducing the width of segmental concrete units by cutting with a concrete/masonry saw is permissible, provided that the cut (rough) edges are located beyond the edge of the geosynthetic sample.

8.5.3 The running joints in the top course of units shall be positioned over the bottom course as described by the user or in the same manner anticipated for field construction. The joint pattern/configuration shall be recorded. When two half-width units are used for one course, then standard bond is permissible at the outer edges of the sample.

8.6 Place and compact granular infill within (if required) and between the segmental concrete units to the density specified by the user. Ensure that the top surface of the wall is level.

8.7 Place and position the normal loading platen over the top of the concrete units using either an airbag or rubber mat, to ensure that there will be a uniform distribution of normal pressure. (see 6.1 and 8.11.1).

8.8 Position and secure vertical load frame and the vertical loading actuator/piston over the center of the connection system.

8.9 Attach the tensile loading clamp to the geosynthetic leaving a minimum free length of 200 mm (7.9 in.) and maximum 600 mm (23.6 in.) between the back of the concrete units and the loading clamp. Measure and record the free length between the concrete units and the loading clamp.

8.10 Attach displacement recording devices to a bar clamp attached to the geosynthetic reinforcement immediately adjacent to the back of the concrete units. It is recommended that the bar clamp be constructed from two lightweight aluminum angle bars that are lightly screw-clamped to the reinforcement and extend the full width of the geosynthetic sample. The displacement recording devices shall be located equi-distance from the centerline of pull and on either side of the tensioning actuator. These devices should be approximately 300 to 600 mm (12 to 24 in.) apart in order to calculate the average displacement of the geosynthetic during the test.

8.11 Apply a predetermined normal (vertical) load to the top of the concrete units that equates to the desired normal load (kN/m) or stress (kPa) for the test. Maintain this normal load (kN/m) or stress (kPa) for the test by measuring the normal load using a load cell and adjusting to maintain this constant value for the duration of testing.

8.11.1 The normal loading arrangement shall be selected to provide a uniform pressure distribution over the top layer of concrete block units. A rigid loading platen is required below the vertical piston/actuator. It must have sufficient area to cover the entire surface of the top layer of concrete units. One or more layers of stiff gum rubber mat placed between the rigid loading platen and concrete units is recommended to provide uniform pressure distribution. Alternatively, a pressurized air bag system may be used.

NOTE 5—Many segmental concrete unit systems exhibit dilatant behavior during connection testing that can produce a significant increase in normal load (kN/m) or stress (kPa).

8.11.2 The range of normal loads for testing should be defined by the user (see 7.2.6).

8.12 Start the test by applying a constant rate of displacement of 10 ± 4 % min of all the initial free length of the geosynthetic reinforcement to the loading clamp using the horizontal actuator/piston.

8.13 During the entire test record normal load, tensile load, actuator displacement, and geosynthetic displacement at the back of the concrete units at regular time intervals not to exceed one minute. A minimum of 10 readings shall be taken. When using computerized data acquisition equipment, an instrumentation recording interval of every 10 to 30 s is recommended.

8.14 Continue the test until there is a sustained loss of tensile resistance recorded at the loading clamp due to failure of the reinforcement at or within the connection system and/or failure of the blocks. In some cases the failure will be defined as excessive displacement or slippage of the reinforcement in the connection without a sustained loss of tensile resistance. Failure or slippage of the geosynthetic within the loading clamp constitutes an invalid test.

8.15 Record the type of connection failure, slippage at the block geosynthetic interface, or rupture of the geosynthetic at the connection, rupture of the geosynthetic outside the connection (between the unit and the clamp) or partial geosynthetic rupture/slippage.

9. Calculations

9.1 For each test plot, the tensile load versus average geosynthetic reinforcement displacement recorded at the back of the concrete units (Fig. 3).

9.2 *Slack Displacement (d_o) and Slack Tension (T_o)*—Slack in the geosynthetic reinforcement and/or connection may have developed during test set-up or due to test equipment. For each test, the tensile load-displacement curve (Fig. 3) may be examined to establish an arbitrary point where the connection starts to engage, (that is, pick-up load). The displacement where this occurs shall be designated the slack displacement, d_o. The applied tension at the slack displacement, d_o, shall be designated the slack Tension, T_o. Record both on Table 1.

9.2.1 The slack Tension, T_o, shall be limited to 10 % of the peak tensile load, F_p, or 0.5 kN/m (34.3 lb/ft), whichever is smaller. A slack displacement, d_o, shall be selected such that the slack Tension, T_o, does not violate these criteria.

NOTE 6—The slack displacement, d_o, and the slack Tension, T_o may both be designated equal to zero even if there is some slack behavior.

9.3 *Peak Connection Strength*—Calculate the peak connection strength, T_{cp} for each test using the Eq 1. This is the maximum force per unit width generated by the connection. Values are to be expressed in kN/m (lb/ft) using Eq 1 as follows:

$$T_{cp} = (F_p - T_o)/W_s \tag{1}$$

where:
T_{cp} = peak connection strength per width of geosynthetic test specimen, kN/m (lb/ft),
F_p = peak tensile connection load, kN (lb),
T_o = slack tensile load, kN (lb), and
W_s = width of geosynthetic test specimen, m (ft).

9.4 *Service State Connection Strength*— Calculate the service state connection strength, T_{sc} for each test using Eq 2:

$$T_{sc} = (F_{MC} - T_o)/W_s \tag{2}$$

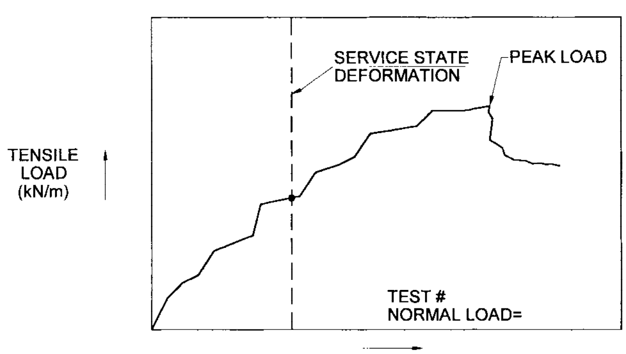

FIG. 3 Tensile Load vs Displacement

TABLE 1 Test Results

Test Series Number	Width of Geosynthetic (m)	Normal Load (kN/m)	Tensile Load at Service State Deformation (kN)	Service State Connection Strength (kN/m)	Peak Tensile Load (kN)	Peak Connection Strength (kN/m)
1						
2						
3						
Average						
4						
5						
6						
7						
8						
9						

Ultimate Tensile Strength T_{indx}(ASTM D 4595) = (lb/ft)

where:
T_{sc} = service state connection strength based upon a prescribed displacement criterion kN/m (lb/ft),
F_{sc} = measured tensile connection load at measured displacement, d; kN (lb),
T_o = slack tensile load kN (lb), and
W_s = width of geosynthetic test specimen, m (ft).

9.4.1 *Measured Displacement (d_m)*—Calculate the measured displacement, d_m, corresponding to the user prescribed displacement criteria, d_c.

$$d_m = d_c + d_o \tag{3}$$

where:
d_m = measured displacement, d_m; mm (in.),
d_c = displacement criteria, d_c; mm (in.), and
d_o = slack displacement, d_o; mm (in.).

9.4.2 If the prescribed displacement criterion is not achieved before peak connection load is reached the service state connection load shall be taken as the peak load, (that is, $F_{sc} = F_{pc}$).

10. Report

10.1 Indicate that these specific tests of the facing connection strength between the stated segmental concrete units and geosynthetic reinforcement was in accordance with this Test Method, or identify any deviations from this method of test.

10.2 Describe in detail the segmental concrete units, mechanical connectors, the stacked segmental concrete unit joint configuration and the method of sampling used.

10.3 Describe the geosynthetic reinforcement with index properties and the method of sampling used. Indicate the tensile strength of the geosynthetic material per Test Method D 4595 modified for geogrids by including a minimum gage length of 2 apertures or 8 in.

10.4 For each test provide a plot of the measured tensile (connection) load versus average geosynthetic reinforcement displacement recorded at the back of the concrete units, see Fig. 3.

10.5 Provide a summary table (see Table 1) of peak and service state connection strengths at each normal load and the average of any repeat tests. On the same table, for each test, report the geosynthetic sample width, slack tension/displacement used in determining the connection strengths and peak displacement. As a reference, at the bottom of the table indicate the tensile strength of the geosynthetic material per

Test Method D 4595 and the service state displacement criteria specified by the user.

10.6 Summarize the results of facing connection testing on a plot (see Fig. 4) of: *1*) connection strength (based on peak load criterion) versus normal load, *2*) connection strength (based on displacement criterion) versus normal load.

10.7 Indicate whether these tests conform to the general range of repeatability for connection testing (see 7.2.7).

NOTE 7—Variability in peak load test results for nominally equivalent tests, should be within ± 10 % of the average of at least three tests (see 7.2.7). Test result variability outside this range may indicate poor execution of the test or questionable connection integrity. Only additional testing will differentiate these conditions.

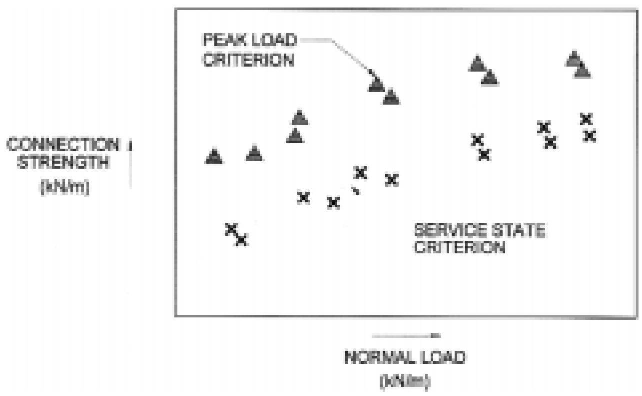

FIG. 4 Connection Strength vs Normal Load

10.8 Report on the type of connection failure(s), its location and description.

10.9 Include as part of the report a sketch or photograph (optional) of the test setup, segmental concrete unit stacking configuration and the failed geosynthetic reinforcement sample.

10.10 Provide a grain size distribution curve of the granular infill for placement in and between segmental concrete units (see Fig. 5, as an example).

10.11 Describe the method used to compact the granular infill and density if measured.

11. Precision and Bias

11.1 *Precision*—The precision of this test method has not been established.

11.2 *Bias*—The true value of this test method can only be defined in terms of a specific test method. Within this limitation, the procedure described herein has no known bias.

12. Keywords

12.1 connections; geogrid; geosynthetic; geosynthetic reinforcement; geotextile; performance test; segmental concrete units; tensile test

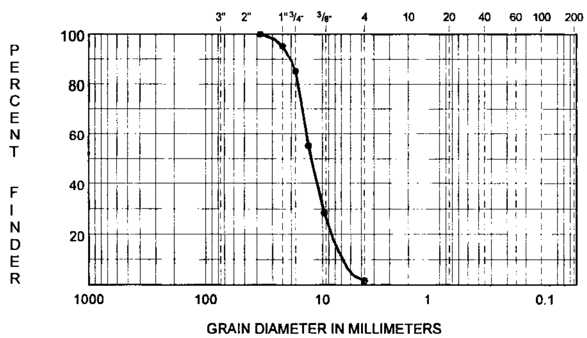

FIG. 5 Grain-Size Distribution Curve

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 This test was formulated based on the testing experience for these retaining wall systems described in the following reference:

X1.1.1 Bathurst, R.J., and Simac, M.R., "Laboratory Testing of Modular Concrete Block Geogrid Facing Connections," ASTM Symposium on Geosynthetic Soil Reinforcement Testing, San Antonio, Texas, January 19, 1993, ASTM STP 1190.

X1.2 The following references for the National Concrete Masonry Association (NCMA) provide more information about segmental concrete units utilized in retaining wall construction:

X1.2.1 TEK 50A "Specification for Segmental Retaining Wall Units."

X1.2.2 "Design Manual for Segmental Retaining Walls," Second Edition, 1997.