



# Standard Test Method for Determining the Shear Strength Between Segmental Concrete Units (Modular Concrete Blocks)<sup>1</sup>

This standard is issued under the fixed designation D 6916; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method is used to determine the shear strength between two layers of 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 facing system at full-scale. The results of a series of tests are used to define a relationship between shear strength developed between segmental concrete units 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 facing system 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:<sup>2</sup>

- D 448 Classification for Sizes of Aggregate for Road and Bridge Construction
- D 4354 Practice for Sampling of Geotextiles for Testing
- D 4439 Terminology for Geosynthetics
- D 4595 Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method
- D 6683 Test Method for Determining the Connection Strength Between Segmental Concrete Units and Geosynthetic Reinforcement

<sup>1</sup> 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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<sup>2</sup> For referenced ASTM standards, visit the ASTM Web Site, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM web site.

## 3. Terminology

### 3.1 Definitions:

3.1.1 *displacement criteria, n*—a user prescribed maximum movement, mm (in.), of the top segmental concrete unit out from the back of lower 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 shear strength, n*—the maximum shear capacity between segmental concrete units.

3.1.5 *segmental concrete depth, n*—the segmental concrete unit dimension perpendicular to the wall face.

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

3.1.7 *segmental concrete unit width, n*—the segmental concrete unit dimension parallel to the wall face.

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

## 4. Summary of Test Method

4.1 In this test method, segmental concrete units are assembled in two rows (layers). The bottom row is laterally restrained. The top row is loaded vertically to a constant surcharge load and the interface is sheared at a constant rate of displacement until a drop of load after the peak load occurs. The test may be run with the geosynthetic reinforcement sandwiched between the two rows of segmental concrete units to determine the shear strength between segmental concrete units at the connection between the units and the geosynthetic reinforcement.

## 5. Significance and Use

5.1 The shear strength between segmental concrete units (with and without geosynthetic reinforcement) and is used in design of reinforced soil retaining walls.

5.2 This test is used to determine the shear strength for the design of the facing stability of segmental retaining walls. Performing a series of these shear tests at varying normal loads

permits development of a relationship between shear strength and normal load. This relationship may be linear, bi-linear, or some other complex mathematical expression.

5.3 This shear 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 Fig. 1. 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 *Horizontal Piston/Actuator*, to apply horizontal load on the top segmental concrete unit.

6.1.6 *Horizontal Load Cell*, to measure applied force on the top segmental concrete unit.

6.1.7 *Two (2) Horizontal Displacement Measurement Devices*, to record displacement of the top segmental concrete unit.

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

6.3 *Shear Loading Plate*—The shear loading plate must be sufficiently rigid to apply a uniform force across the full width of the top course. For some segmental units it may be necessary to apply the load through a deformable material (that is, stiff rubber) which will conform to an irregular block surface, thereby allowing for a uniform load distribution.

6.4 *Restraining Box/Plate*—A rigid restraining box/plate is required to prevent horizontal movement of the lowermost segmental concrete units during shear testing. The restraining box/plate area shall be of sufficient width and depth to accommodate the full scale “as manufactured” segmental concrete units being tested.

6.5 *Shear Loading Assembly*—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 anticipated shear strength of the segmental concrete units. The piston shall be capable of at least 150 mm (6 in.) of movement in order to facilitate test set up and to ensure that there is adequate stroke to achieve peak load. The orientation of the tensioning force shall be horizontal and perpendicular to the back of the segmental units. The horizontal loading arrangement must not permit rotation of the top concrete unit during shear.

6.6 *Load Cells*—A calibrated load cell shall be used to measure the shear force and normal load during the test. The load cell used for measuring shear shall have a capacity that is greater than or equal to 120 % of the anticipated shear force between units. 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  $\pm 0.5\%$  of its full-scale range.

6.7 *Displacement Measuring Devices*—Two (2) Linear Variable Displacement Transducers (LVDTs) or similar electronic displacement measuring devices are recommended to continuously monitor the displacement of the top segmental concrete unit out from the back of the lower segmental 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  $\pm 0.1\text{ mm}$  (0.005 in.).

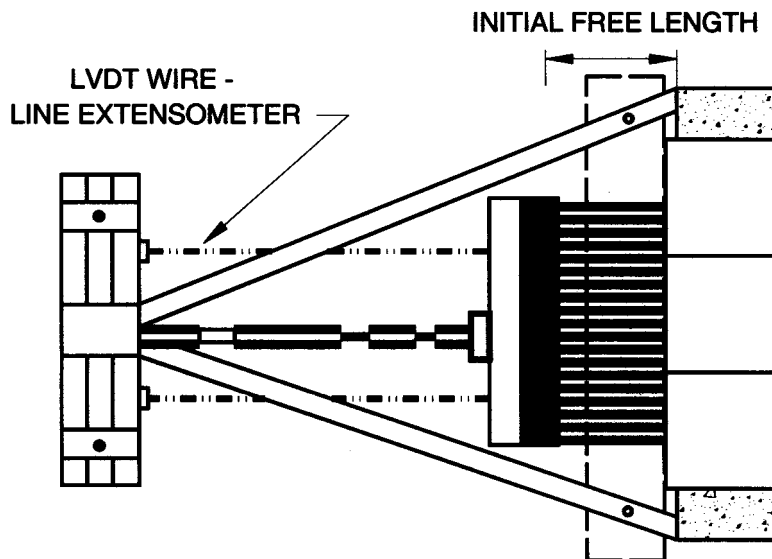


FIG. 1 Connection Test Apparatus (Plan View)

## 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 shear connection must be constructed with full-size segmental concrete units randomly selected from the users sampling of a standard production lot, see 7.1.2.

7.1.4 *Test Width*—The width of the shear connection for testing shall be constructed to a minimum of 750 mm (29.5 in.) in width and contain one segmental unit placed on top of two segmental concrete units and include at least one typical segmental concrete unit running bond joint. The top unit must be the full width of the unit. The bottom units may be adjusted to fit into the test apparatus. Testing of segmental concrete unit widths greater than 500 mm (19.7 in.), may be represented in this test by limiting the test wall to 1000 mm (39.4 in.) in width.

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  $21 \pm 2^\circ\text{C}$  ( $70 \pm 4^\circ\text{F}$ ) and the relative humidity of  $65 \pm 10\%$ . 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 (if required):

7.2.1 If the segmental concrete units are to be used for a geosynthetic reinforced segmental retaining wall, then a layer of a specified geosynthetic material shall be placed between the segmental concrete units.

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

7.2.3 *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  $21 \pm 2^\circ\text{C}$  ( $70 \pm 4^\circ\text{F}$ ) and the relative humidity of  $60 \pm 10\%$ . 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.

7.2.4 *Specimen Width*—The geosynthetic reinforcement test specimen shall be the full width of the segmental concrete unit.

7.2.5 *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 actuator side of the test apparatus to prevent slippage of the front edge of the geosynthetic sample.

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

7.2.7 *Number of Tests*—A sufficient number of tests shall be conducted to adequately define a relationship between shear strength and normal load. 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 7.2.8).

7.2.8 *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 shear strength of these three nominally identical tests is  $\pm 10\%$  from the mean of the three tests (see reference in 13.1). If the test results are outside of this range it shall be duly noted on the report.

## 8. Procedure

8.1 Install and brace lower course of concrete segmental units. Place the units such that a running joint will be located along the centerline of the test apparatus.

8.1.1 The facing system shall be constructed using the geosynthetic reinforcement (if required), 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 single segmental concrete unit 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.

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 1—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 on the running bond joint of the lower course of segmental concrete units. 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 Place a single segmental concrete unit over the bottom layer and center on the running joint.

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

8.6 Place the surcharge/roller plate arrangement (or airbag arrangement) on the top segmental concrete unit and ensure there will be a uniform distribution of surcharge pressure.

8.7 Position and secure vertical load frame and the vertical loading actuator/piston over the center of the top segmental concrete unit.

8.8 Position the shear loading plate against the top segmental concrete unit. The shear load should be applied against the

stacked units immediately above the shear interface to minimize moment loading.

8.9 Attach one displacement recording device to each front (or back) corner of the top segmental concrete unit.

8.10 Apply a predetermined normal (vertical) load to the top of the top segmental concrete unit 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.

8.10.1 The normal loading arrangement shall be selected to provide a uniform pressure distribution over the top segmental concrete block unit. A rigid loading platen is required below the vertical piston/actuator. It must have sufficient area to cover the entire surface of the top segmental concrete unit. 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 2—Many segmental concrete unit systems exhibit dilatant behavior during shear testing that can produce a significant increase in normal load (kN/m) or stress (kPa).

8.11 Start the test by applying a constant rate of displacement of  $1.0 \pm 1$  mm/min.

8.12 During the entire test record normal load, shear force, segmental concrete unit displacement, 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.

8.13 Continue the test until there is a sustained loss of shear resistance recorded.

**9. Calculations**

9.1 For each test provide a plot of, the shear load versus average segmental concrete unit displacement (Fig. 2).

9.2 *Peak Shear Strength*—Calculate the peak shear strength,  $S_p$ , for each test using the Eq 1. This is the maximum shear

force per unit width generated by the segmental concrete units. Values are to be expressed in kN/m (lb/ft) using Eq 1 as follows:

$$S_p = F_p / W_i \tag{1}$$

where:

$S_p$  = Peak shear strength per width of segmental concrete unit, kN/m (lb/ft),

$F_p$  = Peak shear load, kN (lb), and

$W_i$  = Total width of top segmental concrete unit over the interface surface, m (ft).

9.3 *Service State Shear Strength*—Calculate the service state shear strength,  $S_s$  for each test using Eq 2:

$$S_{ss} = F_{ss} / W_i \tag{2}$$

where:

$S_{ss}$  = Service state shear strength based upon a prescribed displacement criterion kN/m (lb/ft),

$F_{ss}$  = Measured shear load at the prescribed displacement criterion; kN (lb), and

$W_i$  = Total width of top segmental concrete unit over the interface surface, m (ft).

**10. Report**

10.1 Indicate that these specific tests of the facing system were 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 (if required) 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 200 mm (8 in.).

10.4 For each test provide a plot of the measured shear load versus average top segmental concrete unit displacement, see Fig. 2.

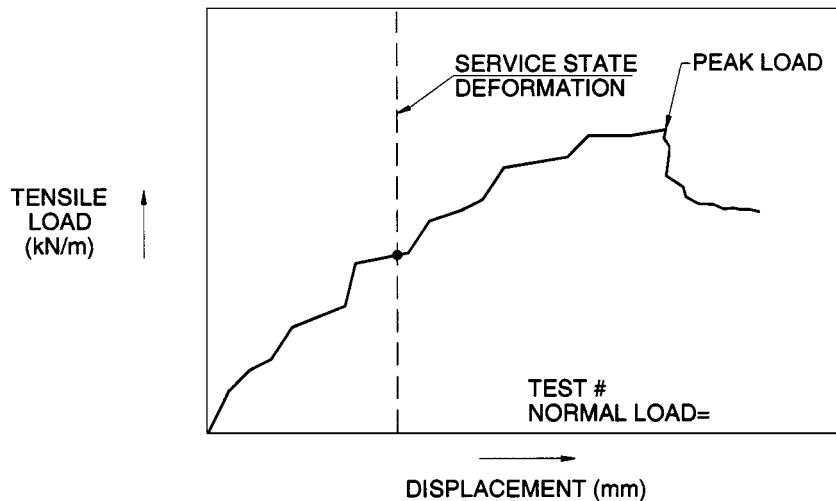


FIG. 2 Tensile Load versus Displacement

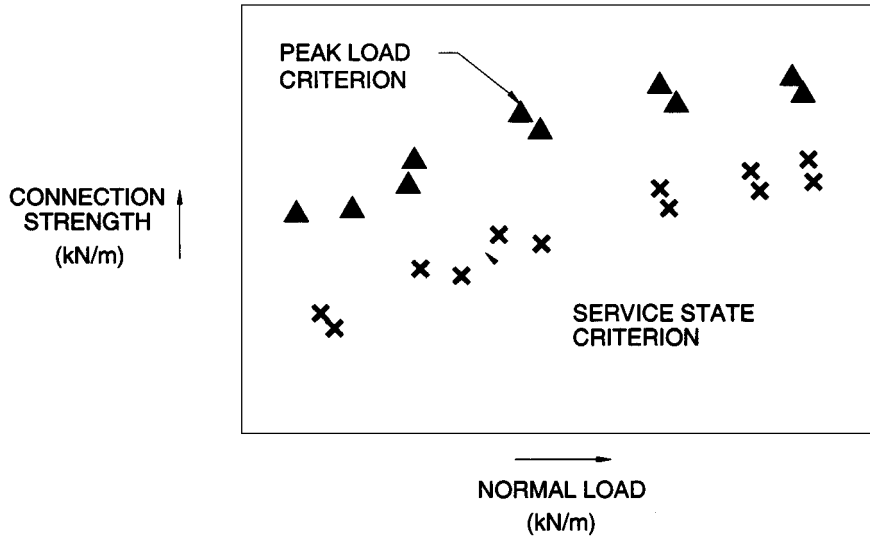


FIG. 3 Connection Strength versus Normal Load

|                           |         |        |      |        |        |      |
|---------------------------|---------|--------|------|--------|--------|------|
| BOULDERS                  | COBBLES | GRAVEL |      | SAND   |        |      |
|                           |         | COARSE | FINE | COARSE | MEDIUM | FINE |
| U.S. STANDARD SIEVE SIZES |         |        |      |        |        |      |

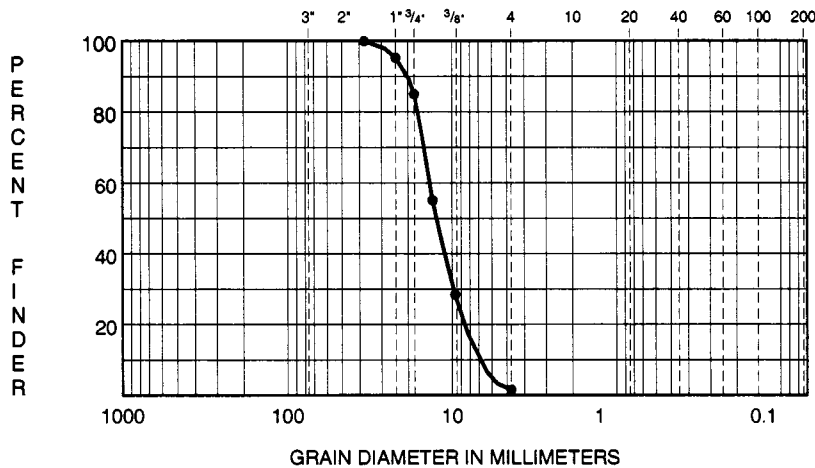


FIG. 4 Grain-Size Distribution Curve

10.5 Provide a summary table (see Table 1) of peak and

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 Strength (kN) | Peak Connection Strength (kN/m) |
|--------------------|---------------------------|--------------------|--|--|---------------------------------|---------------------------------|
| 1                  |                           |                    |  |  |                                 |                                 |
| 2                  |                           |                    |  |  |                                 |                                 |
| 3                  |                           |                    |  |  |                                 |                                 |
| Average            |                           |                    |  |  |                                 |                                 |
| 4                  |                           |                    |  |  |                                 |                                 |
| 5                  |                           |                    |  |  |                                 |                                 |
| 6                  |                           |                    |  |  |                                 |                                 |
| 7                  |                           |                    |  |  |                                 |                                 |
| 8                  |                           |                    |  |  |                                 |                                 |
| 9                  |                           |                    |  |  |                                 |                                 |

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

service state shear strengths at each normal load and the average of any repeat tests. On the same table, for each test, report the geosynthetic sample width. As a reference, at the bottom of the table indicate the tensile strength of the geosynthetic material per Test Method D 4595 provided by the geosynthetic manufacturer and the service state displacement criteria specified by the user.

10.6 Summarize the results of facing shear testing on a plot (see Fig. 3) of:

10.6.1 shear strength (based on peak load criterion) versus normal load, and

10.6.2 shear strength (based on displacement criterion) versus normal load.

10.7 Indicate whether these tests conform to the general range of repeatability for shear testing (see 7.2.8).

10.8 Include as part of the report a sketch or photograph (optional) of the test setup, and segmental concrete unit stacking.

10.9 Provide a grain size distribution curve of the granular infill for placement in and between segmental concrete units (see Fig. 4, as an example).

10.10 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 geogrid; geosynthetic; geosynthetic reinforcement; geotextile; performance test; segmental concrete units; tensile test

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