Designation: D1635/D1635M – 19

Standard Test Method for Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading [1]

This standard is issued under the fixed designation D1635/D1635M; 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 determination of the flexural strength of soil-cement by the use of a simple beam with third-point loading.

NOTE 1—For methods of molding soil-cement specimens, see Practice D1632.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined. The SI units are presented in brackets.

1.2.1 The gravitational system of inch-pound units is used when dealing with inchpound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The rationalized slug unit is not given, unless dynamic (F = ma) calculations are involved.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.3.1 The procedures used to specify how data are collected/recorded or calculated in the standard are regarded as industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of this standard to consider significant digits used in analysis methods for engineering design.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D1632 Practice for Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits in Geotechnical Data

E4 Practices for Force Verification of Testing Machines

3. Terminology

3.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *flexural strength, n*—maximum resistance of a specimen subjected to bending.

3.2.2 *modulus of rupture, n*—calculated stress, assuming linear-elastic behavior, in the tensile face of a beam specimen at the maximum bending moment during a standard test method.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization With Admixtures.

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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.

***A Summary of Changes section appears at the end of this standard**

4. Summary of Test Method

4.1 A beam, typically 3 by 3 by 11¼ in. [76 by 76 by 290 mm], is placed in a third-point loading apparatus and loaded until failure.

4.2 The maximum applied load, specimen dimensions, and span length are used to calculate the modulus of rupture.

4.3 Practice D1632 provides methods of molding soil-cement test specimens.

5. Significance and Use

5.1 This test method is used to determine the flexural strength of soil-cement. Flexural strength is significant in pavement design and can be used to determine the thickness of pavement layers.

NOTE 2—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Compression Testing Machine*—The testing machine may be of any type having sufficient capacity and control to provide the rate of displacement or loading prescribed in 8.2. The testing machine shall be equipped with a spherically seated head block having a bearing surface of at least 75 % of the width of the beam but not greatly in excess of the width of the beam. The movable portion of this block shall be held closely in the spherical seat, but the design shall be such that the bearing face may be rotated freely and tilted through small angles in any direction. The compression machine shall be verified in accordance with Practice E4 at least annually to determine if indicated loads are accurate to ±1.0 % in the applicable range of loading

6.2 *Flexural Testing Apparatus*—A four-point loading apparatus shall employ bearing blocks that will ensure that forces applied to the beam will be vertical only and applied without eccentricity. A diagrammatic drawing of an apparatus that accomplishes this purpose is shown in Fig. 1. This type of loading apparatus is commonly referred to as third-point loading since the bearing blocks are located at third points of the span.

6.2.1 The apparatus shall be designed to incorporate the following principles:

6.2.1.1 The distance between supports and points of load application shall remain constant for a given apparatus.

6.2.1.2 The direction of the reactions shall be parallel to the direction of the applied load at all times during the test.

6.2.1.3 The directions of loads and reactions may be maintained parallel by judicious use of linkages, rocker bearings, and flexure plates. Eccentricity of loading can be avoided by use of spherical bearings.

6.2.1.4 The steel plate and bed of testing machine shall be of sufficient hardness and size to support the testing apparatus.

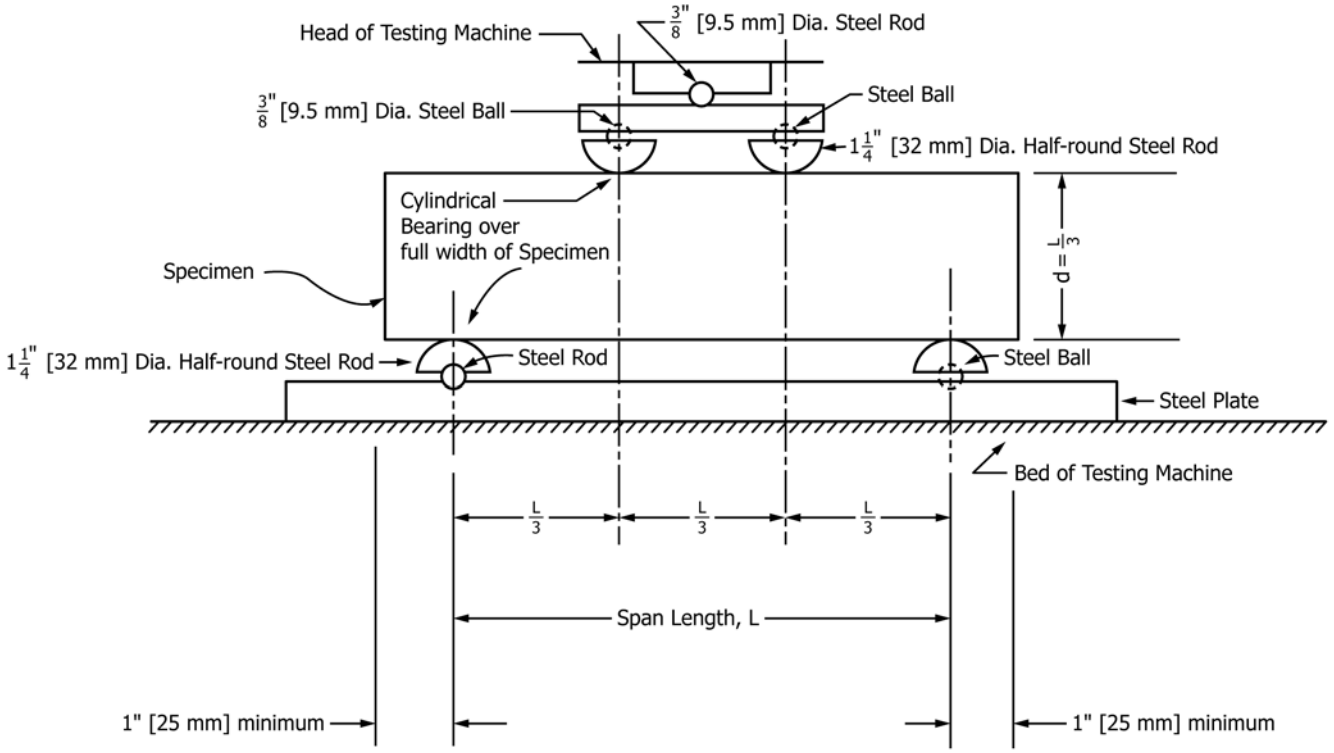

FIG. 1 Diagrammatic View of Suitable Apparatus for Flexure Test of Soil-Cement by Third-Point Loading Method

6.3 *Drying Oven*—Conforming to the requirements of Test Methods D2216.

6.4 *Measuring Device*—A measuring device suitable for measuring the width and depth of test specimens to the nearest 0.01 in. [0.25 mm].

7. Test Specimens

7.1 The standard test specimens are typically beams 3 by 3 by 11¼ in. [76 by 76 by 290 mm] as described in D1632. However, a similar test method may be used for testing specimens of other sizes. Test the specimens on their sides with respect to their molded position.

7.2 Make flexural tests of moist cured specimens as soon as practicable after removing them from the moist room, and during the period between removal from the moist room and testing keep the specimens moist by a wet burlap or blanket covering. Curing and conditioning procedures shall be given in detail in the report.

NOTE 3—Other conditioning procedures, such as soaking in water, air or oven drying, alternate wetting and drying or alternate freezing and thawing, may be specified after an initial moist curing period.

7.3 Measure and record the width and depth of the specimen in the middle third section of the beam to the nearest 0.01 in. [0.25 mm].

NOTE 4—These measurements are taken prior to testing in case the specimen crumbles upon rupture, which may preclude taking the measurements after failure.

7.4 Check the smoothness of the side faces of the beams at the points where loads will be applied with a straightedge. If necessary, cap the faces to meet the requirements of Section 15 of Practice D1632.

8. Procedure

8.1 Turn the specimen on its side with respect to its molded position and center it on the lower half-round steel supports, which have been spaced apart a distance of three times the depth of the beam. Place the load-applying block assembly in contact with the upper surface of the beam at the third points between the supports. Carefully align the center of the beam with the center of thrust of the spherically seated head block of the machine. As this block is brought to bear on the beam-loading assembly, rotate its movable portion gently by hand so that uniform seating is obtained.

8.2 Apply a constant rate of displacement without shock to produce a rate of vertical displacement of approximately 0.05 in./min [0.02 mm/s]. Alternatively, the load may be applied at a constant rate such that the extreme fiber stress is within the limits of 100 ± 5 lbf/in.^{2}/min [690 ± 39 kPa/min]. Record the total load at failure of the specimen.

8.3 If the fracture occurs outside the middle third of the span by more than 5% of the span length, as measured in 9.1.3, discard the results of the test.

8.4 Determine the water content of the test specimen in accordance with Test Methods D2216 using the entire specimen, unless capped. If the specimen is capped, break away as much material as practicable from the capping, for the water content specimen.

9. Measurement of Specimens After Test

9.1 Record the following measurements.

9.1.1 Confirm the width and depth of the specimen, at the section of failure, to the nearest 0.01 in. [0.25 mm].

9.1.2 The span length to the nearest 0.1 in. [2.5 mm].

9.1.3 If the fracture occurs outside the middle third of the span length, by no more than 5% of the span length, measure the distance between the line of fracture and the nearest point of contact with the support to the nearest 0.01 in. [0.25 mm], measured along the center line of the bottom surface of the beam.

10. Calculations

10.1 If the fracture occurs within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = \frac{PL}{bd^2}$$

where:

R = modulus of rupture, lbf/in.^{2} [MPa],
P = maximum applied load, lbf [N],
L = span length, in. [mm],
b = width of specimen, in. [mm], and
d = depth of specimen, in. [mm].

10.2 If the fracture occurs outside the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$$R = \frac{3Pa}{bd^2}$$

where:

a = distance between line of fracture and the nearest support, measured along the center line of the bottom surface of the beam, in. [mm].

11. Report: Test Data Sheet(s)/Form(s)

11.1 The methodology used to specify how data are recorded on the test data sheet(s)/forms(s), as given below, is covered in 1.3 and in Practice D6026.

11.2 Record as a minimum the following general information (data):

11.2.1 Testing date, operator name, location, and unique conditions.

11.2.2 Applicable information about the test specimen.

11.3 Record as a minimum the following test specimen data:

11.3.1 Specimen identification number,

11.3.2 Width and depth as measured in 7.3 and 9.1.1,

11.3.3 Span length,

11.3.4 If applicable, distance between the line of fracture (if outside the middle third of span) to the point of contact with the nearest support,

11.3.5 Maximum load,

11.3.6 Modulus of rupture, calculated to the nearest 5 lbf/in.^{2} [0.05 MPa],

11.3.7 Defects, if any, in specimen,

11.3.8 Age of specimen,

11.3.9 Details of curing and conditioning periods, and

11.3.10 Water content at time of test.

12. Precision and Bias

12.1 *Precision*—Test data on precision is not presented due to the nature of the soil-cement materials tested by this method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program. However, based on test data that are available, the following may serve as a guide to the variability of flexural strength test results.

12.1.1 Tests were performed in a single lab on a silt loam soil with 92 % passing the No. 200 [75-µm] sieve. Liquid limit and plasticity index of soil were 26 and 7, respectively. The series of tests consisted of 24 specimens, 12 at 6 % cement, 12 at 14 % cement. The specimens were cured in a moist room at 73 °F [23 °C] for 28 days. Results[3] of the tests are given in Table 1.

TABLE 1 Precision

	Average flexural strength, lbf/in.^{2} [MPa]	Standard deviation, lbf/in.^{2} [MPa]	Coefficient of variation, %
Specimens with 6 % cement	94 [0.65]	6 [0.04]	6.4
Specimens with 14 % cement	157 [1.08]	9 [0.06]	5.7

12.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

13. Keywords

13.1 flexural strength; soil-cement; soil stabilization

[3] Felt, E. J., Abrams, M. S., *Strength and Elastic Properties of Compacted Soil-Cement Mixtures, ASTM STP 206,* ASTM, 1957.

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D1635–12, that may impact the use of this test method. (Approved November 1, 2019)

(1) Updated and added standard caveats.
(2) Added definitions specific to this standard.
(3) Added Summary of Test Method section.
(4) Added wording to clarify apparatus requirements.
(5) Changed “Third-point” to “four-point” in the apparatus section 6.2 and added explanatory statement on the phrase “third-point” loading.
(6) Added measuring device to the apparatus section.
(7) Moved mandatory language out of Note 3.
(8) Added wording to clarify procedures and specific measurements required.
(9) Deleted the requirement to record the maximum load to the nearest 10 lb in 8.2. The report section specifies how the modulus is to be reported.
(10) Removed previous Note 4 about the mass of the beam.
(11) Added water content measurement to the procedure since it was listed in the Report section.
(12) Replaced “deformation” with “displacement” in 8.2.
(13) Added clarification language on measuring specimen width and depth in Section 7 and 9.
(14) Added equation numbers.
(15) Reworded 11.3.2.
(16) Moved Table 1 to the Precision and Bias section.
(17) Updated the report section.
(18) Added standard precision statement for when precision is not available.