Designation: D1633 – 17

Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders[1]

This standard is issued under the fixed designation D1633; 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 compressive strength of soil-cement using molded cylinders as test specimens.

1.2 Two alternative procedures are provided as follows:

1.2.1 *Method A*—This procedure uses a test specimen prepared in a mold complying with Test Methods D698 (4.0 in. (101.6 mm) in diameter and 4.6 in. (116.8 mm) in height), sometimes referred to as a proctor mold, resulting in a height over diameter ratio of 1.15. This test method may be used only on materials with 30 % or less retained on the 19.0-mm (¾-in.) sieve. See Note 2.

1.2.2 *Method B*—This procedure uses a test specimen with a height over diameter ratio of 2.0 prepared in a cylindrical mold in accordance with Practice D1632 (2.8 in. (71.1 mm) in diameter and 9.0 in. (229 mm) in height). This test method is applicable to those materials that pass the 4.75-mm (No. 4) sieve.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard, except as noted in below. The values given in parentheses are mathematical conversions to SI units, and are provided for information only and are not considered standard. Sieve sizes are identified by the standard designations in Specification E11. The alternative sieve size designation given in parentheses is for information only and does not represent a different standard sieve size.

1.3.1 The gravitational system of inch-pound units is used when dealing with inch-pound units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs.

1.3.2 The slug unit of mass is almost never used in commercial practice, that is, density, balances, etc. Therefore, the standard unit for mass in this standard is either kilogram (kg) or gram (g), or both. Also, the equivalent inch-pound unit (slug) is not given/presented in parentheses.

1.3.3 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales, recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026 unless superseded by this test method.

1.4.1 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the 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 these test methods to consider significant digits used in analysis methods for engineering data.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

D559 Test Methods for Wetting and Drying Compacted Soil-Cement Mixtures

D560 Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))

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

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D6026 Practice for Using Significant Digits in Geotechnical Data

E4 Practices for Force Verification of Testing Machines

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

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

4. Significance and Use

4.1 Method A makes use of the same compaction equipment and molds commonly available in soil laboratories and used for other soil-cement tests. It is considered that Method A gives a relative measure of strength rather than a rigorous determination of compressive strength. Because of the lesser height to diameter ratio (1.15) of the cylinders, the compressive strength determined by Method A will normally be greater than that for Method B.

4.2 Method B, because of the greater height to diameter ratio (2.00), gives a better measure of compressive strength from a technical viewpoint since it reduces complex stress conditions that may occur during the shearing of Method A specimens.

4.3 In practice, Method A has been more commonly used than Method B. As a result, it has been customary to evaluate or specify compressive strength values as determined by Method A. A factor for converting compressive strength values based on height to diameter ratio is given in Section 8.[3]

NOTE 1—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 ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

5. Apparatus

5.1 *Compression Testing Machine*—This machine may be of any type having sufficient capacity and control to provide the rate of loading prescribed in 7.2. The testing machine shall be equipped with two steel bearing blocks with hardened faces, one of which is a spherically seated head block that normally will bear on the upper surface of the specimen, and the other a plain rigid block on which the specimen will rest. The bearing block surfaces intended for contact with the specimen shall have a Rockwell hardness of not less than HRC 60. The bearing faces shall be at least as large, and preferably slightly larger, than the surface of the specimen to which the load is applied. The bearing faces, when new, shall not depart from a plane by more than 0.0005 in. (0.013 mm) at any point, and they shall be maintained within a permissible variation limit of 0.001 in. (0.02 mm). In the spherically seated block, the diameter of the sphere shall not greatly exceed the diameter of the specimen and the center of the sphere shall coincide with the center of the bearing face. The movable portion of this block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction. The compression 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.

5.2 *Molds and Compaction Equipment,* in accordance with Test Methods D559 or D560 for Method A; Practice D1632 for Method B.

5.3 *Balances*—A Class GP5 balance meeting the requirements of Guide D4753 for a balance of 1-g readability and a Class GP2 balance meeting the requirments of Guide D4753 for a balance of 0.1-g readability.

5.4 *Measuring Device*—A Measuring device suitable for measuring the heights and diameters of test specimens to the nearest 0.01 in. (0.25 mm).

6. Test Specimens

6.1 Prepare the test specimens as follows:

6.1.1 *Method A*—Specimens are prepared in accordance with Test Methods D559 or D560 using molds 4.0 in. (101.6 mm) in diameter and 4.584 in. (116.4 mm) in height.

6.1.2 *Method B*—Specimens are prepared in accordance with Practice D1632 using molds 2.8 in. (71.1 mm) in diameter and 9.0 in. (299 mm) in height.

[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] For additional discussion on the significance and use of compressive strength results, see the *Soil-Cement Laboratory Handbook*, Chapter 4, Portland Cement Association, Skokie, IL, 1971, pp 31 and 32.

NOTE 2—These methods may be used for testing specimens of other sizes. If the soil sample includes material retained on the 4.75-mm (No. 4) sieve, it is recommended that Method A be used, or that larger test specimens, 4.0 in. (101.6 mm) in diameter and 8.0 in. (203.2 mm) in height, be molded in a manner similar to Method B.

6.2 Moist cure the specimens in accordance with Practice D1632.

6.3 At the end of the moist-cure period, immerse the specimens in water for 4 h.

6.4 Remove the specimens from the water and complete the following procedures as soon as practicable, keeping specimens moist by a wet burlap or blanket covering.

NOTE 3—Other conditioning procedures, such as air or oven drying, alternate wetting and drying, or alternate freezing and thawing may be specified after an initial moist curing period. Curing and conditioning procedures shall be given in detail in the report.

6.5 Take a minimum of three height measurements (approximately 120° apart), and at least two diameter measurements (approximately 90° apart). Calculate the average height and diameter.

6.6 Record the mass of the test specimen.

6.7 Check the smoothness of the faces with a straightedge. If necessary, cap the faces to meet the requirements of the section on Capping Specimens of Practice D1632.

7. Procedure

7.1 Place the lower bearing block on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Place the specimen on the lower bearing block, making certain that the vertical axis of the specimen is aligned with the center of thrust of the spherically seated block. As this block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

7.2 Apply a constant rate of deformation without shock to produce an approximate rate of strain of 0.05 in./min (1.3 mm/min). Alternatively, the load may be applied at a constant rate that results in a rate of stress of 10 to 30 psi/s (70 to 210 kPa/s). Apply the load until it decreases steadily, indicating failure. Record the maximum load carried by the specimen during the test to the nearest 10 lbf (45 N).

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

8. Calculation

8.1 Calculate the unit compressive strength of the specimen by dividing the recorded maximum load by the cross-sectional area.

NOTE 4—If desired, make allowance for the ratio of height to diameter (h/d) by multiplying the compressive strength of Method B specimens by the factor 1.10. This converts the strength for an h/d ratio of 2.00 to that for the h/d ratio of 1.15 commonly used in routine testing of soil-cement (see Section 4). This conversion is based on that given in Method C42/C42M, which has been found applicable for soil-cement.

8.2 Calculate the unit weight of the test specimen(s) using the dimensions and mass recorded in Section 6.

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

9.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s) is covered in 1.4.

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

9.2.1 Date specimen(s) was prepared;

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

9.3 Record as a minimum the following test specimen data:

9.3.1 Specimen identification number,

9.3.2 Diameter and height,

9.3.3 Cross-sectional areas,

9.3.4 Maximum load carried by the specimen,

9.3.5 Conversion factor for height to diameter ratio (see Note 3), if used,

9.3.6 Compressive strength,

9.3.7 Age of specimen,

9.3.8 Mass of specimen,

9.3.9 Unit weight of specimen,

9.3.10 Water content of test specimen, and

9.3.11 Details of curing and conditioning periods.

10. Precision and Bias

10.1 The precision and bias of this test method have not been established by an interlaboratory test program. However, based on test data from Packard (1962)[4] and Packard and Chapman (1963)[5] the following may serve as a guide as to the variability of compressive strength test results.

10.1.1 Tests were performed in a single lab on 122 sets of duplicate specimens molded from 21 different soil materials. The average difference in strength on duplicate specimens was 8.1 % and the median difference was 6.2 %. These values are expressed as the percent of the average strength of the two specimens as follows:

$$\% \text{ Difference} = \frac{(\text{high value} - \text{low value})}{(\text{high value} + \text{low value})/2} \times 100 \qquad (1)$$

The distribution of the variation is shown in Fig. 1. The data cover a wide range of cement contents and compressive strengths.

11. Keywords

11.1 compressive strength; soil-cement; soil stabilization

[4] Packard, R. G., "Alternate Measures for Measuring Freeze-Thaw and Wet-Dry Resistance of Soil-Cement Mixtures," *Highway Research Bulletin*, 353, Transportation Research Board, 1962, pp 8–41.

[5] Packard, R. G., and Chapman, G. A., "Developments in Durability Testing of Soil-Cement Mixtures," *Highway Research Record*, No. 36, Transportation Research Board, 1963, pp 97–122.

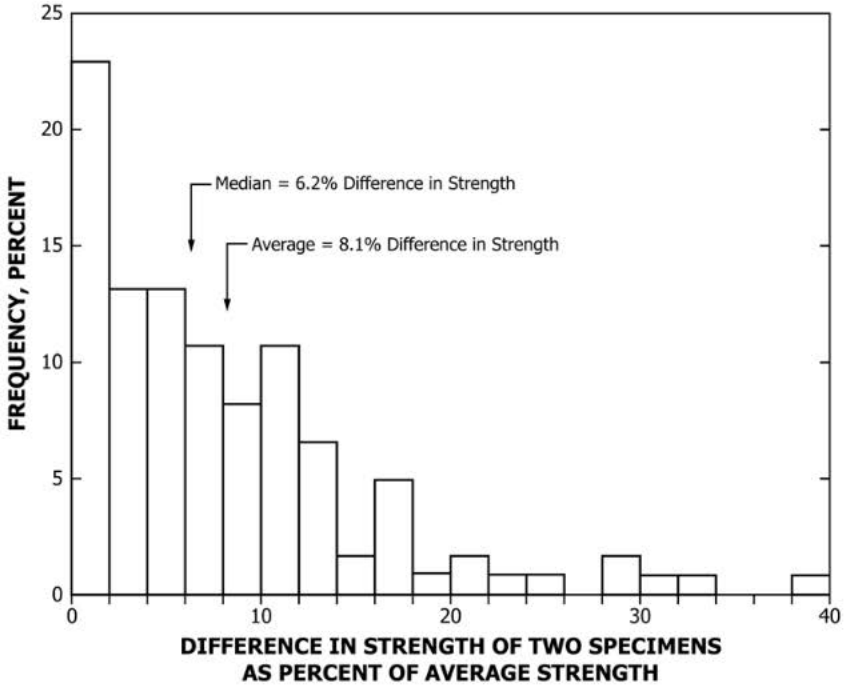

FIG. 1 Distribution of Variation of Test Results for 122 Sets of Duplicate Specimens

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2000 (Reapproved 2007)) that may impact the use of this standard. (November 1, 2017)

(1) Clarified wording in 1.2.1 and 1.2.2.
(2) Updated caveats in Section 1 and renumbered sections as applicable.
(3) Updated 2.1 references
(4) Updated 3.1 Definitions statement.
(5) Updated Note 1.
(6) Added clarification wording in 5.1.
(7) Added balances and measuring device to the Apparatus section.
(8) Added clarification wording and procedural steps in Sections 6 and 7.
(9) Added calculation of unit weight in Section 8.
(10) Updated and expanded the Report section.