Designation: D4943 – 18

Standard Test Method for Shrinkage Factors of Cohesive Soils by the Water Submersion Method[1]

This standard is issued under the fixed designation D4943; 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 determining the shrinkage factors of cohesive soils, using the water submersion technique, whereby the volume of a dried soil pat is determined while suspended in a water bath.

1.2 The data obtained following this test method are also used to determine the shrinkage ratio, volumetric shrinkage, and linear shrinkage of the soil.

1.3 This test method is applicable only for cohesive soils.

1.4 Since this test method is performed only on that portion of a soil which passes the 425-µm (No. 40) sieve, the relative consistency of the tested portion of the soil to the properties of the sample as a whole must be considered when evaluating the entire soil sample.

1.5 All recorded and calculated values shall conform to the guide for significant digits and rounding established in Practice D6026.

1.5.1 The procedures, used to specify how data are collected/recorded and calculated in this standard, are regarded as the industry standard. In addition, they are representative of the significant digits that should generally 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.

1.6 *Units*—The values stated in SI units are to be regarded as standard except the sieve designations are shown using the alternative sieve designation in parentheses. No other units of measurement are included in this standard.

1.7 *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.* For specific safety hazards, see Section 8.

1.8 *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]

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702 Practice for Reducing Samples of Aggregate to Testing Size

D75 Practice for Sampling Aggregates

D420 Guide for Site Characterization for Engineering Design and Construction Purposes

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

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

D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

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

E2251 Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved June 1, 2018. Published July 2018. Originally approved in 1989. Last previous edition approved in 2008 as D4943 – 08, which was withdrawn April 2017 and reinstated in June 2018. DOI: 10.1520/D4943-18.

[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**

3. Terminology

3.1 *Definitions:*

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *shrinkage factors of soils*—determinations made on a soil pat consisting of the Shrinkage Limit, Shrinkage Ratio, Linear Shrinkage and Volumetric Shrinkage.

3.2.1.1 *shrinkage limit*—the shrinkage limit is the water content of a soil where further loss of moisture will result in no additional volume reduction.

3.2.1.2 *shrinkage ratio*—the ratio in the change in soil volume, expressed as a percentage of the dry volume, to the corresponding change in water content above the shrinkage limit, expressed as a percentage of the mass of oven-dried soil.

3.2.1.3 *linear shrinkage*—the decrease in one dimension of a soil mass, expressed as a percentage of the original dimension, when the water content is reduced from a given value to the shrinkage limit.

3.2.1.4 *volumetric shrinkage*—the decrease in volume, expressed as a percentage of the soil mass when dried, of a soil mass when the water content is reduced from a given percentage to the shrinkage limit.

3.2.2 *soil pat*—the intact dry or wetted soil specimen molded in a shrinkage dish.

4. Summary of Test Method

4.1 A sample of fine-grained soil is thoroughly mixed with distilled or demineralized water to form a paste that is slightly wetter than the liquid limit consistency. This paste is used to fill a small dish to form a soil pat. The initial water content of the wet soil pat is determined. The soil pat is slowly dried to a constant mass. The change in volume of the soil, due to drying, is determined using a water submersion technique. A thin coating of wax is used to prevent water absorption by the dry soil pat during submersion in the water. Then, the water content loss to dry the soil to a constant volume is determined and subtracted from the initial water content to calculate the shrinkage limit. The changes in specimen volume and mass are used to compute the shrinkage factors of the soil.

5. Significance and Use

5.1 The shrinkage limit can be used to evaluate the shrinkage potential, crack development potential, and swell potential of earthwork involving cohesive soils.

5.2 The shrinkage limit, along with the liquid limit and plastic limit of soil, are often collectively referred to as the Atterberg limits in recognition of their formation by Swedish soil scientist, A. Atterberg. These limits distinguish the boundaries of the several consistency states of cohesive soils.

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/and the like. 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 *Balance or Scale*—A balance or scale having a minimum capacity of 500 g and meeting the requirements of Specification D4753 for a balance of 0.01-g readability.

6.2 *Suspension Apparatus (optional)*—A device centered on the balance, suitable for suspending the soil specimen in a container of water located in proximity to the balance or scale.

6.3 *Shrinkage Dish*—A circular porcelain or monel metal milk dish having a flat bottom about 40 to 45 mm in diameter and about 12 to 15 mm deep.

6.4 *Drying Oven*—An oven, thermostatically controlled, preferably of the forced draft type, and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

6.5 *Humidity Enclosure (optional)*—Small closed container large enough for shrinkage dishes and a small container of water used in dry climates to slow the initial rate of drying.

6.6 *Mortar and Pestle*—Mortar, iron or porcelain, with rubber tipped pestle.

6.7 *Spatula*—A spatula or pill knife having a blade sufficiently long and wide enough for easy use when mixing and placing the prepared soil in the shrinkage dish. A blade about 100 mm long by 20 mm wide has been found to be acceptable.

6.8 *Straightedge*—A stiff metal straightedge of convenient length. The scraping edge shall be beveled if it is thicker than 3 mm.

6.9 *Sieve*—425-µm (No. 40) sieve conforming to the requirements of Specification E11.

6.10 *Wax*—Microcrystalline or other suitable wax mixture which does not become brittle when dry and does not shrink during solidification. Sufficient quantity when melted in the wax warmer to submerge the soil pat.

NOTE 2—A 50/50 mixture of paraffin wax and petroleum jelly by mass has been demonstrated to provide an adequate alternative.

6.11 *Sewing Thread or Fine Fishing Line*—Fine sewing thread or fine fishing line to hold the specimen to dip into the wax and suspend the specimen during the mass in water determination.

6.12 *Water Bath*—Of sufficient size (for example, 250 mL beaker) to fully submerge the soil pat when determining indicated mass in water.

6.13 *Wax Warmer*—With sufficient temperature control to avoid overheating.

6.14 *Tongs or Gloves*—For handling hot materials.

6.15 *Thermometer*—A thermometer, capable of measuring in the room temperature range with ≤0.5°C gradations and conforming to the requirements of Specification E2251.

6.16 *Glass or Clear Plastic Plate,* about 80 by 80 mm, and about 5 mm thick used for determining the volume of the shrinkage dish.

6.17 *Petroleum Based Lubricant,* used to grease the shrinkage dish.

6.18 *Liquid Limit Device and Grooving Tool,* as described in Test Method D4318.

7. Reagents and Materials

7.1 *Purity of Water*—Where distilled water is referred to in this test method, either distilled or demineralized water may be used.

8. Safety Hazards

8.1 Wax melting equipment and hot wax may burn unprotected skin. Overheated wax may burst into flames; therefore, extreme care should be exercised when working with hot wax. Do not use an open flame device to heat wax.

9. Sampling

9.1 Obtain samples from any location that satisfies testing needs. However, use Practices C702 and D75, as well as Guide D420, as guides for selecting and preserving samples from various types of sampling operations.

9.2 Where sampling operations have preserved the natural stratification of a sample, keep the various strata separated and perform tests on the particular stratum of interest with as little contamination as possible from other strata. Where a mixture of materials will be used in construction, combine the various components in such proportions that the resultant sample represents the actual construction case.

9.3 Where data from this test method are to be used for correlation with other laboratory or field test data, use the same material as used for these tests whenever possible.

9.4 Obtain a representative portion of soil from the total sample sufficient to provide 150 to 200 g of material passing the 425-µm (No. 40) sieve. Mix samples thoroughly in a pan with a spatula or scoop and obtain a representative portion from the total mass by making one or more sweeps with a scoop through the mixed mass.

10. Volume Determination and Standardization

10.1 Determine the volume of each shrinkage dish used in accordance with Annex A1. Since the dishes may have different volumes, each dish must be permanently identified.

10.2 The specific gravity (or density) of the wax must be known in advance to at least two significant digits. This can often be obtained from the manufacturer, but shall be determined in accordance with Annex A2. The specific gravity of the wax shall be determined initially and each time the wax is replenished.

10.3 Equalize the water bath, testing apparatus, and the laboratory environment to about room temperature while performing both the dish volume determinations and the individual test measurement. Temperature differences, as large as 5°C, will not adversely impact the shrinkage limit when reported to the nearest whole number. A thermometer shall be used to verify that the water bath and water, used for the dish volume determinations, are within 5°C. Either distilled, deionized or tap water may be used for the water bath and shrinkage dish volume determination. However, the same type of water shall be used for both purposes.

11. Preparation of Test Specimen

11.1 Prepare the test specimen in accordance with the procedures outlined in Test Method D4318, using either the wet or dry preparation procedure. The water content of the soil shall be adjusted to a consistency that will require about ten blows of the liquid limit device to close the groove along a distance of 13 mm. Dependent upon the soil type, the amount of water required may exceed the liquid limit by as much as 10 percent.

12. Procedure

12.1 Select a shrinkage dish and record its identification designation and its volume. The volume of the shrinkage dish is used as the volume of the wet soil pat and is determined by procedures outlined in A1.3 and A1.4. Lightly grease the inside of the shrinkage dish.

12.2 Determine and record the mass of the greased shrinkage dish.

12.3 Place, in the center of the dish, an amount of the prepared soil equal to about one-third the volume of the dish and cause the soil to flow to the edges by tapping the dish on a firm surface, cushioned by several layers of blotting paper or similar material. Add an amount of soil approximately equal to the first portion, and tap the dish until the soil is thoroughly compacted and entrapped air has been brought to the surface. Add additional soil and continue the tapping until the dish is completely filled and excess soil flows over its edge. Strike off the excess soil with a straightedge and level the soil with the top edge of the shrinkage dish. Wipe off all soil adhering to the outside of the dish.

12.4 Determine and record the mass of the dish plus wet soil immediately after leveling.

12.5 Allow the soil pat to dry in air until the color of the pat turns from dark to light.

12.5.1 Drying the soil pat in air may produce cracking of the soil pat due to rapid moisture loss. This may be a concern in dry climates and precautions should be implemented to slow the rate of moisture loss by drying the soil pat in a humidity controlled environment.

NOTE 3—The time required to air dry the soil pat will depend on the plasticity of the soil, the initial water content, and the relative humidity. In some cases it may take from 1 to 2 weeks for the color of the soil to turn from dark to light.

12.6 Following the specimen color change, check the soil pat for cracking and determine if the pat is intact. If so, continue with the test. If the specimen has cracked or broken, the test will need to be repeated or a substitute specimen used.

NOTE 4—When testing soils that may be susceptible to cracking it is suggested that multiple specimens be molded.

12.7 Oven dry the soil pat to constant mass at 110 ± 5°C.

12.8 Determine and record the mass of the dish plus dry soil pat.