Designation: D 427 – 98

# Standard Test Method for Shrinkage Factors of Soils by the Mercury Method[1]

This standard is issued under the fixed designation D 427; 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 provides a procedure for obtaining the data which are used to calculate the shrinkage limit and the shrinkage ratio.

1.2 This test method uses mercury which is a hazardous substance. Test Method D 4943 does not use mercury and is an acceptable alternate to this procedure.

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

1.4 This test method is performed only on that portion of a soil which passes the 425-µm (No. 40) sieve. The relative contribution of this portion of the soil must be considered when using this test method to evaluate the properties of the soil as a whole.

1.5 The values stated in SI units are to be regarded as the standard. The values stated in inch-pound units are approximate and given for guidance only. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard.

1.6 *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.* This test method involves the use of the hazardous material mercury, see Section 7.

NOTE 1—**Warning:** Mercury is a definite health hazard in use and disposal.

## 2. Referenced Documents

2.1 *ASTM Standards:*

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[2]

D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Analysis and Determination of Soil Constants[3]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[3]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[3]

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction[3]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[3]

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials[3]

D 4943 Test Method for Shrinkage Factors of Soils by the Wax Method[4]

## 3. Terminology

3.1 *Definitions:*

3.1.1 The definitions used in this test method shall be in accordance with Terminology D 653.

3.1.2 *dry strength*—a descriptive measure of the effort required to crush an air-dried 12-mm (½-in.) diameter ball of soil in accordance with Practice D 2488.

## 4. Summary of Test Method

4.1 A sample of fine-grained soil is thoroughly remolded with water to approximate the liquid limit consistency. The saturated paste is placed into a container of known volume and slowly dried. The final mass and volume of the solid soil pat are determined. These measurements are used to compute the soil constants.

## 5. Significance and Use

5.1 The shrinkage factors covered in this test method can only be determined on basically fine-grained (cohesive) soils which exhibit a dry strength when air dried.

5.2 The term shrinkage limit, expressed as a water content in percent, is typically assumed to represent the amount of

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 04.09.

water required to fill the voids of a given cohesive soil at its minimum void ratio obtained by drying (usually oven). Thus, the concept shrinkage limit can be used to evaluate the shrinkage potential or possibility of development, or both, of cracks in earthworks involving cohesive soils.

5.3 Data obtained from this test method may be used to compute the volumetric shrinkage and linear shrinkage.

NOTE 2—Notwithstanding the statements on precision and bias contained in this test method, the precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies which meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself ensure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means of evaluating some of those factors.

## 6. Apparatus

6.1 *Evaporating Dish*, porcelain, about 140 mm (5½ in.) in diameter.

6.2 *Spatula*, or pill knife having a blade about 76 mm (3 in.) in length and about 19.0 mm (¾ in.) in width.

6.3 *Shrinkage Dish*—A circular porcelain or monel metal milk dish having a flat bottom and being about 44 mm (1¾ in.) in diameter and about 12 mm (½ in.) in height.

6.4 *Straightedge*, steel, about 150 mm (6 in.) in length.

6.5 *Glass Cup*, about 57 mm (2¼) in.) in diameter and about 31 mm (1¼ in.) in height, the top rim of which is ground smooth and is in a plane essentially parallel with the bottom of the cup.

6.6 *Glass Plate*, with three metal prongs for immersing the soil pat in mercury, as shown in Fig. 1.

6.7 *Glass Plate*, a plane glass plate large enough to cover the glass cup.

6.8 *Graduate*, glass, having a capacity of 25 mL and graduated to 0.2 mL.

6.9 *Balance*, sensitive to 0.1 g and conforming to the requirements of Class GP2 balances in Specification D 4753.

6.10 *Mercury*, sufficient to fill the glass cup to overflowing.

6.11 *Shallow Pan*, about 20 by 20 by 5-cm (8 by 8 by 2-in.) deep nonmetallic (preferably glass) pan used to contain accidental mercury spills.

## 7. Hazards

7.1 **Warning**—Mercury is a hazardous substance that can cause illness and death. Inhalation of mercury vapor is a serious health hazard. Mercury can also be absorbed through the skin. The effects of mercury are cumulative.

7.2 **Precaution**—In addition to other precautions, store mercury in sealed shatter-proof containers to control evaporation, work in a well-ventilated area (preferably under a fume hood), and avoid contact with skin. Rubber gloves should be worn at all times.

7.3 Minimize uncontrolled spills by performing those parts of the procedure (9.3 and 9.6) in a large shallow pan which can act as a catchment.

7.4 Clean up spills immediately using a recommended procedure explicitly for mercury.

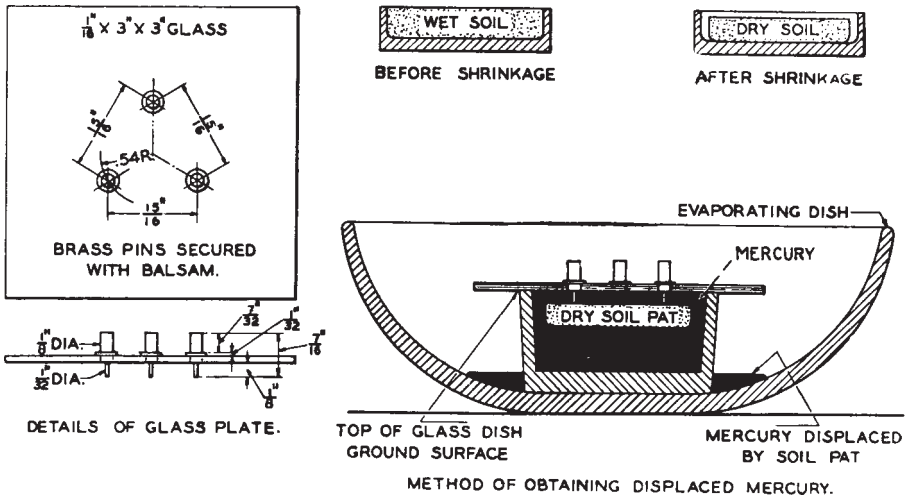
7.5 Dispose of contaminated waste materials including the dry soil pat in a safe and environmentally acceptable manner.

## 8. Sampling

8.1 Select about 30 g of soil from the thoroughly mixed portion of the material passing the No. 40 (425-µm) sieve which has been obtained in accordance with Practice D 421.

## 9. Procedure

9.1 Place the soil in the evaporating dish and thoroughly mix with distilled water. The amount of water added should produce a soil of the consistency somewhat above the liquid limit (Test Method D 4318) based on visual inspection. In physical terms, this is a consistency that is not a slurry but one that will flow sufficiently to expel air bubbles when using gentle tapping action. It is desirable to use the minimum




Metric Equivalents

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| in. | 1/32 | 1/16 | 1/8 | 7/32 | 7/16 | 15/16 | 3 |
| mm | 0.8 | 1.6 | 3.2 | 5.6 | 11.1 | 23.8 | 76.2 |

**FIG. 1 Apparatus for Determining the Volumetric Change of Subgrade Soils**

possible water content. This is of some importance with very plastic soils so that they do not crack during the drying process.

9.2 Coat the inside of the shrinkage dish with a thin layer of petroleum jelly, silicone grease, or similar lubricant to prevent the adhesion of the soil to the dish. Determine and record the mass in grams (pounds/mass) of the empty dish, $M_T$.

9.3 Place the shrinkage dish in the shallow pan in order to catch any mercury overflow. Fill the shrinkage dish to overflowing with mercury. Remove the excess mercury by pressing the glass plate firmly over the top of the shrinkage dish. Observe that there is no air trapped between the plate and mercury and if there is, refill the dish and repeat the process. Determine the volume of mercury held in the shrinkage dish either by means of the glass graduate or by dividing the measured mass of mercury by the mass density of mercury (equal to 13.55 $Mg/m^3$). Record this volume in cubic centimetres (cubic feet) of the wet soil pat, $V$.

NOTE 3—**Caution:** Mercury is a hazardous substance which can cause serious health effects from prolonged inhalation of the vapor or contact with the skin, see Section 7.

NOTE 4—It is not necessary to measure the volume of the shrinkage dish (wet soil pat) during each test. The value of a previous measurement may be used provided that it was obtained as specified in 9.3 and the shrinkage dish is properly identified and in good physical condition.

9.4 Place an amount of the wetted soil equal to about one third the volume of the dish in the center of the dish, and cause the soil to flow to the edges by taping 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 all included air has been brought to the surface. Add more soil and continue the tapping until the dish is completely filled and excess soil stands out above its edge. Strike off the excess soil with a straightedge, and wipe off all soil adhering to the outside of the dish. Immediately after it is filled and struck off, determine and record the mass in grams (pounds/mass) of the dish and wet soil, $M_w$.

9.5 Allow the soil pat to dry in air until the color of the soil turns from dark to light. Oven-dry the soil pat to constant mass at 110 ± 5°C (230 ± 9°F). If the soil pat is cracked or has broken in pieces, return to 9.1 and prepare another soil pat using a lower water content. Determine and record the mass in g (lbm) of the dish and dry soil, $M_D$.

9.6 Determine the volume of the dry soil pat by removing the pat from the shrinkage dish and immersing it in the glass cup full of mercury in the following manner.

9.6.1 Place the glass cup in the shallow pan in order to catch any mercury overflow. Fill the glass cup to overflowing with mercury. Remove the excess mercury by pressing the glass plate with the three prongs (Fig. 1) firmly over the top of the cup. Observe that there is no air trapped between the plate and mercury and if there is, refill the dish and repeat the process. Carefully wipe off any mercury that may be adhering to the outside of the cup.

9.6.2 Place the evaporating dish in the shallow pan in order to catch any mercury overflow. Place the cup filled with mercury in the evaporating dish and rest the soil pat on the surface of the mercury (it will float). Using the glass plate with the three prongs gently press the pat under the mercury and press the plate firmly over the top of the cup to expel any excess mercury. Observe that there is no air trapped between the plate and mercury, and, if there is, repeat the process starting from 9.6.1. Measure the volume of the mercury displaced into the evaporating dish either by means of the glass graduate or by dividing the measured mass of mercury by the mass density of mercury. Record the volume in cubic centimetres (cubic feet) of the dry soil pat, $V_o$.

## 10. Calculation

10.1 Calculate the initial wet soil mass as:

$$M = M_w - M_T \quad (1)$$

10.2 Calculate the dry soil mass as:

$$M_o = M_D - M_T \quad (2)$$

10.3 Calculate the initial water content of the soil as a percentage of the dry mass as:

$$w = [(M - M_o)/M_o] \times 100 \quad (3)$$

10.4 Calculate the shrinkage limit as a water content of the soil as a percentage of the dry mass as:

$$SL = w - \{[(V - V_o)\rho_w/M_o] \times 100\} \quad (4)$$

where:

$\rho_w$ = approximate density of water equal to 1.0 $g/cm^3$(62.4 $lb/ft^3$)

$V$, $V_o$ are defined in the procedures section.

10.5 Calculate the shrinkage ratio, $R$ from the data obtained in the volumetric shrinkage determination by the following equation:

$$R = M_o/(V_o \times \rho_w) \quad (5)$$

## 11. Report

11.1 Report the following information:

11.1.1 Identification data and visual description of sample.

11.1.2 Value of initial water content to the nearest whole number and omitting the percentage designation.

11.1.3 Value of shrinkage limit to the nearest whole number and omitting the percentage designation.

11.1.4 Value of shrinkage ratio to the nearest 0.01.

## 12. Precision and Bias

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

12.2 *Precision*[5]—Table 1 presents estimates of precision based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program of testing conducted on Samples 103 and 104. These samples were found to be a CL material having 59.4 % fines, a liquid limit of 33 and a plastic limit of 18.

12.2.1 The column labeled "Acceptable Range of Two Results" quantifies the maximum difference expected between two measurements on samples of the same material under the

[5] Research Report RR:D18-1002 contains the data used to establish this precision statement and is available from ASTM Headquarters.

**TABLE 1 Table of Precision Estimates**

| Material and Type Index | Average Value | Standard Deviation[A] | Acceptable Range of Two Results[A] |
|---|---|---|---|
| Single-Operator: | | | |
| Shrinkage limit | 16 | 0.6 | 1.8 |
| Shrinkage ratio | 1.90 | 0.04 | 0.13 |
| Multilaboratory: | | | |
| Shrinkage limit | 16 | 1.7 | 4.8 |
| Shrinkage ratio | 1.90 | 0.07 | 0.19 |

[A]These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

conditions listed in the first column. These values only apply to soils which are similar to Proficiency Samples 103 and 104.

NOTE 5—The figures given in Column 3 are the standard deviations that have been found to be appropriate for the test results described in Column 1. The figures given in Column 4 are the limits that should not be exceeded by the difference between two properly conducted tests.

NOTE 6—Criteria for assigning standard deviation values for highly plastic or noncohesive soils are not available at the present time.

## 13. Keywords

13.1 Atterberg limits; cohesive soils; dry strength; linear shrinkage; mercury; shrinkage ratio; volumetric shrinkage

## SUMMARY OF CHANGES

Committee D-18 has identified the location of selected changes to this standard since the last issue (D 427 – 93 (1998)) that may impact the use of this test method.

1. Added Note 2 referencing Practice D 3740. Subsequently renumbered notes affected by adding Note 2.
2. In 9.3, changed ... $mg/m^3$ to $Mg/m^3$.
3. Moved location of Table 1 to be follow 12.2.1.