



Designation: D 854 – 00

## Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer<sup>1</sup>

This standard is issued under the fixed designation D 854; 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 These test methods cover the determination of the specific gravity of soil solids that pass the 4.75-mm (No. 4) sieve, by means of a water pycnometer. When the soil contains particles larger than the 4.75-mm sieve, Test Method C 127 shall be used for the soil solids retained on the 4.75-mm sieve and these test methods shall be used for the soil solids passing the 4.75-mm sieve.

1.1.1 Soil solids for these test methods do not include solids which can be altered by these methods, contaminated with a substance that prohibits the use of these methods, or are highly organic soil solids, such as fibrous matter which floats in water.

NOTE 1—The use of Test Method D 5550 may be used to determine the specific gravity of soil solids having solids which readily dissolve in water or float in water, or where it is impracticable to use water.

1.2 Two methods for performing the specific gravity are provided. The method to be used shall be specified by the requesting authority, except when testing the types of soils listed in 1.2.1.

1.2.1 *Method A*—Procedure for Moist Specimens, described in 9.2. This procedure is the preferred method. For organic soils; highly plastic, fine grained soils; tropical soils; and soils containing halloysite, Method A shall be used.

1.2.2 *Method B*—Procedure for Oven-Dry Specimens, described in 9.3.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D 6026.

1.3.1 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 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 design.

1.4 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in these test methods.

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

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate<sup>2</sup>
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>3</sup>
- D 1140 Test Method for Amount of Material in Soils Finer Than the No. 200 (75- $\mu$ m) Sieve<sup>3</sup>
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass<sup>3</sup>
- D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>3</sup>
- 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<sup>3</sup>
- D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil, Rock, and Related Construction Materials Testing<sup>3</sup>
- D 5550 Test Method for Specific Gravity of Soil Solids by Gas Pycnometer<sup>3</sup>
- D 6026 Practice for Using Significant Digits in Geotechnical Data<sup>4</sup>
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>5</sup>
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods<sup>5</sup>
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method<sup>5</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in these test

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.08.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.09.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 14.02.

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



methods, refer to Terminology D 653.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *specific gravity of soil solids,  $G_s$ ,  $n$* —the ratio of the mass of a unit volume of a soil solids to the mass of the same volume of gas-free distilled water at 20°C.

## 4. Significance and Use

4.1 The specific gravity of a soil solids is used in calculating the phase relationships of soils, such as void ratio and degree of saturation.

4.1.1 The specific gravity of soil solids is used to calculate the density of the soil solids. This is done by multiplying its specific gravity by the density of water (at proper temperature).

4.2 The term soil solids is typically assumed to mean naturally occurring mineral particles or soil like particles that are not readily soluble in water. Therefore, the specific gravity of soil solids containing extraneous matter, such as cement, lime, and the like, water-soluble matter, such as sodium chloride, and soils containing matter with a specific gravity less than one, typically require special treatment (see Note 1) or a qualified definition of their specific gravity.

4.3 The balances, pycnometer sizes, and specimen masses are established to obtain test results with three significant digits.

NOTE 2—The quality of the result produced by these test methods 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 D 3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of these test methods are cautioned that compliance with Practice D 3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

## 5. Apparatus

5.1 *Pycnometer*—The water pycnometer shall be either a stoppered flask, stoppered iodine flask, or volumetric flask with a minimum capacity of 250 mL. The volume of the pycnometer must be 2 to 3 times greater than the volume of the soil-water mixture used during the deairing portion of the test.

5.1.1 The stoppered flask mechanically sets the volume. The stoppered iodine flask has a flared collar that allows the stopper to be placed at an angle during thermal equilibration and prevents water from spilling down the sides of the flask when the stopper is installed. The wetting the outside of the flask is undesirable because it creates changes in the thermal equilibrium. When using a stopper flask, make sure that the stopper is properly labeled to correspond to the flask.

5.2 *Balance*—Meeting the requirements of Specification D 4753, class GP1. This balance has a readability of 0.01 g and capacity of at least 2000 g.

5.3 *Drying Oven*—Thermostatically controlled oven, capable of maintaining a uniform temperature of  $110 \pm 5^\circ\text{C}$  throughout the drying chamber. These requirements usually require the use of a forced-draft oven.

5.4 *Thermometer*—Thermometer capable of measuring the temperature range within which the test is being performed, readable to the nearest  $0.1^\circ\text{C}$  and an immersion depth ranging between 25 to 80 mm. Full immersion thermometers shall not be used. Either a general-purpose precision mercury thermom-

eter or a digital thermometer with a  $-1$  to  $57^\circ\text{C}$  range will meet this requirement.

5.5 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulfate.

NOTE 3—It is preferable to use a desiccant that changes color to indicate when it needs reconstitution.

5.6 *Entrapped Air Removal Apparatus*—To remove entrapped air (deairing process), use one of the following:

5.6.1 *Hot Plate or Bunsen Burner*, capable of maintaining a temperature adequate to boil water.

5.6.2 *Vacuum System*, a vacuum pump or water aspirator, capable of producing a partial vacuum of 100 mm of mercury (Hg) or less absolute pressure.

NOTE 4—A partial vacuum of 100 mm Hg absolute pressure is approximately equivalent to a 660 mm (26 in.) Hg reading on vacuum gauge at sea level.

5.7 *Insulated Container*—A Styrofoam cooler and cover or equivalent container that can hold between three and six pycnometers plus a beaker, a water bottle, and a thermometer. This is required to maintain a controlled temperature environment where changes will be uniform and gradual.

5.8 *Funnel*—A non-corrosive smooth surface funnel with a stem that extends past the calibration mark on the volumetric flask or stoppered seal on the stoppered flasks. The diameter of the stem of the funnel must be large enough that soil solids will easily pass through.

5.9 *Pycnometer Filling Tube with Lateral Vents (optional)*—A device to assist in adding deaired water to the pycnometer without disturbing the soil-water mixture. The device may be fabricated as follows. Plug a  $\frac{1}{4}$  to  $\frac{3}{8}$  in. diameter plastic tube at one end and cut two small vents (notches) just above the plug. The vents should be perpendicular to the axis of the tube and diametrically opposed. Connect a valve to the other end of the tube and run a line to the valve from a supply of deaired water.

5.10 *Sieve*—No. 4 (4.75 mm) conforming to the requirements of Specification E 11.

5.11 *Blender (optional)*—A blender with mixing blades built into the base of the mixing container.<sup>6</sup>

5.12 *Miscellaneous Equipment*, such as a computer or calculator (optional), specimen dishes, and insulated gloves.

## 6. Reagents

6.1 *Purity of Water*—Distilled water is used in this test method. This water may be purchased and is readily available at most grocery stores; hereafter, distilled water will be referred to as water.

## 7. Test Specimen

7.1 The test specimen may be moist or oven-dry soil and shall be representative of the soil solids that passes the U. S. Standard No. 4 sieve in the total sample. Table 1 gives guidelines on recommended dry soil mass versus soil type and pycnometer size.

<sup>6</sup> Manufacturers of such blenders include, but are not limited to, Waring or Osterizer.

**TABLE 1 Recommended Mass for Test Specimen**

Soil Type	Specimen Dry Mass (g) When Using 250 mL Pycnometer	Specimen Dry Mass (g) When Using 500 mL Pycnometer
SP, SP-SM	60 ± 10	100 ± 10
SP-SC, SM, SC	45 ± 10	75 ± 10
Silt or Clay	35 ± 5	50 ± 10

7.1.1 Two important factors concerning the amount of soil solids being tested are as follows. First, the mass of the soil solids divided by its specific gravity will yield four-significant digits. Secondly, the mixture of soil solids and water is a slurry not a highly viscous fluid (thick paint) during the deairing process.

## 8. Calibration of Pycnometer

8.1 Determine the mass of the clean and dry pycnometer to the nearest 0.01 g (typically five significant digits). Repeat this determination five times. One balance should be used for all of the mass measurements. Determine and record the average and standard deviation. The standard deviation shall be less than or equal to 0.02 g. If it is greater, attempt additional measurements or use a more stable or precise balance.

8.2 Fill the pycnometer with deaired water to above or below the calibration mark depending on the type of pycnometer and laboratory preference to add or remove water.

8.2.1 It is recommended that water be removed to bring the water level to the calibration mark. The removal method reduces the chances of altering the thermal equilibrium by reducing the number of times the insulated container is opened.

8.2.2 The water must be deaired to ensure that there are no air bubbles in the water. The water may be deaired using either boiling, vacuum, combination of vacuum and heat, or a deairing device. This deaired water should not be used until it has equilibrated to room temperature. Also, this water shall be added to the pycnometer following the guidance given in 9.6.

8.3 Up to six pycnometers can be calibrated concurrently in each insulated container. Put the pycnometer(s) into a covered insulated container along with the thermometer (in a beaker of water), stopper(s) (if a stoppered pycnometer is being used), and deaired water in a bottle along with either an eyedropper or pipette. Let the pycnometer(s) come to thermal equilibrium (for at least 3 h). The equilibrium temperature should be within 4°C of room temperature and between 15 and 30°C.

8.4 Move the insulated container near the balance or vice versa. Open the container and remove one pycnometer. Only the rim of the pycnometer shall be touched as to prevent the heat from handling changing the thermal equilibrium. Either work in the container or place the pycnometer on an insulated block (Styrofoam) while making water level adjustments.

8.4.1 If using a volumetric flask as a pycnometer, adjust the water to the calibration mark, with the bottom of the meniscus level with the mark. If water has to be added, use the thermally equilibrated water from the insulated container. If water has to be removed, use a small suction tube or paper towel. Check for and remove any water beads on the pycnometer stem or on the exterior of the flask. Measure and record the mass of pycnometer and water to the nearest 0.01 g.

8.4.2 If a stoppered flask is used, place the stopper in the

bottle, then remove the excess water using an eyedropper. Dry the rim using a paper towel. Be sure the entire exterior of the flask is dry. Measure and record the mass of pycnometer and water to the nearest 0.01 g.

8.5 Measure and record the temperature of the water to the nearest 0.1°C using the thermometer that has been thermally equilibrated in the insulated container. Insert the thermometer to the appropriate depth of immersion (see 5.4). Return the pycnometer to the insulated container. Repeat the measurements for all pycnometers in the container.

8.6 Readjust the water level in each pycnometer to prepare for the next calibration and allow the pycnometers to thermally equilibrate (for at least 3 h). Repeat the procedure to obtain five independent measurements on each pycnometer. The temperatures do not need to bracket any particular temperature range.

8.7 Using each of these five data points, compute the calibrated volume of each pycnometer,  $V_p$ , using the following equation:

$$V_p = \frac{(M_{pw,c} - M_p)}{\rho_{w,c}} \quad (1)$$

where:

$M_{pw,c}$  = the mass of the pycnometer and water at the calibration temperature, g,

$M_p$  = the average mass of the dry pycnometer at calibration, g, and

$\rho_{w,c}$  = the mass density of water at the calibration temperature g/mL, (Table 2).

8.8 Calculate the average and the standard deviation of the five volume determinations. The standard deviation shall be less than or equal to 0.05 mL (rounded to two decimal places). If the standard deviation is greater than 0.05 mL, the calibration procedure has too much variability and will not yield accurate specific gravity determinations. Evaluate areas of possible refinement (adjusting the volume to the calibration mark, achieving temperature equilibrium, measuring temperature, deairing method or changing to the stoppered flasks) and revise the procedure until the standard deviation is less than or equal to 0.05 mL.

## 9. Procedure

9.1 *Pycnometer Mass*—Using the same balance used to calibrate the pycnometer, verify that the mass of the pycnometer is within 0.06 g of the average calibrated mass. If it is not, re-calibrate the dry mass of the pycnometer.

9.2 *Method A—Procedure for Moist Specimens:*

9.2.1 Determine the water content of a portion of the sample in accordance with Test Method D 2216. Using this water content, calculate the range of wet masses for the specific gravity specimen in accordance with 7.1. From the sample, obtain a specimen within this range. Do not sample to obtain an exact predetermined mass.

9.2.2 Disperse the soil using a blender or equivalent device to disperse the soil. Add the soil to about 100 mL of water. The minimum volume of slurry that can be prepared by this equipment will typically require using a 500-mL pycnometer.

9.2.3 Using the funnel, pour the slurry into the pycnometer. Rinse any soil particles remaining on the funnel into the pycnometer using a wash/spray squirt bottle.