Designation: D854 – 23

Standard Test Methods for Specific Gravity of Soil Solids by the Water Displacement Method[1]

This standard is issued under the fixed designation D854; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 These test methods cover the determination of the specific gravity of soil solids that pass the ⅜-in. (9.5-mm) or smaller sieve by means of the water displacement method. When the total sample contains larger particles, it is separated into a coarser and finer portion using a ⅜-in. (9.5-mm) or No. 4 (4.75-mm) or finer sieve. Separation on the No. 4 sieve is the referee method. Test Method C127 shall be used to obtain the specific gravity of the coarser portion. The D854 test methods shall be used to obtain the specific gravity of the finer portion. The total sample specific gravity is computed from the two portions as described in 12.5.

1.1.1 These test methods do not apply to solids which can be altered by these methods, contaminated with a substance that prohibits the use of these methods, or are highly organic, such as fibrous matter which floats in water (see Note 1).

NOTE 1—Test Method D5550 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 This standard provides two methods for performing the specific gravity test. 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 11.1. This procedure is the preferred method. Method A shall be used for organic soils; highly plastic, fine-grained soils; tropical soils; and soils containing halloysite.

1.2.2 *Method B—Procedure for Oven-Dry Specimens,* described in 11.2. This procedure requires less time and may be used for clean sands.

1.3 *Units*—The values stated in SI units are to be regarded as standard, except the sieve designations. The sieve designations are identified using the "alternative" system in accordance with Practice E11, such as 3-in. and No. 200, instead of the "standard" designation of 75-mm and 75-µm, respectively. Reporting of test results in units other than SI shall not be regarded as non-conformance with this test method. The use of balances or scales recording pounds of mass (lbm) 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 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.

1.5 *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. Glassware under vacuum has the potential for implosion. Proper personal protective equipment shall be used at all times. See Section 8.*

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

[1] This standard 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 Nov. 1, 2023. Published November 2023. Originally approved in 1945. Last previous edition approved in 2014 as D854 – 14, which was withdrawn in May 2023 and reinstated November 2023. DOI: 10.1520/D0854-23.

[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**

C127 Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedures)
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
D5550 Test Method for Specific Gravity of Soil Solids by Gas Pycnometer
D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data
D7928 Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
E1406 Specification for Laboratory Glass Filter Flasks

3. Terminology

3.1 *Definitions:*

3.1.1 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 *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 pure water at 20 °C.

3.2.2 *equilibrated test water, n*—test water that is in air equilibrium at room temperature and pressure.

3.2.2.1 *Discussion*—Exposing test water to the atmosphere for several hours allows dissolved air to escape and prevents formation of air bubbles during the test.

3.2.3 *reduced sample, n*—the minus ⅜-in. (9.5-mm) sieve, No. 4 (4.75-mm) sieve, or finer material that has been separated from the sample and then split to reduce the mass while still having sufficient quantity to meet the minimum dry mass requirements of Table 1.

4. Summary of Test Method

4.1 A representative reduced sample is prepared in either a moist (Method A) or dry (Method B) state. For moist preparation, a subspecimen of the reduced sample is dispersed and blended into a slurry using one of four options. The dry mass of the test specimen is determined at the end of the test. For dry preparation, the material is oven dried prior to testing and the specimen mass is measured once the material is placed in the pycnometer. Test water is added to immerse the specimen. One of three techniques are used to deair the specimen: boiling, vacuuming, or a combination of both. Equilibrated test water is added to fill the pycnometer. The pycnometer, thermometric device, and additional test water are placed into an insulating container to achieve thermal equilibrium. The mass and temperature are recorded after adjusting the water volume. The calibrated mass of the pycnometer with water, mass of the dry specimen, and mass of the specimen and pycnometer filled with water are used for calculation of specific gravity. The final specific gravity is reported relative to water density at 20°C.

5. Significance and Use

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

5.1.1 The specific gravity of soil solids is used to calculate the density of the soil solids. This is done by multiplying the specific gravity by the density of water at 20°C. The soil solids density is nearly independent of temperature.

5.2 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 2) or a qualified definition of their specific gravity.

NOTE 2—For some soils containing a significant fraction of organic matter, kerosene is a better wetting agent than water and may be used in place of test water for oven-dried specimens. Kerosene is a flammable liquid that must be used with extreme caution. This standard should not be used when using kerosene as the test fluid.

5.3 The balances, pycnometer sizes, and specimen masses are specified to obtain test results reportable to four significant digits.

NOTE 3—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 D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of these test methods 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 *Pycnometer*—The pycnometer (see Note 4) shall be either a stoppered flask, stoppered iodine flask, or volumetric flask with a minimum capacity of 250 mL (see Note 5). The stopper and flask shall remain a matched pair and labeled accordingly. The volume of the pycnometer shall be 2 to 3 times greater than the volume of the soil-water mixture used during the deairing portion of the test.

NOTE 4—Heavy duty pycnometers are commonly used to perform this test using the vacuum method. However, there are no products on the market that are certified for vacuum applications. See the Hazards section (Section 8) for more information.

NOTE 5—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 of the outside of the flask is undesirable because it creates changes in the thermal equilibrium and requires careful drying.

6.2 *Balance*—A balance meeting the requirements of Guide D4753 for 0.01 g readability and sufficient capacity (see Note 6). One balance shall be used for all of the mass measurements.

NOTE 6—Depending on the dry mass of the specimen, the balance should handle between 500 and 1000 g when using a 250 mL pycnometer and between 1000 g and 1500 g when using 500 mL pycnometers.

6.3 *Drying Oven*—Vented, thermostatically controlled oven, capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber. These requirements usually require the use of a forced-draft oven.

6.4 *Thermometric Device*—A thermometric device capable of measuring the temperature range within which the test is being performed, having a readability of 0.1°C and an accuracy of 0.5°C.

6.4.1 The thermometric device must be capable of being immersed in the specimen and calibration solutions to a depth ranging between 25 mm below the water surface and 25 mm from the bottom of the pycnometer. A partial immersion thermometric device shall have an immersion line at least 25 mm from the bottom of the sensor tip. Total or full immersion thermometric devices shall not be used.

6.5 *Oven Drying Containers*—To obtain oven dried specimen mass depending on the option:

6.5.1 *Method A*—Containers of sufficient size to hold the volume of the pycnometer plus any wash water.

6.5.2 *Method B*—Container of sufficient size to hold the test specimen.

6.6 *Specimen Cooling Device*—To prevent water absorption while cooling oven dried specimens use one or both of the following:

6.6.1 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing desiccant.

6.6.2 *Desiccant*—Silica gel or anhydrous calcium sulfate with a color indicator placed in the desiccator. Desiccant in use must be effectively dry according to manufacturer's instructions.

6.6.3 *Covers for Oven Drying Containers*—Tight fitting lids or aluminum foil to cover containers.

6.7 *Degassing Apparatus*—To remove entrapped air (deairing process), one or more of the following as appropriate to the method:

6.7.1 *Hot Plate or Bunsen Burner*—Capable of maintaining a temperature adequate to boil water in the pycnometer. The Bunsen Burner shall be equipped with a ceramic shield, baffle plate, sand bath, or other means to distribute the heat.

6.7.2 *Water Bath*—A shallow water container of sufficient size to hold the pycnometers while heating.

6.7.3 *Vacuum System*—A vacuum pump or water aspirator, capable of producing at least a partial vacuum of 660 mm of mercury (Hg) (see Note 7).

NOTE 7—A partial vacuum of 660 mm of mercury is approximately equivalent to an absolute pressure of 100 mm of Hg (13 kPa) at sea level. Vacuum gages often indicate the vacuum as a positive number with zero being atmospheric pressure.

6.7.4 *Vacuum Gauge*—A gauge having a readability of at least 5 kPa and capable of measuring either gauge pressure to –95 kPa or absolute pressure as low as 5 kPa.

6.8 *Insulated Container*—A styrofoam cooler with cover or container with equivalent insulation effectiveness. The container shall have capacity to hold between three and six pycnometers plus a beaker (or bottle) of test water, and the sensor of the thermometric device. The container is required to maintain a stable temperature environment to allow the pycnometers to come to thermal equilibrium.

6.9 *Insulated Block*—A styrofoam block or similar material with equivalent insulation effectiveness to that of the insulated container and large enough to support one pycnometer.

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

6.11 *Pycnometer Filling Device*—To assist in adding equilibrated test water to the pycnometer without disturbing the soil-water mixture use one of the following:

6.11.1 *Pycnometer Filling Tube with Lateral Vents*—A device may be fabricated as follows. Plug a 6 mm to 10 mm 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 test water.

6.11.2 *Small Diameter Flexible Tube*—A piece of flexible tubing having a diameter of 6 mm to 10 mm and long enough to connect from a container of equilibrated test water to the bottom of the pycnometer. The tubing shall be soft enough to pinch off the flow with finger pressure.

6.12 *Water Dispenser*—A pipet, eyedropper, or squeeze bottle of sufficient length for the tip to extend past the calibration mark on the volumetric flask or stoppered seal on the stoppered flasks.

6.13 *Spoon*—Spoon or similar instrument of sufficient size to transfer material directly into the funnel and prevent loss of material.

6.14 *Separation Sieve*—⅜-in. (9.5-mm), No. 4 (4.75-mm) or finer sieve conforming to the requirements of Specification E11.

6.15 *Soil Dispersion apparatus (Method A)*—One of the following devices used to disperse the soil:

6.15.1 *Blender*—A blender either with mixing blades build into the base or with mixing blades attached to the shaft and baffle rods built into the mixing container. This latter device is described in detail as the Stirring Apparatus and Dispersion Cup in D7928. The blades shall be in good condition.

6.15.2 *Shake Bottle*—A hard plastic bottle with tight fitting cap and several ceramic grinding balls (about 13 mm diameter).

6.16 *Mortar and Rubber-Covered Pestle (Method B)*—Apparatus suitable for breaking up aggregations of air-dried soil particles without breaking individual particles.

6.17 *Miscellaneous Equipment*—Such as specimen dishes, spatulas, glass plate, and insulated gloves.

7. Reagents

7.1 *Test Water*—Distilled, demineralized, deionized, or reverse osmosis pure water is the only permissible test fluid. The use of tap water is not permitted.

8. Hazards

8.1 Glass pycnometers under vacuum pose an implosion hazard. Annex 1 of Specification E1406 provides a test method to establish that a glass vessel, that is not abraded, bruised, or otherwise damaged in subsequent service, is expected to indefinitely withstand a vacuum. This test should be considered in the absence of a manufacturer specification. In all circumstances, proper personal protective equipment is required to prevent injury from flying glass debris when glass is exposed to differential pressures.

9. Test Specimen

9.1 The test specimen may be moist or oven-dry soil and shall be representative of the soil solids that pass the ⅜-in. (9.5-mm) or No. 4 or finer sieve from the total sample. Separation using the No. 4 sieve is the referee method. The test specimen shall meet the minimum dry mass requirements provided in Table 1 based on the maximum particle size. The recommended ranges provided in Table 1 provide guidelines based on particle size, and pycnometer size (see Note 8). High plasticity soils will expand excessively making it necessary to use small test specimens.

NOTE 8—The recommended limits provided in Table 1 are intended to increase precision in the test and account for practical details in handling the materials. The dry mass values are large enough to yield four-significant digits in the computed specific gravity. Increasing the dry mass increases the precision of the results. The mixture of soil solids and water for the fine-grained soils needs to be dilute during the deairing process.

10. Calibration of Pycnometer

10.1 Measure and record the mass of the clean and dry pycnometer, M_p, to the nearest 0.01 g (typically five significant digits). If using a stoppered flask, include the stopper as part of the pycnometer mass. Repeat this determination five times. One balance shall be used for all the mass measurements. Calculate 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.

10.2 Fill the pycnometer with equilibrated test water to above or below the calibration mark depending on the type of pycnometer and laboratory preference to add or remove water (see Note 9). The water shall be added to the pycnometer following the guidance given in 11.5.

NOTE 9—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.

10.2.1 The water must be equilibrated to standard room pressure and temperature conditions to make sure that there are no air bubbles in the water. The water may be deaired using either boiling, vacuum, combination of vacuum and heat, a deairing device or stored overnight in an open container. This deaired water shall not be used until it has temperature equilibrated to room temperature.

10.3 No more than six pycnometers shall be calibrated concurrently in each insulated container. Put the pycnometer(s) into a covered insulated container along with the thermometric device, a beaker (or bottle) of test water, stopper(s) (if a stoppered pycnometer is being used), and the water dispenser. Let the pycnometer(s) come to thermal equilibrium for at least 3 h. The equilibrium temperature shall be within 4°C of room temperature and between 15°C and 30°C.

10.4 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 to prevent the heat from handling changing the thermal equilibrium. Place the pycnometer on the insulated block while making water level adjustments and temperature measurements.

10.4.1 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 must be added, use the thermally equilibrated water from the insulated container. If water must be removed, use a small suction tube, squeeze bottle, 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, $M_{pw,i}$, to the nearest 0.01 g using the balance.

10.4.2 If using a stoppered flask, adjust the water to prevent entrapment of any air bubbles below the stopper during its placement. Place the stopper in the flask. While inserting the stopper remove excess water using an eyedropper or squeeze

TABLE 1 Dry Mass Test Specimen Requirements and Recommendations

Maximum Particle Size of Reduced Sample		Test Specimen Dry Mass (g)				
			Recommended Range for Test Specimen			
99 % or more passes		Minimum	For 250 mL Pycnometer		For 500 mL Pycnometer	
Alt. Sieve	(mm)		Minimum	Maximum	Minimum	Maximum
No. 100	0.150	20	30	50	30	75
No. 40	0.425	40	40	60	40	100
No. 10	2.00	50	50	75	50	125
No. 4	4.75	75	75	125	75	200
⅜ in.	9.50	165	165	200	165	300