



Designation: D5550 – 23

Standard Test Method for Specific Gravity of Soil Solids by Gas Pycnometer¹

This standard is issued under the fixed designation D5550; 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 specific gravity of soil solids by means of a gas pycnometer. Particle size is limited by the dimensions of the test specimen container of the particular pycnometer being used.

1.2 Test Method **D854** may be used instead of or in conjunction with this test method for performing specific gravity tests on soils. Note that Test Method **D854** does not require the specialized test apparatus needed by this test method. However, Test Method **D854** may not be used if the test specimen contains matter that can readily dissolve in water, whereas this test method does not have that limitation.

1.3 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice **D6026**.

1.3.1 For purposes of comparing a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal or significant digits in the specified limits.

1.3.2 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.

1.4 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only and are not considered standard.

1.4.1 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. The converted slug unit is not given, unless dynamic ($F = ma$) calculations are involved.

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.*

2. Referenced Documents

2.1 ASTM Standards:²

- [D653 Terminology Relating to Soil, Rock, and Contained Fluids](#)
- [D854 Test Methods for Specific Gravity of Soil Solids by Water Pycnometer](#)
- [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](#)
- [D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils](#)
- [D4542 Test Methods for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer](#)
- [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 and Data Records in Geotechnical Data](#)

3. Terminology

3.1 Definitions:

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 Jan. 1, 2023. Published February 2023. Originally approved in 1994. Last previous edition approved in 2014 as D5550 – 14. DOI: 10.1520/D5550-23.

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

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

4. Summary of Test Method

4.1 This test method is used to determine the specific gravity of soil grains using a gas pycnometer. This test method also contains equations for correcting the initial specific gravity value for dissolved matter within the pore fluid.

5. Significance and Use

5.1 The specific gravity value is used in many phase relation equations to determine relative volumes of particle, water, and gas mixtures.

5.2 The term soil particle typically refers to a naturally occurring mineral grain that is not readily soluble in water. Therefore, the specific gravity of soils that contain extraneous matter (such as cement, lime, and the like) or water-soluble material (such as salt) must be corrected for the precipitate that forms on the test specimen after drying. If the precipitate has a specific gravity less than the parent soil grains, the uncorrected test result will be too low. If the precipitate has a higher specific gravity, then the uncorrected test value will be too high.

5.3 Heating during drying may diagenetically alter the structure of some clay minerals.³ Therefore caution should be exercised if the mineral composition of a clay test specimen is going to be determined after drying. It is possible to dry the test specimen at a lower temperature. However, the effect on water content⁴ and hence specific gravity should be investigated. In addition, some materials other than clay may be affected by drying at 110°C, such as gypsum, soils containing organics, fly ash containing residual coal, island sands. Test Method **D2216** includes recommendations for drying gypsum using a lower temperature, such as 60°C.

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. 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.

6. Apparatus

6.1 *Pycnometer*—The gas pycnometer shall be one of the commercially available models that determines the volume of a solid test specimen. Some pycnometers measure the pressure drop that occurs after a gas at a known pressure is allowed to flow into another chamber (typically the first chamber contains the solid material being tested). The amount of pressure drop is related to the volume of soil present. Some others place a known volume of gas into a chamber containing the test specimen. The increase in pressure is related to the volume of the material. Either type of instrument is acceptable provided that the required accuracy of the instrument produces a volume

measurement that is $\pm 0.2\%$ of the test specimen volume. The use of gas pycnometry described in this test method pertains to both types of pycnometers used for test specimen volume determination, so no further method differentiation and apparatus description is needed, regardless of which type of pycnometer is used. In addition, the pycnometer chosen will use one or more test specimen containers of specific dimensions. Refer to manufacturer's documentation for test specimen container dimensions, as the container dimensions will limit the size of the test specimen.

NOTE 2—Commercially available instruments should be checked using materials with known specific gravities to ensure that they provide acceptable precision and accuracy for the range of soil types to be tested. Some instruments require an operator to manually perform the test (that is, physically move the working components of the apparatus), whereas, other instruments are fully automatic (after the test specimen has been loaded) and can produce a digital display of the volume and specific gravity value (the test specimen mass has to be input). Some instruments can also send the test results to a separate printer. Obviously, inherent errors are more possible with one type of equipment than another. Furthermore, some instruments are constructed differently than others and can therefore produce more accurate and reproducible results.

6.2 *Balance*—Balance meeting the requirements of Specifications **D4753** and readable, without estimation, to at least 0.1 % of the test specimen mass.

6.3 *Compressed Gas System*—Typically research grade helium is required by the instruments. A tank capable of storing the required volume of gas and associated pressure regulator(s) required to deliver the gas at the specified pressure.

NOTE 3—Other inert gas may be substituted for helium; refer to manufacturer's suggestions. Helium is often used because it obeys the ideal gas law and is able to penetrate small soil pores. Ordinary air may produce acceptable results for non-reactive test specimens in some instruments, however, that practice should be discouraged because of the uncertainty introduced into the test results.

6.4 *Drying Oven*—Thermostatically-controlled oven, capable of maintaining a uniform temperature of $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$) throughout the drying chamber.

6.5 *Desiccator*—A desiccating cabinet or jar with air-tight seal containing silica gel or an anhydrous calcium sulfate desiccant. The desiccator needs to be capable of providing isolation for the test specimen after drying while cooling to ambient temperature to limit adsorption of moisture or other vapors. The desiccator does not necessarily need to have features such as inert gas purge or ESD protection, though if these are present with the selected desiccator no harm to the test specimen should occur while under storage.

6.6 *Anhydrous Calcium Sulfate*—Desiccant used to reduce adsorption of moisture onto dried test specimen while cooling to ambient temperature. Note that this is a desiccant and will adsorb water from skin, eyes, and lungs, possibly causing irritation of contacted surfaces. Therefore, follow recommendations given in Safety Data Sheet (SDS) obtained from the supplier.

NOTE 4—Indicating desiccant changes color when it is no longer able to absorb moisture. However, indicating desiccant is more expensive than the non-indicating variety. To save cost, indicating desiccant can be mixed in with the non-indicating type. A ratio of one part indicating desiccant to approximately four parts non-indicating has proven to be acceptable in many applications.

³ Carroll, D., Clay Minerals: A Guide to Their X-Ray Identification, *Geological Society of America Special Paper 126*, 1970.

NOTE 5—Anhydrous calcium sulfate can be rejuvenated by heating at 204°C (400°F) for 1 h. Silica gel can be rejuvenated by heating at 149°C (300°F) for 3 h. Indicating desiccant that still has the capacity to absorb moisture will change color back to or close to the original color after heating.

6.7 *Vacuum System*—A vacuum pump or aspirator may be required by some instruments. Refer to the manufacturer's specifications to determine the requirements of the particular apparatus.

NOTE 6—Some pycnometers do not require a vacuum system to remove gas from the chambers, but instead, rely on a series of purges with an inert gas to clear the instrument of reactive gases.

6.8 *Mortar and Pestle*, used to pulverize some dried soil test specimens.

6.9 *Miscellaneous Equipment*, test specimen dishes or weighing paper and insulated gloves or tongs.

7. Reagents and Materials

7.1 Research grade Helium unless otherwise specified as being acceptable by the manufacturer.

8. Sampling and Test Specimen

8.1 The test specimen must be oven dried and shall be representative of the total material of interest. Typically a greater test specimen mass used in the instrument will produce a more accurate measured volume. The test specimen container within the available pycnometers varies in size from 1 to 350 cm³. Because of the principles involved with instrument function, most manufacturers require that a majority of the test specimen container be filled with soil to produce acceptably accurate volume results. Choose a test specimen accordingly so as to fill at least one-half of the bulk volume of the test specimen container. Soil grains of any size are acceptable to test provided that they are easily placed within and do not protrude from the test specimen container.

NOTE 7—Using a small test specimen container may require the use of a more accurate balance with higher precision to attain the specified accuracy required by this test method.

9. Calibration

9.1 The calibration of each type of pycnometer is different. The manufacturer's instructions should be followed. There are generally two common calibration checks. The first one requires the test specimen container be checked when empty. The determined volume should be within manufacturer's tolerances of zero. Each pycnometer should also be supplied with an object of known volume (\pm manufacturer's tolerances) that can be placed in the test specimen container. The measured object's volume should fall within specifications.

9.2 The zero check should be made at the beginning of testing on a daily basis. The calibration volume check should be performed after twenty-five soil test specimens are tested. Depending on its configuration, a pycnometer may also require the periodic checking of an internal chamber volume(s). If any calibration check falls outside the tolerances set forth by the manufacturer, the problem must be found and rectified before testing on soil test specimens resumes.

NOTE 8—It may be beneficial to have several soil specimens that are

used as internal laboratory standards that behave more similarly to test specimens than the stainless-steel spheres often supplied with the instruments. Several different minerals (or combinations) can be used periodically to check for accuracy or precision, or both. One easily obtained mineral is quartz with a specific gravity of 2.65. One additional benefit of calculating actual mineral grain specific gravity values is that it is also an indirect check on the operation of the balance (there is however an unlikely possibility that compensating errors in both the mass and volume determinations will produce the expected result).

10. Procedure

10.1 Record initial mass of test specimen, $M_{s,i}$, then dry the test specimen in an oven per recommendations found in Test Method D2216 until a constant mass is obtained.

10.2 Remove the test specimen from the oven and pulverize it into sand size particles using a mortar and pestle.

10.2.1 In some instances the test specimen may not have to be ground to a finer size, for example, cohesionless coarse grained sand. Multiple tests using pulverized and intact specimens can be performed and results compared. If a difference is obtained, the pulverized procedure is preferred.

10.3 Place the test specimen back in the oven until a constant mass is again obtained. Care should be exercised to avoid losing any soil during the transfer process.

10.4 For soils with a liquid limit of less than about 25, as determined using an appropriate Test Method such as D4318, remove the test specimen from the oven and place it into a desiccator for it to cool to within $\pm 2^\circ\text{C}$ of ambient temperature. The temperature at which the soil volume is measured can be reported but is not required by this test method because of the negligible effect of temperature on the volume of soil solids. However, temperature may have a significant effect on performance of the gas pycnometer. While in the instrument, the test specimen should not be warmer than room temperature. The test specimen should not be exposed to air (even within the desiccator) any longer than is required to reach thermal equilibrium because of the potential for some types of minerals to adsorb moisture, which would change the measured mass and volume. A tight-fitting metal cover placed over metal test specimen containers has been successfully used to prevent moisture adsorption during the cooling period. Therefore, testing should be conducted within the specified operating temperature range of the apparatus.

10.4.1 Quickly obtain and record the mass of the specimen, M_s , to the nearest 0.01 g.

10.4.2 Transfer the soil into the test chamber.

10.5 For soils with a liquid limit of about 25 or greater, as determined using an appropriate Test Method such as D4318, remove the test specimen from the oven, and quickly place the test specimen directly into the instrument while still hot. Allow the test specimen to come to thermal equilibrium with the pycnometer by waiting for it to cool to a constant temperature, $\pm 2^\circ\text{C}$, as determined using the temperature reading of the pycnometer, prior to commencement of analysis. This typically takes between 15 and 30 minutes. The mass of the test specimen will be determined post-analysis as described in 10.7.

10.6 Following the manufacturer's instructions, obtain and record the volume of the test specimen, V_s , to the nearest 0.05

cm³. This will allow reporting of specific gravity to 0.01 so long as the test specimen size is selected according to Section 8. In order to report specific gravity with higher resolution, it is necessary to record the volume of the test volume with more resolution, such as 0.005 cm³. Verify that the accuracy specifications of the pycnometer justify reporting specific gravity to 0.001.

10.7 After the test is finished, quickly obtain the mass of the test specimen again, M_s^2 to the nearest 0.01 g.

10.7.1 The comparison of the second mass measurement, M_s^2 , to the first value, M_s , is another informal way to check the operation of the instrument. If the two mass values differ by more than the precision of the balance, re-run the test or determine what the cause of the difference is. A gain in mass may indicate that the test specimen adsorbed water which would produce a low specific gravity. A loss in mass could indicate that some of the test specimen was carried into the instrument by faulty procedure or by equipment malfunction.

11. Calculation

11.1 *Density*—Calculations as shown are for the SI system of units. Other units are permissible provided appropriate conversion factors are used to maintain consistency of units throughout the standard.

11.2 Determine the specific gravity of the soil, G_s , by using the equation:

$$G_s = \frac{\left(\frac{M_s}{V_s}\right)}{\rho_w} \quad (1)$$

where:

M_s = mass of the test specimen determined prior to placement in the pycnometer, g,

V_s = volume of the test specimen, cm³, and

ρ_w = distilled water density at a temperature of 4°C, 1 g/cm³.

NOTE 9—Grain specific gravity values are typically reported to the nearest 0.01, however the most accurate and precise pycnometers (in conjunction with the appropriate balance) may produce results that would allow reporting to the nearest 0.005 or better.

11.3 If the soil contained salt (or other dissolved matter), determined perhaps using Test Methods D4542, in the pore fluid, the G_s value should be corrected for the additional mass and volume that precipitated out during drying. The following equation can be used if the test specimen water content has not been corrected for salt content (assume salt represents any kind of dissolved matter):

$$G_{sc1} = \frac{M_s - \left[\left(\frac{S}{1000 - S}\right)WM_s\right]}{\left[V_s - \frac{\left(\frac{S}{1000 - S}\right)WM_s}{\rho_s}\right] \rho_w} \quad (2)$$

where:

G_{sc1} = grain specific gravity corrected for a particular salinity and salt density using a non-corrected water content,

M_s = mass of pycnometer test specimen including salt, g,
 V_s = volume of pycnometer test specimen including salt, cm³,

S = salinity of pore fluid, parts per thousand by mass,

W = water content (mass of water without salt loss during drying/mass of solids including salt, determined after drying, difference between M_{si} and M_s), not corrected for salinity, decimal form,

ρ_s = density of dissolved matter (sea salt density is typically 2.18 g/cm³), and

ρ_w = distilled water density at a temperature of 4°C, 1 g/cm³.

11.4 The following equation can be used if the test specimen water content has been corrected for salt content (assume salt represents any kind of dissolved matter):

$$G_{sc2} = \frac{M_s - \left[\frac{W_c \left(\frac{S}{1000}\right) M_s}{1 + w_c \left(\frac{S}{1000}\right)}\right]}{\left\{V_s - \left[\frac{W_c \left(\frac{S}{1000}\right) M_s}{\left(1 + W_c \left(\frac{S}{1000}\right)\right) \rho_s}\right]\right\} \rho_w} \quad (3)$$

where:

G_{sc2} = grain specific gravity corrected for a particular salinity and salt density using a salinity-corrected water content,

M_s = mass of pycnometer test specimen including salt, g,
 V_s = volume of pycnometer test specimen including salt, cm³,

S = salinity of pore fluid, parts per thousand by mass,

W_c = water content (mass of water including salt/mass of solids excluding salt), corrected for salinity, decimal form,

ρ_s = density of dissolved matter (sea salt density is typically 2.18 g/cm³), and

ρ_w = distilled water density at a temperature of 4°C, 1 g/cm³.

11.5 The following equation can be used to obtain a water content corrected for pore water salinity:

$$W_c = \frac{\left(1 + \frac{S}{1000 - S}\right) M_w}{M_s - \left[\left(\frac{S}{1000 - S}\right) M_w\right]} \quad (4)$$

where:

W_c = water content corrected for pore water salinity, decimal form,

M_w = mass of water without salt, g,

M_s = mass of test specimen including salt, g, and

S = salinity of the pore fluid, by mass, in parts per thousand.

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

12.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below is covered in 1.3 and Practice D6026.