Designation: D5550 – 14

# Standard Test Method for Specific Gravity of Soil Solids by Gas Pycnometer[1]

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 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 specimen contains matter that can readily dissolve in water, whereas this test method does not have that limitation.

1.3 All measured 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 mathematical conversions to inch-pound units, which are provided for information only and are not considered standard.

1.4.1 The converted inch-pound units use the gravitational system of 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 and health practices and determine the applicability of regulatory limitations prior to use.*

## 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

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

## 3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of 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.

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of SubcommitteeD18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[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**

## 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 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.

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 by one of two methods. One measures 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. The other type of instrument puts a known volume of gas into a chamber containing the 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 ±0.2 % of the specimen volume.

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 specimen has been loaded) and can produce a digital display of the volume and specific gravity value (the 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 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 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 ± 5°C (230 ± 9°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.

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.

NOTE 5—Anydrous 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.

6.6 *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.

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

6.8 *Miscellaneous Equipment,* 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. Test Specimen

8.1 The test specimen must be oven dried and shall be representative of the total sample. Typically a greater specimen mass used in the instrument will produce a more accurate measured volume. The sample container within the available pycnometers varies in size from 1 to 350 $cm^3$. Because of the principles involved with instrument function, most manufacturers require that a majority of the specimen cup be filled with soil to produce acceptably accurate volume results. Soil grains of any size are acceptable to test provided that they are easily placed within and do not protrude from the specimen container.

NOTE 7—Using a small sample 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 specimen holder cup 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 (± manufacturer's tolerances) that can be placed in the specimen cup. 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 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 specimens resumes.

NOTE 8—It may be beneficial to have a number of soil specimens that are used as internal laboratory standards that behave more similarly to test samples than the stainless steel spheres often supplied with the instruments. A number of 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 Dry the specimen in an oven at 110 ± 5°C (230 ± 9°F) until a constant mass is obtained.

NOTE 9—Heating may diagenetically alter the structure of some clay minerals.[3] Therefore caution should be exercised if the mineral composition of a clay specimen is going to be determined after drying. It is possible to dry the specimen at a lower temperature. However the effect on water content[4] 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.

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

NOTE 10—In some instances the 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 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 Remove the specimen from the oven and place it into a desiccator for the minimum time required for it to cool to 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. Therefore, testing should be conducted within the specified operating temperature range of the apparatus.

NOTE 11—While in the instrument, the soil specimen should not be warmer than room temperature because the operation of many pycnometers is adversely affected by such a specimen temperature change. The 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 specimen containers has been successfully used to prevent moisture adsorption during the cooling period.

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

10.6 Transfer the soil into the test chamber.

10.7 Following the manufacturer's instructions, obtain and record the volume of the specimen, $V_s$, to the nearest 0.05 cm$^3$.

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

NOTE 12—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 specimen adsorbed water which would produce a low specific gravity. A loss in mass could indicate that some of the specimen was carried into the instrument by faulty procedure or by equipment malfunction.

## 11. Calculation

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

$$G_s = \frac{\left(\frac{M_s}{V_s}\right)}{\rho_W} \tag{1}$$

where:

$M_s$ = mass of the soil specimen determined prior to placement in the pycnometer, g,
$V_s$ = volume of the specimen, cm$^3$, and
$\rho_W$ = distilled water density at a temperature of 4°C, 1 g/cm$^3$.

NOTE 13—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.

11.2 If the soil contained salt (or other dissolved matter) 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 specimen water content has not been corrected for salt content (assume salt represents any kind of dissolved matter):

$$G_{sc1} = \frac{M_s - \left[\left(\frac{S}{1000 - S}\right) W M_s\right]}{\left[V_s - \frac{\left(\frac{S}{1000 - S}\right) W M_s}{\rho_s}\right] \rho_W} \tag{2}$$

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 specimen including salt, g,
$V_s$ = volume of pycnometer specimen including salt, cm$^3$,
$S$ = 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), not corrected for salinity, decimal form,

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

[4] Lambe, T. W., *Soil Testing for Engineers*, Wiley, 1951.

$\rho_s$ = density of dissolved matter (sea salt density is typically 2.18 g/cm$^3$), and
$\rho_W$ = distilled water density at a temperature of 4°C, 1 g/cm$^3$.

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

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

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 specimen including salt, g,
$V_s$ = volume of pycnometer specimen including salt, cm$^3$
$S$ = 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,
$\rho_s$ = density of dissolved matter (sea salt density is typically 2.18 g/cm$^3$), and
$\rho_W$ = distilled water density at a temperature of 4°C, 1 g/cm$^3$.

NOTE 14—The following equation can be used to obtain a water content corrected for pore water salinity:

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

where:

$W_c$ = water content corrected for pore water salinity, decimal form,
$M_W$ = mass of water without salt, g,
$M_s$ = mass of 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.

12.2 Report at a minimum the following information in the report or data sheet:

12.2.1 Specimen identifying information, such as project name, sample/core/boring identification, and depth of specimen. This information can be modified if applicable,

12.2.2 Date of test performance and name of individual that performed the test,

12.2.3 Temperature at which the specimen was dried (to the nearest 0.1°C),

12.2.4 Specimen mass, $M_s$ (to the nearest 0.01 g). Specimen mass $M_{s2}$ should also be recorded if measured,

12.2.5 Volume of specimen determined with the pycnometer (to the nearest 0.05 cm$^3$),

12.2.6 The calculated specimen specific gravity, $G_s$, to the nearest 0.01,

12.2.7 If salt or other matter was dissolved in the pore fluid, then the corrected or uncorrected water content should be recorded, as mass, to the nearest 0.01 g.

12.2.8 The corrected specific gravity should be calculated using the appropriate equation if necessary and recorded, and

12.2.9 Specimen type, either intact or pulverized using a mortar and pestle.

## 13. Precision and Bias

13.1 *Precision*[5]—The repeatability standard deviation from a single operator has been determined to be ±0.001 g/cm$^3$, or ±0.04%.

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

## 14. Keywords

14.1 desiccant; salinity; soil; specific gravity; water content

[5] An interlaboratory study is being organized and a complete precision statement is expected to be available on or before June 2016.

## SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the 2000 edition that may impact the use of this standard.

*(1)* Removed comma in 1.3.1 and correction of typo "specifies" to "specified", to improve readability.
*(2)* Revised 1.4, Units statement, and added new 1.4.1, so as to match approved language.
*(3)* Added Test Method D2216 to Reference Documents, 2.1.
*(4)* Revised 3.1.1 to match approved language.
*(5)* Removed 3.2.1 and original Note 1, and renumbered Notes throughout standard.
*(6)* Revised Note 1 to match approved language.
*(7)* Revised Note 2 to improve readability.
*(8)* Removed original Note 4, along with footnote three, referring specifically to Drierite, with necessary renumbering of Notes.
*(9)* Revised 7.1 to improve clarity.
*(10)* Increased sample quantity range up to 350 cm$^3$ in Section 8.

*(11)* Revised 9.1 to improve clarity.
*(12)* Revised Note 9 to reference Test Method D2216 with precautions on drying samples containing water.
*(13)* Added a portion of Note 1 to 10.4 concerning temperature of soil specimen under analysis.
*(14)* Revised Note 11 to improve clarity.
*(15)* Changed "grams" to "g" in 10.5, 10.8, and 12.2.4.
*(16)* Revised Note 12 removing reference to Lab Manager and skipping of step 10.8.
*(17)* Revised 11.2 to improve clarity of w, the water loss on drying.
*(18)* Revised 11.3 to use same symbol in text as in Eq 4 for $W_c$.
*(19)* Revised 12.1, 12.2, and 12.2.1 to match approved language.
*(20)* Added units and tolerance for recording water content in 12.2.7.
*(21)* Revised 13.1 to include temporary repeatability statement, with added footnote concerning upcoming ILS.
*(22)* Removed specific reference to Drierite in Keywords.