Standard Method of Test for

# Specific Gravity of Soils

## AASHTO Designation: T 100-15
## ASTM Designation: D854-00

AASHTO

## 1. SCOPE

1.1. This method covers determination of the specific gravity of soils composed of particles smaller than the 4.75-mm (No. 4) sieve by means of a pycnometer. When the soil is composed of particles larger than the 4.75-mm (No. 4) sieve, the method outlined in T 85 shall be followed. When the soil is composed of particles both larger and smaller than the 4.75-mm (No. 4) sieve, the sample shall be separated on the 4.75-mm (No. 4) sieve, the appropriate test method should be used on each portion, and a weighted average should be calculated.

1.2. The values stated in SI units are to be regarded as the standard.

1.3. *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 92, Wire-Cloth Sieves for Testing Purposes
- M 231, Weighing Devices Used in the Testing of Materials
- R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories
- R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
- T 85, Specific Gravity and Absorption of Coarse Aggregate
- T 88, Particle Size Analysis of Soils

2.2. *ASTM Standards*:

- C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- E1, Standard Specification for ASTM Liquid-in-Glass Thermometers
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E77, Standard Test Method for Inspection and Verification of Thermometers
- E563, Standard Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature
- E644, Standard Test Methods for Testing Industrial Resistance Thermometers
- E1137, Standard Specification for Industrial Platinum Resistance Thermometers
- E2251, Standard Specification for Liquid-in-Glass ASTM Thermometers with Low-Hazard Precision Liquids

## 3. TERMINOLOGY

3.1. *Definition*:

3.1.1. *specific gravity*—The ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled or deionized water at a stated temperature.

## 4. SIGNIFICANCE AND USE

4.1. The specific gravity of a soil is used in almost every equation expressing the phase relationship of air, water, and solids in a given volume of material.

4.2. The term "solid particles," as used in geotechnical engineering, is typically assumed to mean naturally occurring mineral particles that are not soluble in water. Therefore, the specific gravity of materials containing extraneous matter (such as cement, lime, etc.), water-soluble matter (such as sodium chloride), and soils containing matter with a specific gravity of less than one, typically require special treatment or a qualified definition of specific gravity.

## 5. APPARATUS

5.1. *Pycnometer*—Either a volumetric flask having a capacity of at least 100 mL or a stoppered bottle having a capacity of at least 50 mL (Note 1). A 500-mL flask is required for samples of clayey soils containing their natural moisture content (see Section 9.2). If a bottle is used, the stopper shall be of the same material as the bottle, and of such size and shape that it can be easily inserted to a fixed depth in the neck of the bottle. The stopper shall have a small hole through its center to permit the emission of air and surplus water.

**Note 1**—The use of either the volumetric flask or the stoppered bottle is a matter of individual preference. However, the flask should be used when the sample is too large to fit into the stoppered bottle, based on the maximum grain size of the sample.

5.2. *Balance*—Either of the following, depending upon the type of pycnometer used.

5.2.1. A Class G1 balance meeting the accuracy requirements of M 231 for use with the volumetric flask.

5.2.2. A Class B balance meeting the accuracy requirements of M 231 for use with the stoppered bottle.

5.3. *Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 110° ± 5°C (230 ± 9°F).

5.4. *Apparatus for Removing Entrapped Air*—One of the following devices shall be used:

5.4.1. *Vacuum*—Capable of subjecting the contents of the pycnometer to a partial vacuum of 13.33 kPa (100 mmHg) or less absolute pressure. Subjection of the contents to reduced air pressure may be done either by connecting the pycnometer directly to an aspirator or vacuum pump, or by use of a bell jar; or

5.4.2. *Heat Source*—A hot plate, Bunsen burner, or similar apparatus capable of bringing the contents of the pycnometer to a gentle boil for a minimum of 10 min.

5.5. *Thermometer*—The thermometer shall be one of the following:

5.5.1. A liquid-in-glass partial immersion thermometer of suitable range with subdivisions and maximum scale error of 0.5°C (1.0°F) that conforms to the requirements of ASTM E1. Calibrate the thermometer in accordance with one of the methods in ASTM E77 or verify its original calibration at the ice point (Notes 2 and 3).

**Note 2**—ASTM E563 provides instructions on the preparation and use of an ice-point bath as a reference temperature.

**Note 3**—If the thermometer does not read 0.0 ± 0.5°C (32.0 ± 1.0°F) at the ice point, then the thermometer should be recalibrated.

5.5.2. A liquid-in-glass partial immersion thermometer of suitable range with subdivisions and maximum scale error of 0.5°C (1.0°F) that conforms to the requirements of ASTM E2251. Calibrate the thermometer in accordance with one of the methods in ASTM E77 or verify its original calibration at the ice point (Notes 2 and 3).

5.5.3. A platinum resistance thermometer (PRT) with a probe that conforms to the requirements of ASTM E1137. The PRT shall have a 3- or 4-wire connection configuration and the overall sheath length shall be at least 50 mm (2 in.) greater than the immersion depth. Calibrate the PRT system (probe and readout) in accordance with E644 or verify its original calibration at the ice point (Notes 2 and 3). Corrections shall be applied to ensure accurate measurements within 0.5°C (1.0°F).

5.5.4. A metal-sheathed thermistor with a sensor substantially similar in construction to the PRT probe described in Section 5.5.3. Calibrate the thermistor system (sensor and readout) in accordance with ASTM E644 or verify its original calibration at the ice point (Notes 2 and 3). Corrections shall be applied to ensure accurate measurements within 0.5°C (1.0°F).

5.6. *Water—*Distilled or deionized.

5.7. *For Samples of Clayey Soils Containing Natural Moisture—*The following additional equipment is required for samples containing natural moisture:

5.7.1. *Dispersing Equipment—*As specified in T 88.

## 6. CALIBRATIONS, STANDARDIZATIONS, AND CHECKS

6.1. Unless otherwise specified, follow the requirements and intervals for equipment calibrations, standardizations, and checks in R 18.

6.2. Follow the procedures for performing equipment calibrations, standardizations, and checks found in R 61.

## 7. GENERAL REQUIREMENTS FOR WEIGHING

7.1. When the volumetric flask is used in the specific gravity determination, determine all masses to the nearest 0.01 g. When the stoppered bottle is used in the specific gravity determination, determine all masses to the nearest 0.001 g.

## 8. STANDARDIZATION OF PYCNOMETER

8.1. Select a clean, dry pycnometer and record its mass. Fill the pycnometer with distilled or deionized water at room temperature (Note 4). Determine and record the mass of the pycnometer and water, $W_a$. Insert the thermometer into the water and determine its temperature $T$, to the nearest whole degree.

**Note 4**—Kerosene is a better wetting agent than water for most soils and may be used in place of distilled or deionized water for oven-dried samples. If kerosene is used in place of water, a temperature correction factor based on the relative density of kerosene should be used in place of Table 1.

8.2. A table of values of mass $W_a$ shall be prepared for a series of temperatures that are likely to prevail when the mass $W_b$ of the pycnometer, sample, and water is determined at the end of testing (Note 5). These values of $W_a$ shall be calculated as follows:

$$W_a = \left[\left(\frac{D_x}{D_i}\right)\left(W_i - W_f\right)\right] + W_f \qquad (1)$$

where:

$W_a$ = mass of pycnometer and water at temperature $T_x$, g;

$W_i$ = mass of pycnometer and water at temperature $T_i$, g;

$W_f$ = mass of empty pycnometer, g;

$D_i$ = relative density of water at temperature $T_i$;

$D_x$ = relative density of water at temperature $T_x$;

$T_i$ = observed temperature of water, °C; and

$T_x$ = any other desired temperature, °C.

**Note 5**—This method provides a procedure that is most convenient for laboratories making many determinations with the same pycnometer. It is equally applicable to a single determination. Bringing the pycnometer and contents to some designated temperature when masses $W_a$ and $W_b$ are taken requires considerable time. It is much more convenient to prepare a table of masses $W_a$ for various temperatures likely to prevail when masses $W_b$ (see Section 10.3) are taken. It is important that masses $W_a$ and $W_b$ be based on water at the same temperature. Values for the relative density of water at temperatures from 18 to 30°C are given in Table 1.

**Table 1**—Relative Density of Water and Correction Factor *K* for Various Temperatures

| Temperatures, °C | Relative Density of Water | Correction Factor *K* |
|---|---|---|
| 18 | 0.9986244 | 1.0004 |
| 19 | 0.9984347 | 1.0002 |
| 20 | 0.9982343 | 1.0000 |
| 21 | 0.9980233 | 0.9998 |
| 22 | 0.9978019 | 0.9996 |
| 23 | 0.9975702 | 0.9993 |
| 24 | 0.9973286 | 0.9991 |
| 25 | 0.9970770 | 0.9989 |
| 26 | 0.9968156 | 0.9986 |
| 27 | 0.9965451 | 0.9983 |
| 28 | 0.9962652 | 0.9980 |
| 29 | 0.9959761 | 0.9977 |
| 30 | 0.9956780 | 0.9974 |

## 9. SAMPLE

9.1. The soil to be used in the specific gravity test may contain its natural moisture or be oven-dried. The mass of the test sample on an oven-dry basis shall be at least 25 g when the volumetric flask is to be used, and at least 10 g when the stoppered bottle is to be used. When the specific gravity value is to be used in calculations in connection with the hydrometer portion of T 88, it is intended that the specific gravity test be made on that portion of the soil that passes the 2.00-mm (No. 10) sieve.

9.2. *Samples Containing Natural Moisture*—When the sample contains its natural moisture, determine the mass of the oven-dried soil, $W_o$, at the end of the test by evaporating the water in an oven maintained at 110° ± 5°C (230 ± 9°F) (Note 6). Disperse samples of clay soils containing their natural moisture content in distilled or deionized water using the dispersing equipment specified in T 88 (Note 7) before placing in a 500-mL flask.

9.3. *Oven-Dried Samples*—Dry the sample for at least 12 h, or to constant mass, in an oven maintained at 110° ± 5°C (230 ± 9°F) (Note 6). Cool the sample to room temperature, record its mass, and transfer it to the pycnometer. Alternatively, the sample may be transferred to the pycnometer and then weighed. Add distilled or deionized water into the pycnometer in an amount that will provide complete sample coverage. Soak the sample for at least 12 h.

**Note 6**—Drying of certain soils at 110°C may bring about a change in composition. In such cases, drying may be done in reduced air pressure and at a lower temperature.

**Note 7**—The minimum volume of slurry that can be prepared by the dispersing equipment specified in T 88 is such that a 500-mL flask is needed as the pycnometer.

## 10. PROCEDURE

10.1. Add distilled or deionized water to the previously prepared sample (see Section 9) to a maximum level of about three-fourths full in the volumetric flask, or about one-half full in the stoppered bottle (Note 8).

10.2. Remove entrapped air by one of the following methods: (1) subject the contents to a partial vacuum of 13.33 kPa (100 mmHg) or less absolute pressure by use of an aspirator or vacuum pump, (2) subject the contents to a partial vacuum of 13.33 kPa (100 mm Hg) or less absolute pressure by use of a bell jar, or (3) boil gently for at least 10 min, while occasionally rolling the pycnometer to assist in the removal of the air. Some soils boil violently when subjected to reduced air pressure. It will be necessary in those cases to reduce the air pressure at a slower rate or to use a larger flask (Note 9). Cool samples that have been subjected to boiling to room temperature.

**Note 8**—If the vacuum method of air removal is used, the required amount of distilled or deionized water may be added in layers, with each layer being subjected to the vacuum until the sample ceases to release air.

**Note 9**—When using a partial vacuum, agitate the flask gently at intervals during the evacuation process. Samples containing natural moisture with high plasticity may require 6 to 8 h to remove air; samples with low plasticity may require 4 to 6 h to remove air. Oven-dried samples may require 2 to 4 h to remove air.

10.3. Fill the pycnometer with distilled or deionized water to its standardized capacity. Clean and dry the outside of the pycnometer with a clean, dry cloth. Determine the mass of the pycnometer and contents $W_b$, and the temperature in degrees Celsius, $T_x$, of the contents as described in Section 8, after the added water and existing water have reached the same temperature.

## 11. CALCULATION AND REPORT

11.1. Calculate the specific gravity of the soil, based on water at a temperature $T_x$, as follows:

$$S_x = W_o / \left[ W_o + \left( W_a - W_b \right) \right] \tag{2}$$

where:

$S_x$ = specific gravity of soil based on water at temperature $T_x$;

$T_x$ = temperature of the contents of the pycnometer when mass $W_b$ was determined, °C;

$W_o$ = mass of sample of oven-dried soil, g;

$W_a$ = mass of pycnometer filled with water at temperature $T_x$ (Note 10), g; and

$W_b$ = mass of pycnometer filled with water and soil at temperature $T_x$, g.

**Note 10**—Take this value from the table of values of $W_a$ (see Section 8.2), for the temperature prevailing when mass $W_b$ was taken.

11.2. Unless otherwise required, report specific gravity values based on water at 20°C. Calculate the value based on water at 20°C from the value based on water at the observed temperature $T_x$, as follows:

$$S_{20°C} = K \times S_x \tag{3}$$

where:

$S_{20°C}$ = specific gravity of soil based on water at 20°C, and

$K$ = a number found by dividing the relative density of water at temperature $T_x$ by the relative density of water at 20°C. Values for a range of temperatures are given in Table 1.

11.3. When it is desired to report the specific gravity value based on water at 4°C, such a specific gravity value may be calculated by multiplying $S_x$ by the relative density of water at temperature $T_x$.

11.4. When any portion of the original sample of soil is eliminated in the preparation of the test sample, report the portion on which the test has been made.

11.5. If this test method is run in conjunction with T 85 to determine the specific gravity of the portion of the sample larger than the 4.75-mm (No. 4) sieve, the specific gravity value for the soil shall be the weighted average of the two values (Note 11).

11.6. When using the volumetric flask to determine specific gravities, report results to at least the nearest 0.01.

11.7. When using the stoppered bottle to determine specific gravities, report results to at least the nearest 0.001.

11.8. When the specific gravity value is to be used in calculations in connection with the hydrometer portion of T 88, it is intended that the specific gravity test be made on that portion of the soil that passes the 2.00-mm (No. 10) sieve.

**Note 11**—The weighted average specific gravity should be calculated using the following equation:

$$G_{avg} = \frac{1}{\frac{R_1}{100G_1} + \frac{P_1}{100G_2}} \tag{4}$$

where:

$G_{avg}$ = weighted average specific gravity of soils composed of particles larger and smaller than the 4.75-mm (No. 4) sieve;

$R_1$ = percent of soil particles retained on the 4.75-mm (No. 4) sieve;

$P_1$ = percent of soil particles passing the 4.75-mm (No. 4) sieve;

$G_1$ = apparent specific gravity of soil particles retained on the 4.75-mm (No. 4) sieve as determined by T 85; and

$G_2$ = specific gravity of soil particles passing the 4.75-mm (No. 4) sieve as determined by this test method.

11.9. For the purposes of determining conformance to specification requirements, round off the observed value or a calculated value "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with ASTM E29.

## 12. PRECISION AND BIAS

12.1. Criteria for judging the acceptability of specific gravity test results obtained by this test method on material passing the 4.75-mm (No. 4) or 2.00-mm (No. 10) sieve are given in Table 2 (see Note 12):

**Table 2**—Specific Gravity Test Results

| Material and Type Index | Standard Deviation[a] | | Acceptable Range of Two Results (% of Mean)[a] | |
|---|---|---|---|---|
| | ASTM[b] Passing 4.75 mm (No. 4) | AASHTO[c] Passing 2.00 mm (No. 10) | ASTM[b] Passing 4.75 mm (No. 4) | AASHTO[c] Passing 2.00 mm (No. 10) |
| *Single-operator precision*: | | | | |
| Cohesive soils | 0.021 | 0.02 | 0.06 | 0.05 |
| Noncohesive soils | [d] | [d] | [d] | [d] |
| *Multilaboratory precision*: | | | | |
| Cohesive soils | 0.056 | 0.04 | 0.16 | 0.11 |
| Noncohesive soils | [d] | [d] | [d] | [d] |

[a] These numbers represent, respectively, the (1s) and (d2s) limits as described in ASTM C670.
[b] These numbers represent standard deviation values assigned by ASTM Committee on Materials.
[c] These numbers represent standard deviation values assigned by AASHTO Subcommittee on Materials.
[d] Criteria for assigning standard deviation values for noncohesive soils are not available at the present time.

**Note 12**—The figures given in Column 2 are the standard deviations that have been found to be appropriate for the materials described in Column 1. The figures given in Column 3 are the limits that should not be exceeded by the difference between the results of two properly conducted tests.