METHODS OF SAMPLING AND TESTING
MT 220-04
SPECIFIC GRAVITY OF SOILS
(*Modified AASHTO T 100*)

1 Scope

1.1 This method covers determination of the specific gravity of soils 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 MT 205 Specific Gravity and Absorption of Coarse Aggregate shall be followed. When the soil is composed of particles both larger and smaller than the 4.75 mm sieve, the sample shall be separated on the 4.75 mm sieve and the appropriate test method used on each portion. The specific gravity value for the soil shall be the weighted average of the two values (See Note 1). When the specific gravity value is to be used in calculations in connection with the hydrometer portion of AASHTO T 88, Particle-Size Analysis of Soils, 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.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value.

Note 1 – The weighted average specific gravity should be calculated using the following equation:

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

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 sieve,

P_1 = percent of soil particles passing the 4.75 mm sieve,

G_1 = apparent specific gravity of soil particles retained on the 4.75 mm sieve as determined by MT 205, and

G_2 = specific gravity of soil particles passing the 4.75 mm sieve as determined by this test method.

1.3 The values stated in acceptable metric units are to be regarded as the standard.

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

2 Referenced Documents

AASHTO

T 2 Sampling Aggregates
T 88 Particle Size Analysis of Soils
T 100 Specific Gravity of Soils

ASTM

C670 Practice for Preparing Precision Statements for Test Methods for Construction Materials
E12 Definition of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases

MT Materials Manual

MT 200 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Tests
MT 205 Specific Gravity and Absorption of Coarse Aggregate
MT 405 Wire Cloth Sieves for Testing Purposes
MT 607 Reducing Field Samples of Aggregate to Testing Size

3 Terminology

3.1 Definitions

3.1.1 *Specific Gravity* – the ratio of the mass in air of a given volume of a material at a stated temperature to the mass in air of the same volume of gas free distilled water at a stated temperature (per Definition E 12).

4 Apparatus

4.1 *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 (See Note 2). 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, and shall have a small hole through its center to permit the emission of air and surplus water.

Note 2 – The use of either the volumetric flask or the stoppered bottle is a matter of individual preference, but in general, the flask should be used when a larger sample than can be used in the stoppered bottle is needed due to maximum grain size of the sample.

4.2 *Balance* – A balance having a capacity of 1 kilogram or more and sensitive to 0.001 gram or less.

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

4.4 *Thermometer* – A thermometer covering the range of 0 to 50°C (32 to 122°F), readable and accurate to 1°C (2°F).

5 General Requirements for Weighing

5.1 When the volumetric flask is used in the specific gravity determination, all masses shall be determined to the nearest 0.01 g. When the stoppered bottle is used in the specific gravity determination, all masses shall be determined to the nearest 0.001 g.

6 Calibration of Pycnometer

6.1 The pycnometer shall be cleaned, dried, weighed, and the mass recorded. The pycnometer shall be filled with distilled water (See Note 3) essentially at room temperature. The mass of the pycnometer and water, W_a, shall be determined and recorded. A thermometer shall be inserted in the water and its temperature, T_i determined to the nearest whole degree.

Note 3 – Kerosene is a better wetting agent than water for most soils and may be used in place of distilled water for oven-dried samples.

6.2 From the mass W_a determined at the observed temperature T_i a table of values of mass W_a shall be prepared for a series of temperatures that are likely to prevail when masses W_b are determined later (See Note 4). These values of W_a shall be calculated as follows:

$$W_a \text{ (at } T_x) = (\text{density of water at } T_x / \text{density of water at } T_i) \text{ X } (W_a(\text{at } T_i) - W_f) + W_f$$

where:

W_a = mass of pycnometer and water, in grams,

W_f = mass of pycnometer, in grams,

T_i = observed temperature of water, in degrees Celsius, and

T_x = any other desired temperature, in degrees Celsius.

Note 4 – 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 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 Conversion Factor K for Various Temperatures

Temperature, deg 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

7 Sample

7.1 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.

7.2 *Samples Containing Natural Moisture* - When the sample contains its natural moisture, the mass of the soil, W_a, on an oven-dry basis shall be determined at the end of the test by evaporating the water in an oven maintained at 110 ± 5°C (230 ± 9°F) (See Note 5). Samples of clay soils containing their natural moisture content shall be dispersed in distilled water before placing in the flask, using the dispersing equipment specified in AASHTO T 88 (See Note 6).

7.3 *Oven-Dried Samples* - When an oven-dried sample is to be used, the sample shall be dried for at least 12 h, or to constant mass, in an oven maintained at 110 ±5°C (230 ± 9°F)(See Note 5), cooled to room temperature, then weighed and transferred to pycnometer or transferred to pycnometer then weighed. Distilled water shall be added into pycnometer in an amount that will provide complete sample coverage. The sample shall then soak for at least 12 h.

Note 5 – Drying of certain soils at 110°C may bring about loss of moisture of composition or hydration, and in such cases drying shall be done, if desired, in reduced air pressure and at a lower temperature.

Note 6 – The minimum volume of slurry that can be prepared by the dispersing equipment specified in AASHTO T 88 is such that a 500-ml flask is needed as the pycnometer.

8 Procedure

8.1 The sample as prepared in Section 7 shall have distilled water added to fill the volumetric flask about three-fourths full or the stoppered bottle about half full.

8.2 Remove entrapped air by either of the following methods: (1) subject the contents to a partial vacuum of 100 mm Hg or less absolute pressure or (2) boil gently for at least 10 min., while occasionally rolling the pycnometer to assist in the removal of the air. 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. 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 (See Note 7). Samples that are heated shall be cooled to room temperature.

Note 7 – When using partial vacuum agitate the flask gently at intervals during the evacuation process. (A) Samples containing natural moisture with high plasticity may require 6 to 8 hours to remove air; samples with low plasticity may require 4 to 6 hours to remove air. (B) Oven-dried samples may require 2 to 4 hours to remove air.

8.3 Fill the pycnometer with distilled water to its calibrated capacity, clean the outside and dry 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 6.

9 Calculation and Report

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

$$\text{Specific gravity, } T_x/T_x = W_o/[W_o + (W_a - W_b)]$$

where:

W_o = mass of sample of oven-dried soil in grams.

W_a = mass of pycnometer filled with water at temperature T_x, (See Note 8) in grams, and

T_x = temperature of the contents of the pycnometer when mass W_b was determined, in degrees Celsius.

Note 8 – This value shall be taken from the table of values of W_a, prepared in accordance with Section 7.2 for the temperature prevailing when mass W_b was taken.

9.2 Unless otherwise required, specific gravity values reported shall be based on water at 20°C. The value based on water at 20°C shall be calculated from the value based on water at the observed temperature T_x, as follows:

$$\text{Specific gravity, } T_x/20°C = K * \text{specific gravity, } T_x/T_x$$

where:

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.

9.3 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 the specific gravity value at temperature T_x by the relative density of water at temperature T_x.

9.4 When any portion of the original sample of soil is eliminated in the preparation of the test sample, the portion on which the test has been made shall be reported.

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

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