## Standard Method of Test for

# Density of Soil In-Place by the Sand-Cone Method

## AASHTO Designation: T 191-14 (2018)

AASHTO

## Technical Subcommittee: 1b, Geotechnical Exploration, Instrumentation, Stabilization and Field Testing

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## 1. SCOPE

1.1. This method is intended for determining the in-place density of soils. The apparatus described herein is restricted to tests in soils containing particles not larger than 50 mm (2 in.) in diameter.

1.2. The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value shall be rounded off to "the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off method of ASTM E29.

## 2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:

- M 231, Weighing Devices Used in the Testing of Materials
- T 19M/T 19, Bulk Density ("Unit Weight") and Voids in Aggregate
- T 99, Moisture–Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
- T 217, Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
- T 265, Laboratory Determination of Moisture Content of Soils

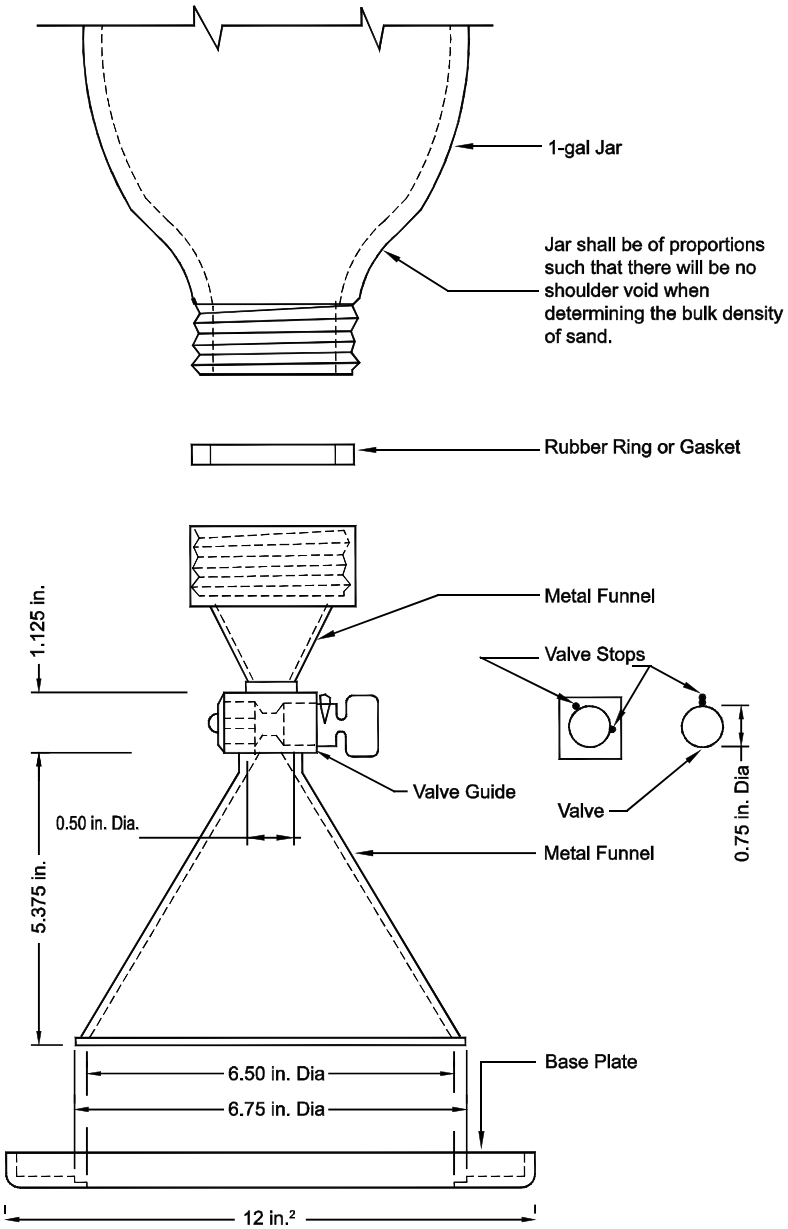
2.2. *ASTM Standards*:

- D4643, Standard Test Method for Determination of Water Content of Soil by Microwave Oven Heating
- D4959, Standard Test Method for Determination of Water Content of Soil by Direct Heating
- E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

## 3. APPARATUS

3.1. *Density Apparatus with Base Plate*—The density apparatus shall consist of a 4-L (1-gal) jar and a detachable appliance consisting of a cylindrical valve with an orifice 12.7 mm ($^1/_2$ in.) in diameter and having a small funnel connecting to a standard G mason jar top on one end and a large funnel on the other end. The valve shall have stops to prevent rotating the valve past the completely open

or completely closed positions. The base plate shall be made of metal and sufficiently rigid. The plate shall have a flanged center hole to receive the large funnel. The apparatus shall conform to the requirements shown in Figure 1. The apparatus described here represents a design that has proven satisfactory. Other apparatus of similar proportions will perform equally well so long as the basic principles of the sand-volume determination are observed. The base plate is required for calibrations and testing.




Metric Equivalents

| in. | mm | in. | mm |
|---|---|---|---|
| 0.50 | 12.7 | 6.50 | 165.1 |
| 0.75 | 19.1 | 6.75 | 171.5 |
| 1.125 | 28.6 | 12 | 304.8 |
| 5.375 | 136.5 | | |

**Figure 1**—Density Apparatus

3.2. *Calibration Container*—A sturdy cylindrical container of known volume ($V_c$). The container shall be dimensionally approximate to the largest test hole that will be dug. The container shall be calibrated according to T 19M/T 19.

**Note 1**—The internal diameter of the container shall be equal to or slightly less than the diameter of the opening of the base plate used with the sand-cone. The 944-cm$^3$ ($^1/_{30}$-ft$^3$) and 2830-cm$^3$ ($^1/_{13.33}$-ft$^3$) molds specified in T 99 and T 180 are suitable.

3.3. *Sand*—Any clean, dry, free-flowing, uncemented sand having few, if any, particles passing the 0.075-mm or retained on the 2.00-mm sieves. In selecting a sand for use, several bulk density determinations should be made using the same representative sample for each determination. To be acceptable, the sand shall not have a variation in bulk density greater than 1 percent.

3.4. *Balances*—A balance conforming to the requirements of M 231, Class G 20. Also, a balance conforming to the requirements of M 231, Class G 2.

3.5. *Drying Equipment*—Stove or oven or other suitable equipment for drying moisture content samples.

3.6. *Miscellaneous Equipment*—Small pick, chisels, or spoons for digging test hole; 254 mm (10 in.) frying pan or any suitable container for drying moisture samples; buckets with lids, canvas sacks, or other suitable containers for retaining the density sample, moisture sample, or density sand, respectively; small paintbrush, slide rule, and notebook.

## 4. CONE CORRECTION AND BULK DENSITY FACTORS

4.1. *Filling the apparatus*:

4.1.1. Fill the apparatus with sand that is dried and conditioned to the same state anticipated during testing.

**Note 2**—The apparatus may be filled either with or without the metal funnel being attached. The funnel may be removed and reattached as needed in order to fill the apparatus with the funnel detached.

4.1.2. Determine and record the mass of the apparatus filled with sand ($m_1$).

4.2. Determine the mass of sand required to fill the funnel and base plate (cone correction).

4.2.1. Place the base plate on a clean, level, plane surface. Invert the sand-cone filled with sand and seat the funnel in the recess of the base plate.

4.2.2. Open the valve fully, and allow the sand to flow until it stops (Note 2).

4.2.3. Close the valve sharply, remove the apparatus, and determine the mass of the apparatus and the remaining sand ($m_2$).

4.2.4. The mass of sand required to fill the cone and base plate is calculated by the difference between the initial mass (step in Section 4.1.2) and final mass (step in Section 4.2.3). Record this mass as the cone correction ($C_c = m_1 - m_2$) (see Section 4.4).

4.3. Determine the bulk density of sand ($D_B$) to be used in the field test.

4.3.1. Replace the sand removed in the funnel determination according to Section 4.1, close the valve, and determine the mass of the apparatus and sand ($m_3$).

4.3.2. Position the calibration container on a clean, level, plane surface. Place the base plate on the calibration container (Note 1). Invert the apparatus and seat the funnel in the recess of the base plate.

4.3.3. Open the valve fully and keep open until the sand stops flowing (Note 2).

4.3.4. Close the valve sharply, remove the apparatus, and determine the remaining mass of the apparatus and sand ($m_4$).

4.3.5. Calculate the mass of the sand needed to fill the container, funnel, and base plate. Subtract the final mass (step in Section 4.3.4) from the initial mass (step in Section 4.3.1).

4.3.6. The mass of the sand needed to fill the container only is determined by subtracting the mass of the cone correction (step in Section 4.2.4) from the total mass required to fill the container with the funnel and base plate (step in Section 4.3.5).

4.3.7. Determine the bulk density of the calibration sand (sand calibration factor). Determine the mass of the sand needed to fill the container three times and average the results. Divide the mass of the sand needed to fill the container (step in Section 4.3.6) by the volume of the calibration container as determined according to T 19M/T 19.

$D_B = (m_3 - m_4 - C_c)/V_c$

4.3.8. Record this factor for future reference (see Section 4.4).

4.4. Each container/bag of sand will have a unique cone correction and sand calibration factor. Each sand-cone and matched base plate set will also have unique cone corrections and bulk sand densities. Consequently, each sand-cone and base plate should be marked and the associated correction/density factors recorded.

## 5. PROCEDURE

5.1. *Determine the density of the soil in place as follows*:

5.1.1. Fill the apparatus with sand according to Section 4.1. Record the total mass ($m_5$).

5.1.2. Prepare the surface of the location to be tested so that it is a level plane.

5.1.3. Seat the base plate on the prepared surface. Dig the test hole inside the opening of the base plate, being very careful to avoid disturbing the soil that will bound the hole. Soils that are essentially granular require extreme care. Place all loosened soil in a container, being careful to avoid losing any material. Care must be taken to avoid moisture loss during excavation.

5.1.4. Place the apparatus on the base plate and open the valve. After the sand has stopped flowing, close the valve (Note 2).

5.1.5. Weigh the apparatus with the remaining sand ($m_6$) and record.

5.1.6. Weigh the moist material that was removed from the test hole.

5.1.7. Mix the material thoroughly and secure and weigh a representative sample for moisture determination.

5.1.8. Dry and weigh the soil sample for moisture content determination in accordance with T 265 or in accordance with rapid methods such as T 217, ASTM D4959, or ASTM D4643. The results

obtained using these or other rapid test methods must be corrected to the values obtained in accordance with T 265. Calculate the moisture content to the nearest 0.1 percent.

5.1.9. The minimum test hole volumes suggested in determining the in-place density of soil mixtures are given in Table 1. This table shows the suggested minimum mass of the moisture content sample in relation to the maximum particle size in soil mixtures.

**Table 1**—Minimum Test Hole Volumes and Minimum Moisture Content Samples Based on Maximum Size of Particle

| Maximum Particle Size | | Minimum Test Hole, Volume | | Minimum Moisture Content Sample, g |
|---|---|---|---|---|
| mm | Alternate | $cm^3$ | $ft^3$ | |
| 4.75 | No. 4 Sieve | 710 | 0.025 | 100 |
| 12.5 | 1/2 in. | 1415 | 0.050 | 250 |
| 25.0 | 1 in. | 2125 | 0.075 | 500 |
| 50.0 | 2 in. | 2830 | 0.100 | 1000 |

## 6. CALCULATIONS

6.1. Calculate the volume of the test hole ($V_H$):

$$V_H = (m_5 - m_6 - C_c)/D_B \quad (1)$$

where:

$V_H$ = volume of the test hole,
$m_5$ = initial mass of the apparatus and sand,
$m_6$ = final mass of the apparatus and sand,
$C_c$ = cone correction, and
$D_B$ = bulk density of the sand.

6.1.1. Calculate the volume of the test hole to the nearest 1 $cm^3$ (0.0001 $ft^3$).

6.2. Calculate the dry mass of the material removed from the test hole as follows:

$$M_{DS} = (M_{WS} / (1 + (w/100)) \quad (2)$$

where:

$M_{DS}$ = dry mass of the material removed from the test hole,
$M_{WS}$ = moist mass of the material removed from the test hole, and
$w$ = percentage of moisture, in material removed from the test hole.

6.2.1. Calculate the dry mass of the material to the nearest 1 g (0.01 lb).

6.3. Calculate the in-place dry density of the material removed from the test hole as follows:

$$D_D = M_{DS}/V_H \quad (3)$$

where:

$D_D$ = in-place dry density of the material removed from the test hole,
$M_{DS}$ = dry mass of the material removed from the test hole (Section 6.2), and
$V_H$ = volume of the test hole (Section 6.1).

6.3.1. Calculate the in-place dry density to the nearest 1 kg/m$^3$ (0.1 lb/ft$^3$) (see Notes 3 and 4).

**Note 3**—0.001 g/cm$^3$ = 1 kg/m$^3$

**Note 4**—It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory maximum density determined in accordance with T 99. This relationship can be determined by dividing the in-place density by the maximum density and multiplying by 100.

## 7. KEYWORDS

7.1. In-place density; sand-cone; soil density.