

**Moisture-Density Relations of Soils using a
4.54-kg (10-lb.) Rammer and a 457-mm (18-in.) Drop
AASHTO T-180-01 (2004)
(Method D-Modified)**

The compaction test for soils and aggregate materials determines the dry weight per cubic foot under a given compactive effort and varying water contents over a sufficient range to indicate the maximum dry weight per cubic foot and the optimum moisture content.

- Modification:*
1. *T-180, Method D, shall be used for base course material ONLY. No replacement of material greater than the 19.0 mm (3/4 in.) sieve will be utilized. All representative sample material shall be used for the completion of Method D.*
 2. *A minimum of five (5) points shall be run.*
 3. *A minimum moisture sample size shall be 1000 grams.*
 4. *Only a mechanical hammer will be used.*
 5. *Only a sector face rammer shall be used.*
 6. *Weigh to the nearest 0.1 of a gram or 0.01 of a pound.*
 7. *Maximum dry density and optimum moisture shall be reported to the nearest 0.1 lb/ft³ and 0.1 percent moisture.*

Key Elements:

1. **Obtain Sample.** Obtain sample by AASHTO T-2.
2. **Prepare Sample.** If sample is wet, it may be dried until it becomes friable under a trowel. Drying may be accomplished either by air-drying or oven drying at a temperature 60°C (140°F) or lower. After drying, the aggregations are to be broken up in such a manner as to avoid reducing the natural size of individual particles (8.1). Various methods of pulverizing may be used as long as it does not cause degradation to the material. T-180, Method D, shall be used for base course material only. All representative sample material shall be used for the completion of Method D.
3. **Inspect and Prepare Apparatus.** The apparatus shall consist of the following: cylindrical mold with detachable collar and base plate (3.1). A metal rammer with a mass of 4.536 ± 0.009 kg (10.00 ± 0.02 lb.), and having a sector face with an area equal to 50.80 ± 0.25 mm (2.000 ± 0.01 in) (3.2). A hardened steel straightedge at least 250 mm (10 in.) in length and having one beveled edge (3.6). Balance (3.4), drying oven (3.5), sieves (3.7), graduated cylinder and miscellaneous mixing tools such as mixing pans, spoon, spatula (3.8), sample extruder (3.3), containers (3.9). Only a mechanical compaction hammer will be used, and must be calibrated against a hand hammer of correct weight and drop (3.2.2 & Note 3).
4. **Determine Empty Weight of Cylindrical Mold.** Weigh mold and base plate without detachable collar and record to the nearest 0.1 g or 0.01 of a pound.

5. **Add Predetermined Amount of Moisture to Sample.** A representative sample having a minimum mass of approximately 11 kg (25 lb.) and shall be thoroughly mixed with sufficient water to dampen it to approximately four percentage points below optimum moisture content (11.1). An alternative method is the “5-Bag Method.” Five separate and approximately equal representative samples shall be weighed and placed in a bowl or plastic bag used for mixing purposes. A different percentage of moisture can be added to each sample to create the five points required for this test.
6. **Compact Specimen.** Form a specimen by compacting the prepared soil in a 152.40 mm (6 in.) mold, with collar attached, in five approximately equal layers to give a compacted depth of about 125 mm (5 in.). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 50 mm (2 in.) (9.2). Each layer shall be compacted by 56 uniformly distributed blows over the surface of the layer (11.1) from the rammer dropping free from a height of 457 ± 2 mm (18.00 ± 0.06 in.) above the elevation of the soil (3.2.1). During compaction, the sector face hammer shall overlap the hammer surface area for each blow. During compaction the mold shall rest firmly on a dense, uniform, rigid and stable foundation or base. This base shall remain stationary during the compaction process (9.2).
7. **Trim Top of Compacted Soil.** With the extension collar removed, carefully trim the compacted soil even with the top of the mold, using the steel straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller sized material (9.2.1).
8. **Weigh Mold and Base Plate with Compacted Soil.** Clean excess material from the outside of the mold and base. Weigh the mold with soil to the nearest 0.1 g or 0.01 of a pound and record (9.2.1).
9. **Obtain Moisture Sample and Weigh.** Remove the material from the mold; it may be necessary to use a sample extruder to remove the compacted specimen. Slice the specimen vertically through the center. Take a representative sample from one of the cut faces; sample the entire length of the specimen (9.3). Place this moisture sample in a suitable container and weigh to the nearest 0.1g and record. The moisture sample shall weigh not less than 1000 grams.
10. **Place in oven at $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) and dry to constant mass.** Dry sample in accordance with AASHTO T-265. Constant mass is defined as after initial drying the weight of the material decreases by less than 0.1% after a minimum of 10 minutes additional drying.

$$\frac{W1 - W2}{W2} \times 100, \frac{W2 - W3}{W3} \times 100, \text{ etc.}$$

11. **Repeat Steps 5 through 11.** If the “5-Bag Method” is not used, thoroughly break up the remaining portion of the molded specimen and repeat steps 5 through 11. Add water in sufficient amounts to increase the moisture content by approximately one to two percentage points. Continue this series of determinations until there is either a decrease or no change in

the wet weight per cubic foot of the compacted soil (9.4). A minimum of five points shall be run to accurately determine maximum density and optimum moisture, with three points up and two points down being obtained.

12. Calculate the Wet Weight of Compacted Soil. Multiply the weight of the compacted specimen, minus the weight of the mold, by **471** for masses recorded in kilograms and **13.33** for masses recorded in pounds (11.1). This result is recorded as the wet weight in kilograms per cubic meter (kg/m³) or pounds per cubic foot (lb/ft³) of the compacted soil.

13. Perform Calculations. Calculate the moisture content and the dry weight of the soils as compacted for each specimen (12.1).

$$\% \text{ Moisture in specimen} = \frac{A - B}{B - C} \times 100$$

A = Weight of container and wet soil.

B = Weight of container and dry soil.

C = Weight of container.

$$\text{Dry Weight} = \frac{W_1}{\% \text{ Moisture} + 100} \times 100$$

W₁ = Wet weight, in lbs/ft³ of compacted soil.

14. Plot Data on Appropriate Form. Plot calculated data on appropriate form and graph to determine maximum dry density and optimum moisture content. When the densities and corresponding moistures have been plotted, it will be found that by connecting the points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the “**optimum moisture content**” of the soil (13.2). The oven-dry density in kilograms per cubic meter or pounds per cubic foot of the soil at optimum moisture shall be termed “**maximum dry density**” (13.3).

15. Report Maximum Dry Density and Optimum Moisture. Report the maximum dry density in kg/m³ to the nearest 10 kg/m³, or in lb/ft³ to the nearest 0.1 lb/ft³, and the optimum moisture content shall be reported to the nearest 0.1 percent moisture (14).