A. Scope

For a complete list of GDTs, see the Table of Contents.

Use this method to determine the relation between the moisture content and the density of soils, soil/ aggregate, or crusher-run mixtures containing more than 45 percent retained on the No. 10 (2 mm) sieve.

The mixture is compacted in a mold of a given size with a 5.5 lb (2.5 kg) rammer dropped from a height of 12 in (305 mm). This method also applies to all similar mixtures containing admixtures.

B. Apparatus

The apparatus consists of the following:

NOTE: Apparatus items followed by a warehouse stock number may be obtained from the Central Laboratory warehouse.

1. Mold: Use a cylindrical mold having a capacity of 1/13.33 (.075) ft³ (0.0021 m³) with an internal diameter of 6.0, ± .026 in (150 mm, ± 0.66 mm) and a height of 4.584, ± .005 in (116.434, ± 0.0127 mm).

NOTE: Check new molds for compliance with the dimensions before use and periodically thereafter.

   A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent.

   Also, the volume of the mold, calibrated in accordance with Section 3 (Calibration of Measure) of AASHTO T 19, Unit Weight of Aggregate, is used in the calculations in lieu of 1/13.33 (.075) ft³ (0.0021 m³).

2. Rammer

   Manually operated. Use a metal rammer with a flat, circular face of 2.000, ± .005 in (50.8, ± 0.0127 mm) diameter and weighing 5.50, ± 0.02 lbs (2.5, ± 0.009 kg). Ensure the rammer has a suitable guide-sleeve to control the height of drop to a free fall of 12.00, ± 0.06 in (304.8, ± 1.524 mm) above the material surface. The guide-sleeve must have at least 4 vent holes no smaller than 3/8 in (9.5 mm) diameter, spaced approximately 90 degrees apart, and approximately 3/4 in (19.05 mm) from each end. It must provide sufficient clearance so the freefall of the rammer shaft and head is unrestricted (WR-1).

   Mechanically operated. Use a metal rammer equipped with a device to control the height of drop to a free fall of 12.00, ± 0.06 in (304.8, ± 1.524 mm) above the surface of the material. The rammer must have a sector face with area and weight equal to the manual, circular-face rammer.

3. Balance: Use a balance with a capacity of 22 lbs (10.0 kg) and a 0.00022 lb (1.0 g) sensitivity.
4. Drying Device: Use an oven, open flame stove, or infrared heater for rapidly drying material during moisture determinations.
5. Straightedge: Use a steel straightedge at least 12 in (305 mm) long (WS-13).
6. Pans: Use flat pans suitable for drying soil samples.
7. Graduated Cylinder: Use a glass or plastic graduated cylinder with at least 3.4 oz (100 ml) capacity.

C. Sample Size and Preparation

1. Determine individual dry gradations on all ingredients for use in this test. Each gradation sample should contain approximately 50 lbs (23 kg) of material.
2. After determining the gradations, separate the individual fractions retained on each sieve for each ingredient as shown in the table:

Passing	Retained On
3/4" (19.0 mm)	1/2" (12.5 mm)
1/2" (12.5 mm)	3/8" (9.5 mm)
3/8" (9.5 mm)	No. 4 (4.75 mm)
No. 4 (4.75 mm)	No. 10 (2.00 mm)
No. 10 (2.00 mm)	Pan

3. Recombine the individual fractions either among themselves or with individual fractions from other types of material (if using a blended sample).
   a. If you test a blended sample, establish a blend of the individual materials so the gradation of the composite will meet the requirements of the governing specifications.
   b. When establishing the blend, use both the 3/4 in (19.0 mm) and No.10 (2.00 mm) gradation.
   c. To calculate the blend gradations, set the material passing the No.10 (2.00 mm) sieve at about 38 percent.

      Calculate the material passing the 3/4 in (19.0 mm) sieve. If the material passing the 3/4 in (19.0 mm) sieve is not within the Specification requirements, adjust the percentage of material passing the No.10 (2.00 mm) sieve until the percentage of material passing the 3/ 4 in (19.0 mm) sieve is within the Specification requirements.

      See Table 24a1 for an example of determining the blend.

TABLE NO. 24a1
EXAMPLE OF BLEND DETERMINATION

GRADATION............................%PASSING						
Blend A. Stone Fraction = 0.66				B. Soil Fraction = 0.34		
C. Sieve Size	D. Stone	E. Soil	F. Stone Adjusted (AXD)	G. Soil AdJusted (BXE)	H. Stone & Soil Combined (F&G)	I. Specification Requirements
1 1/2" (37.5 mm)	100	100	66.0	34.0	100	100
3/4" (19.0 mm)	75	100	49.5	34.0	83.5	60-95
1/2" (12.5 mm)	39	100	25.7	34.0	59.7	-
3/8" (9.5 mm)	25	100	16.5	34.0	50.5	-
No. 4 (4.75 mm)	13	100	8.6	34.0	42.6	-
No. 10 (2.00 mm)	9	100	5.9	34.0	39.9	25-45

4. After calculating the individual gradations and the theoretical blend, recombine the individual fractions retained from the gradation determinations as follows. (See Table 24a2)

NOTE: If using a blend, use both sides of Table 24a2. If not, use only one side and make appropriate adjustments in Column F, "Stone Weights for Batching," to ensure a 22 lb (10 000 g) sample.

   a. Compute the percent of individual fractions retained on each sieve (Column D) by subtracting the consecutive percentages passing each sieve in the original gradation (Column B) of the material.
   b. Compute the percent retained on the 3/4 in (19 mm) sieve and the percent passing the 3/4 in (19 mm) sieve, but retained on the No. 4 (4.75 mm) sieve (Column D Aggregate.).
   c. Replace the coarse material retained on the 3/4 in (19 mm) sieve with material passing the 3/4 in (19 mm) and retained on the No. 4 (4.75 mm) sieve. Use replacement material proportionately from the 3/4 in (19 mm) to 1/2 in (12.5 mm), 1/2 in (12.5 mm) to 3/8 in (9.5 mm), and 3/8 in (9.5 mm) to No. 4 (4.75 mm) fractions.
   d. Compute this proportional percentage as follows:

      where: $$P = \frac{a + a(c)}{b}$$

P = Adjusted percentage of the required grading

a = Percent passing 3/4 in (19 mm) and retained on 1/2 in (12.5 mm), or percent passing 1/2 in (12.5 mm) and retained on 3/8 in (9.5 mm), or percent passing 3/8 in (9.5 mm) and retained on No. 4 (4.75 mm)

b = Total percent passing 3/4 in (19 mm), but retained on the No. 4 (4.75 mm) in the original sample

c = Total percent retained on the 3/4 in (19 mm) original sample

Column E shows calculations for only three fractions.

e. Compute the quantities of each fraction necessary to fabricate the sample by multiplying adjusted percentages (Column E) by the total weight of sample necessary.

f. Enter these quantities in Column F.

g. Total the fractions. The sum should result in a 22 lb (10 000 g) test sample.

h. Make the test specimens from this test sample.

D. Procedures

1. Materials Without Stabilizing Admixtures

   a. Thoroughly mix the 22 lb (10,000 g) representative sample with enough water to increase the moisture content of the wet sample to about 3 percent below the anticipated optimum moisture content.

   b. Compact the prepared material in the 6in (152 mm) mold (with collar attached) in 3 separate but approximately equal layers. The total compacted depth should be about 5 in (127 mm).

      Compact each layer with 56 uniformly distributed blows from the rammer.

   c. After compacting the three layers, remove the collar.

   d. Carefully trim the consolidated material even with the top and bottom of the mold and compacted material.

   e. Weigh mold and compacted material.

   f. Remove the compacted material from the mold.

   g. Slice the material vertically through the center.

   h. From the exposed center material, take a representative sample of at least 500 g.

   i. Weigh the sample and immediately dry it at 230 °, ± 9 °F (110 °, ± 5 °C) to constant weight.

   j. Reweigh the sample.

   k. Thoroughly break up the remainder of the compacted material until it will pass the 3/4 in sieve.

   l. Add this portion to the remaining portion of the prepared sample.

   m. Add enough water to increase the moisture of the sample approximately one percent and repeat the procedure for compacting the specimen and determining the moisture content.

   n. Continue the compaction and moisture determinations until there is either no change or a decrease in the wet weight pounds per cubic foot (kilograms per cubic meter) of compacted material.

   o. Use this data in Calculations.

2. Materials Stabilized With Portland Cement

   a. Compute the amount of material from each fraction necessary to fabricate a 22 lb (10 000 g) test sample (see Sample Size and Preparation).

   b. Compute the amount of cement to be added to the sample (see Calculations).

   c. Add the cement computed above to the material passing the No. 10 (2.00 mm) sieve and mix thoroughly.

   d. After mixing the cement and minus No. 10 (2.00 mm) material, add the remainder of the sample, and mix again thoroughly.

   e. Follow Procedures in D.1.a through D.1.o.

E. Calculations

1. Weight of Portland Cement For Stabilization

   where: Wc = Ws x C

   Wc = Weight of cement in grams

Ws = Weight of sample 22 lbs (10,000 g)

C = Percent cement expressed as a decimal (if 9 percent, use .09, if 10 percent use .10, etc.)

2. Moisture Determination

where: $M = \left(\frac{A - B}{B}\right) \times 100$

M = Percent moisture in the material

A = Weight in grams of the wet sample

B = Weight in grams of the dry sample

3. Wet Density

where: $Dw = \left[\frac{Wt\,(grams) - Wm\,(grams)}{454\ g/lb}\right] \div \frac{1}{13.33\ ft^3}$

Dw = Wet density of compacted material, pounds per cubic foot (kilograms per cubic meter)

Wt = Weight of compacted material and mold

Wm = Weight of mold

NOTE: The volume of the mold is 1/13.33 ft³ (0.0021 m³). Therefore, 13.33 times the weight of material in the mold is necessary to fill a space with a volume of 1 ft³ (0.028 m³). If you have determined the actual mold volume in Apparatus.l, use it.

4. Dry Density

where: $Dd = \frac{Dw}{1 = M}$

Dd = Density of compacted material in pounds per cubic foot (kilograms per cubic meter)

Dw = Wet density of compacted material in pounds per cubic foot (kilograms per cubic meter)

M = Percent moisture in the mixture expressed as a decimal

5. Interpretation Of Data

a. When you must determine the theoretical maximum dry density and optimum moisture:

1. Plot on linear graph paper the calculated dry densities on the ordinate versus the corresponding moisture contents on the abscissa (see Figure 24a1).

2. Figure 24a1 .

The moisture content corresponding to the maximum dry density on the resulting curve is the "optimum moisture content." The dry density at "optimum moisture content" is the "theoretical maximum dry density."

Dry Density* (kg/m³)	Moisture* (%)
117.0 (1873)	4.0
118.2 (1892)	5.4
121.0 (1937)	7.6
122.8 (1966)	9.8
118.4 (1896)	12.2

NOTE: Use the values calculated in Calculations.

b. From Figure 24a1, the "optimum moisture content" is 9.8 percent and the "theoretical maximum dry density" is 122.8 lbs/ft³ (1966 kg/m³). The maximum of the curve will not always coincide with one of the points used to establish the curve as it did in the example.

F. Report

Report the “optimum moisture content” to the nearest 0.1 percent and the “theoretical maximum dry density” to the nearest 0.1 lb/ft^3 (1 kg/m^3).

TABLE NO. 24a2

Sieve Size	66% of 10,000 gram batch = 6600					34% of 10,000 gram batch = 3400 grams				
	Stone Gradations					Soil Gradations				
	Accumulative % Passing	Non-Accumulative % Retained on Sieves		+ 3/4" Stone Redistributed Proportionally above the #4 Sieve	Stone Weights for Batching	Accumulative % Passing	Non-Accumulative % Retained on Sieves		Redistri-bution of + 3/4" Material	Soil Weights for Matching
A	B	C	D	E	F	B	D	C	E	F
1/12" (37.5 mm)	100	100-100 = 0	25	--	--	100	100-100 = 0	0	--	--
3/4" 19.0 mm)	75	100-75 = 25		--	--	100			--	--
1/2" (12.5 mm)	39	75-39 = 36		36+{ 36 x 25 } = 50.6 { 62 }	3339	100	100-100 = 0		0	0
3/8" (9.5 mm)	25	39-25 = 14		14+{ 14 x 25 } = 19.6 { 62 }	1294	100	100-100 = 0		0	0
#4 (4.75 mm)	13	25-13 = 12		12+{ 12 x 25 } = 16.8 { 62 }	1109	100			0	0
#10 (2.00 mm)	9	13-9 = 4		4.0	264	100	100-100 = 0		0	0
Pan	0	9-0 = 9	13	9.0	594	0	100-100 = 0	100	100	3400
--	--	100	100	100	6600	--	100-0 = 100	100	100	3400
							100-0 = 100			
							100			

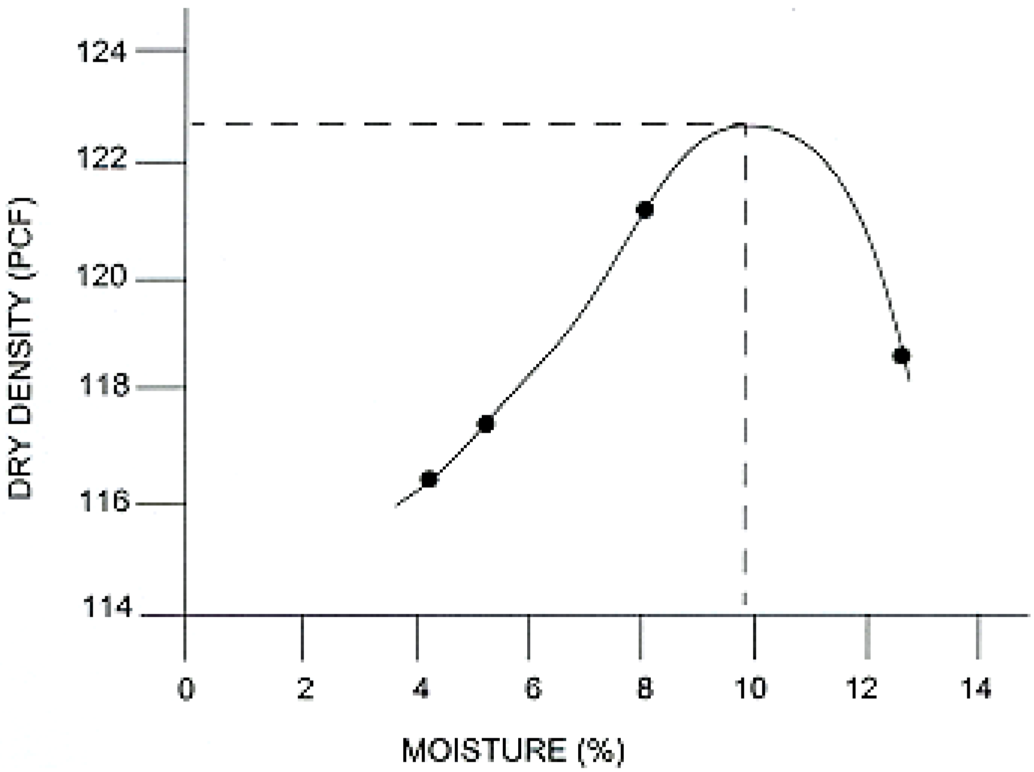

Figure 24a1

Dry Density - pcf (kg/m³)	Moisture* (%)
117.0 (1873)	4.0
118.2 (1892)	5.4
121.0 (1937)	7.6
122.8 (1966)	9.8
118.4 (1896)	12.2