April 16, 2013 Matls. IM 309
Supersedes April 17, 2012

DETERMINING STANDARD PROCTOR MOISTURE DENSITY RELATIONSHIP OF SOILS

SCOPE

This test is used to determine the relationship between the moisture content and density of soils or base materials compacted according to a modification of standard procedure, AASHTO T-99, Method C. This test method is the field procedure for Laboratory Test Method 103. The sampling procedure to obtain soils used for this test is given in IM 312.

PROCEDURE

A. Apparatus

1. Cylindrical metal mold 4-in. in diameter and 4.584 in. high having a capacity of 1/30 cubic foot with base plate and collar.

2. Scale, capable of weighing at least 5000 grams and sensitive to 0.5 grams

3. Manual compaction device complying with AASHTO T99. Compaction should be performed on a rigid, uniform, and stable concrete foundation or base.

4. A rigid steel straight edge, 9-in. long, with one beveled cutting edge

5. Drying equipment, such as an oven capable of maintaining a temperature of 230°F ± 9°F, a microwave, or a hot plate.

6. Mixing equipment. A stainless steel mixing (dish) pan, long handled spoon, rubber or rawhide mallet, putty knife, graduate, and tared weighing scoop

7. Sample extruder, lever or hydraulic type

8. Tared moisture pans

B. Calibration

Check the rammer diameter (2.00 ± 0.01 in.) and the free-dropping-height of the rammer (12.00 ± 0.06 in.) by measurement with a 0.01-in. steel rule. Visually check the condition of the rammer.

1. Check the internal diameter of the mold (4.00 ± 0.02 in.) and the height of the mold (4.58 ± 0.01 in.) with the 0.01-in. steel rule.

C. Sample Preparation

1. Quarter the field sample to a representative sample of about 5000 grams. Spread out and allow to dry to a moisture content at least 5% below the estimated optimum moisture content.

2. Screen the sample over a 3/4-inch sieve and replace the aggregate retained with an equal weight of No. 4 to 3/4 in. aggregate from the same source, or break up the material larger than ¾" to pass the ¾" sieve and return it to the sample.

D. Test Procedure

1. Pulverize the prepared sample so that at least 90% of all non-aggregate material will pass the No. 4 sieve. Place the sample in the mixing pan and sprinkle sufficient water to dampen it to approximately 4% below optimum moisture content. The sample is ready for test when, after thorough mixing, a handful of soil squeezed tightly in the palm will barely hold together when pinched between the fingers.

2. Form a specimen by compacting the prepared soil in the mold in three approximately equal layers. Weigh in a tared scoop, and place loose soil in the assembled mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose state. Place the mold under the hammer for compaction. Deliver twenty-five uniformly distributed blows. Measure to determine if there is a deviation from the needed 1/3 height in the mold. Adjust the weight of soil taken for the second layer as needed to give the desired height, and compact the same as with the first layer. Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed. Repeat this process for a third layer. During this entire operation, do not allow sample to accumulate on the bottom of the hammer. After compaction of the final layer, the sample should extend 0.1 to 0.4 in. above the height of the mold.

3. Move the mold and contents to a table, remove the collar with a twisting motion and cut off the excess sample in thin layers with the straightedge. If the soil projects more than 0.4 in. above the mold or if the mold is not completely filled, the compactive effort is incorrect and the compacted specimen must be extruded, pulverized, and returned to the mixing pan. After remixing, adjust the weight for each layer as needed and recompact by the same procedure. Replace any small aggregate, which are pulled from the surface with finer hand tamped material. Leave in place large, well-embedded aggregate, and finish the top to arrive at a surface that will average level full.

4. Detach the mold from the base plate and determine the mass of the mold and compacted soil. Extrude the specimen from the mold. Slice vertically through the center of the specimen. Place into a weighted pan at least a 500 gram moisture sample from one of the cut faces. Follow IM 335 to determine moisture content. Pulverize the remaining portion of the specimen and return to the mixing pan.

5. Sprinkle the sample with water, not to exceed 2% of the remaining sample weight, and thoroughly mix until moisture uniformity is reached. The compaction and moisture determination for this moisture content is the same as for the first. Repeat this procedure of adding water, compacting a specimen and taking a moisture sample while increasing the moisture content until a compacted weight is reached that is no more than 20 grams higher than the preceding one. This signifies that the resultant moisture density curve is past the optimum percent moisture. Since the proctor curve is based on dry density, each 2% moisture increase is the equivalent of approximately 30 grams for a proctor specimen. Thus if the last specimen is only 20 grams heavier than the previous (2% drier) point, this will show a reduced dry density.

E. Calculations

$$\%\,\text{Moisture} = \frac{(\text{Wet soil} + \text{pan}) - (\text{Dry soil} + \text{pan})}{(\text{Dry soil} + \text{pan}) - (\text{pan})}(100)$$

Example:

$$\%\,\text{Moisture} = \frac{500 - 460}{460 - 170}(100) = 13.8\%$$

Compacted Dry Density for kg/m^3

$$\frac{\text{Net Wet Mass compacted soil x } 0.06614}{(\%\,\text{Moisture} + 100)}(100)$$

Example:

Compacted Dry Density for lb./ft.^{3}

$$\frac{(1983)(0.06614)}{(13.8 + 100)}(100) = 115.2 \text{ lb./ft.}^3$$

F. Moisture-Density Relationship

1. Make the preceding calculations for each compacted specimen at each corresponding moisture content.

2. Using these results, plot points with densities (dry weight per cubic foot) as ordinates (vertical) and percent of moisture as abscissas (horizontal).

3. Use the resulting points to draw a smooth curve. The peak of the curve will give the maximum, or Proctor density and the corresponding optimum moisture content.

G. One-Point Procedure

1. Grade material other than crushed stone, gravel, black soils, or soils containing a considerable amount of aggregate may be tested for maximum density and optimum moisture according to this procedure. Those excluded above shall be run as in "D", "E", and "F" above.

2. Moisten a representative sample of approximately 3000 grams to an estimated moisture content of two to three percentage points below Proctor optimum moisture.

3. Following the procedure outlined in D2 through D4, compact and obtain net wet weight of a single specimen at the moisture content in G2. Determine the moisture content and wet density (in pounds per cubic foot) for this single compacted specimen.

4. In the family of curves, plot the point of intersection of the above wet weight and moisture. If the plotted point falls outside the "Range of Confidence," recompact another specimen at an adjusted moisture content that will place the plot within these bounds.

5. Using the number of the nearest curve, obtain the dry Proctor density and optimum moisture values from the attached table.

H. Calculations for One-Point Test

Calculate the moisture content and wet weight of sample per cubic foot as follows:

$$w = \frac{A - B}{B - C} \times 100 \qquad W_2 = W_1 (0.06614^3)$$

Where:

w = Percentage of moisture in the specimen, based on oven dry weight of soil.

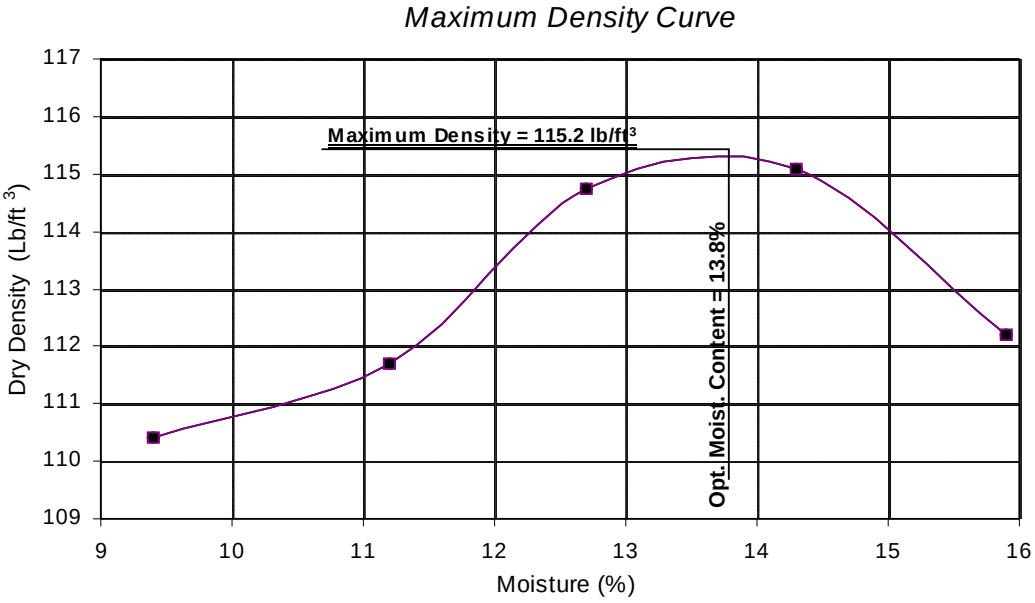
A = Weight of moisture pan plus wet soil.

B = Weight of moisture pan plus dry soil.

C = Weight of moisture pan.

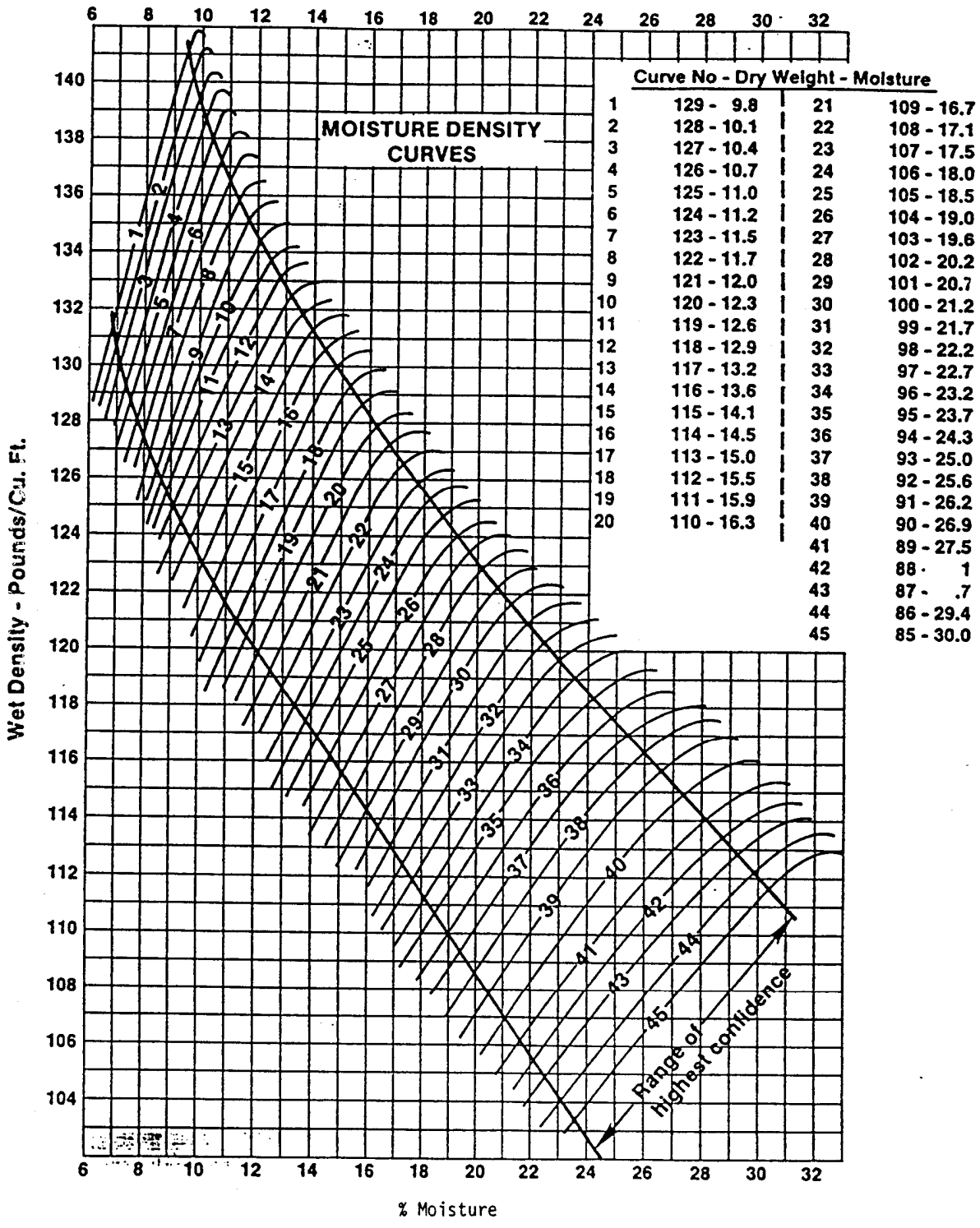
W_1 = Wet weight, in grams, of compacted specimen.

W_2 = Wet weight, in pounds per cubic foot of compacted specimen.


Maximum Density Curve
Maximum Density = 115.2 lb/ft³
Opt. Moist. Content = 13.8%
Dry Density (Lb/ft 3)
Moisture (%)
117
116
115
114
113
112
111
110
109
9
10
11
12
13
14
15
16

PROCTOR DENSITY CURVES

Curve No.	Dry Wt.	% Moisture
1	129	9.8
2	128	10.1
3	127	10.4
4	126	10.7
5	125	11.0
6	124	11.2
7	123	11.5
8	122	11.7
9	121	12.0
10	120	12.3
11	119	12.6
12	118	12.9
13	117	13.2
14	116	13.6
15	115	14.1
16	114	14.5
17	113	15.0
18	112	15.5
19	111	15.9
20	110	16.3
21	109	16.7
22	108	17.1
23	107	17.5
24	106	18.0
25	105	18.5
26	104	19.0
27	103	19.6
28	102	20.2
29	101	20.7
30	100	21.2
31	99	21.7
32	98	22.2
33	97	22.7
34	96	23.2
35	95	23.7
36	94	24.3
37	93	25.0
38	92	25.6
39	91	26.2
40	90	26.9
41	89	27.5
42	88	28.1
43	87	28.7
44	86	29.4
45	85	30.0


MOISTURE DENSITY CURVES
Wet Density - Pounds/Cu. Ft.
% Moisture
Range of highest confidence
Curve No - Dry Weight - Moisture
1 129 - 9.8
2 128 - 10.1
3 127 - 10.4
4 126 - 10.7
5 125 - 11.0
6 124 - 11.2
7 123 - 11.5
8 122 - 11.7
9 121 - 12.0
10 120 - 12.3
11 119 - 12.6
12 118 - 12.9
13 117 - 13.2
14 116 - 13.6
15 115 - 14.1
16 114 - 14.5
17 113 - 15.0
18 112 - 15.5
19 111 - 15.9
20 110 - 16.3
21 109 - 16.7
22 108 - 17.1
23 107 - 17.5
24 106 - 18.0
25 105 - 18.5
26 104 - 19.0
27 103 - 19.6
28 102 - 20.2
29 101 - 20.7
30 100 - 21.2
31 99 - 21.7
32 98 - 22.2
33 97 - 22.7
34 96 - 23.2
35 95 - 23.7
36 94 - 24.3
37 93 - 25.0
38 92 - 25.6
39 91 - 26.2
40 90 - 26.9
41 89 - 27.5
42 88 - 1
43 87 - .7
44 86 - 29.4
45 85 - 30.0