October 19, 2004 Matls. IM 309
Supersedes October 26, 1999

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-99-81, Method C. This test method is the field procedure for Laboratory Test Method 103.

PROCEDURE

A. Apparatus

1. Cylindrical brass mold 4-in. in diameter and 4.584 in. high having a capacity of 1/30 cubic foot with base plate and collar. A counterbalance equal to the weight of the mold is useful.

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

3. Compaction device, consisting of an arrangement of a 5.5-pound hammer inside a cage of 4 metal rods, with the capacity of delivering a 12-in. fall of the hammer to each of three layers of soil. The device shall be bolted to a concrete pedestal of at least 200 lbs. weight, or secured to a base giving an equivalent rigidity.

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

5. Drying equipment, preferably an oven capable of maintaining a temperature of 230°F ± 9°F, or a gas 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

1. Check the height of hammer fall periodically. With the base plate in position and the hammer stop in the bottom indent, adjust to distance between the base plate and the bottom of the hammer to 13.53 in. The nuts holding the cage to the frame shall be well tightened. The hammer shall fall freely and the cage shall be vertical.

2. Calibrate the volume of the brass mold by water content. This should be done in the Central Laboratory at least once a year. Field checks can be made by measurement with a 0.01-in. steel rule and appropriate calculations.

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. material taken from the original field sample.

D. Test Procedure

1. Pulverize the prepared sample so that 90% of all material except aggregate will pass the No. 4 sieve. Place the sample in the mixing pan and sprinkle water on the sample while stirring. 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. Weigh in a tared scoop, and loosely place in the assembled mold, an amount of the dampened sample that, after compaction, will yield 0.1 in. more than the height of the mold. Place the mold under the hammer with the depression in the bottom of the mold base plate over the projection on the base. Put the hammer stop in the lowest indent, raise the hammer with a pulling, flipping motion, so that is will hit the stop firmly, and then let fall freely with no restraint from the chain. Deliver twenty-five such blows with 1/6 turn of the mold base between each blow. Measure to determine if a slight excess over that needed to fill α of the mold is present. Adjust the weight of soil taken for the second layer as needed to give the desired height, place in the mold, raise the hammer stop to the second indent and compact the same as with the first layer. Repeat this process for a third layer with the hammer stop placed in the top indent. During this entire operation, do not allow sample to accumulate on the bottom of the hammer or on the cage rods.

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 3/8 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 and contained specimen from the base plate and weigh, using the mold counterbalance if needed, and cut a vertical pie-shaped moisture sample from the compacted specimen such that the sample and pan together will have a weight of approximately 500 grams. Weigh this moisture sample in a tared pan, record the weight and pan number, and then obtain a dry weight and a moisture loss from which the percent of moisture can be calculated. 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, while constantly mixing 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 lower that the preceding one. This signifies that the resultant moisture density curve is complete and will be past the peak or optimum.

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 $lb./ft.^3$

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

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.

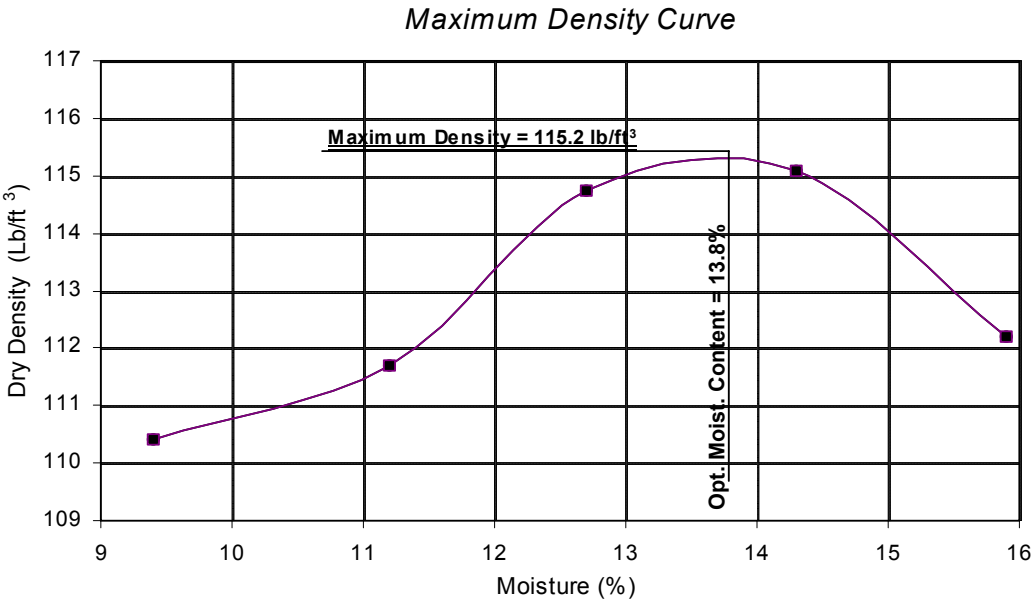
A = Weight of moisture pan plus wet soil.

B = Weight of moisture pan plus dry soil.

C = Weight of moisture pan.

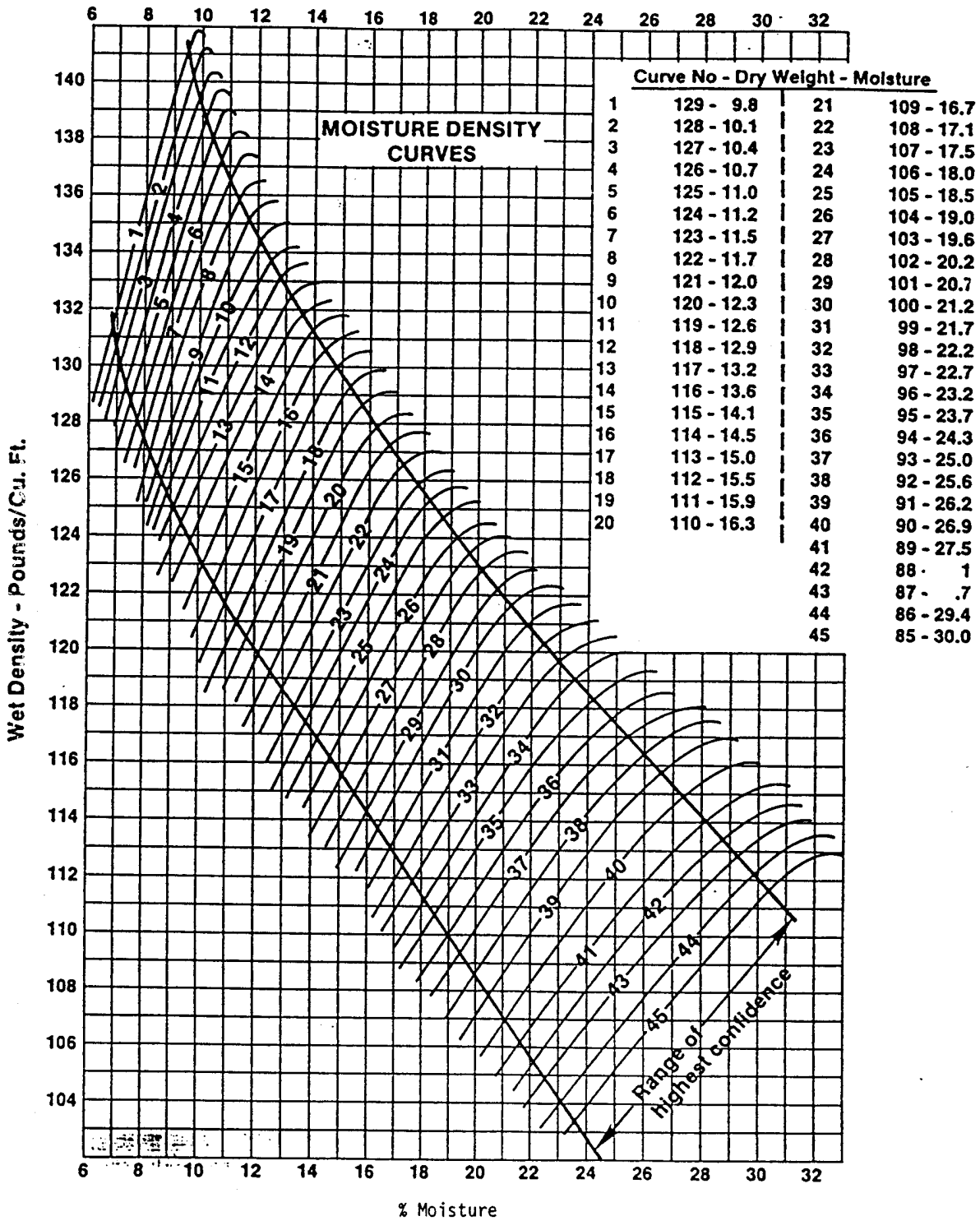
W_1 = Wet weight, in grams, of compacted specimen.

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