1305 THE MOISTURE-DENSITY RELATIONS OF SOILS USING A 2.5kg (5.5 LB) RAMMER AND A 305mm (12 INCH) DROP

AASHTO Designation T 99, Method "C"
(Mn/DOT Modified)

1305.1 SCOPE

This method of test is intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 2.5kg (5.5 lb.) rammer dropped from a height of 305mm (12 ").

1305.2 APPARATUS

A. Molds - The molds shall be solid-wall, metal cylinders manufactured with dimensions and capacities shown in 1305.2A.1 and 2A.2 below. They shall have a detachable collar assembly of, approximately, 60mm (2 3/8") in height, to permit the preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material.

NOTE 1: Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlations shall be maintained and readily available for inspection, when alternate types of molds are used.

1. A 101.6mm (4") mold having a capacity of 0.000943 ± 0.000008m^3; (1/30 [0.0333] ± 0.0003 cubic feet) with an internal diameter of 101.60mm ± 0.41mm (4.000 ± 0.016 inches) and a height of 116.43mm ± 0.13mm (4.584 ± 0.005 inches).

2. A 152.4mm (6") mold having a capacity of 0.002124 ± 0.000021m^3; (1/13.33 [0.07500] ± 0.00075 cubic feet) with an internal diameter of 152.40mm ± 0.66mm (6.000 ± 0.026 inches) and a height of 116.43mm ± 127.0mm (4.584 ± 0.005 inches).

B. Rammer

1. Manually Operated - Metal rammer having a flat circular face of 50.80mm ± 0.25mm (2.000 ± 0.01 inches), a manufacturing tolerance of ± 0.25mm (0.01 inches) and weighing 2.495kg ± 9g (5.50 ± 0.02 pounds). The rammer shall be equipped with a suitable guide-sleeve to control the height of the drop to a free fall of 305 ± 2mm (12.00 ± 0.06 inches) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes no smaller than 9.5mm (3/8") in diameter which are spaced approximately 1.57 radians (90°) apart and approximately 19mm (3/4") from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

2. Mechanically Operated - A metal rammer which is equipped with a device to control the height of drop to a free fall of 305 ± 2mm (12.00 ± 0.006 inches) above the elevation of the soil and uniformly distributes such drops to the soil surface. The rammer shall have a flat circular face 50.80mm ± 0.25mm (2.000 ± 0.01") in diameter and a manufactured mass of 2.495kg ± 9g (5.50 ± 0.02 pounds).

NOTE 2: The mechanical rammer shall be calibrated with several soil types and the mass of the rammer adjusted, if necessary, to give the same moisture-density results as with the manually operated rammer.

It may be impractical to adjust the mechanical apparatus so the free fall is 305mm (12.00”) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the drop is determined. Subsequent blows on the layer of soil being compacted may all be applied by dropping the rammer from a height of 305mm (12") above the initial setting elevation. Or, when the mechanical apparatus is designed with a height adjustment for each blow, all subsequent blows should have a rammer free fall of 304.8mm (12.00") measured from the elevation of the soil as compacted by the previous blow.

3. Rammer Face - The circular rammer shall be used but a sector face may be used as an alternative provided the report shall indicate type of face used other than the 50.8mm (2") circular face. It shall have an area equal to that of the circular face rammer.

C. Sample Extruder - A jack, lever, frame, or other device adopted for the purpose of extruding specimens from the mold.

D. Balances - Balance conforming to the requirements of AASHTO M 231 (Classes G2 & G20) having a sensitivity and readability to 0.1 grams and an accuracy of 0.1 grams or 0.1%. Balances shall be appropriate for the specific use.

E. Drying Oven - A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5 °C (230 ± 9 °F) for drying moisture samples.

F. Straightedge - A hardened-steel straightedge at least 250mm (10") in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.250mm per 250mm (0.01" per 10") (0.1 percent) of length within the portion used for trimming the soil.

G. Sieves - 50, 19.0, 9.5 and 4.75mm (2", 3/4", 3/8", and #4) sieves with bottom pan conforming to the requirements of AASHTO M 92.

H. Mixing Tools - Miscellaneous tools such as mixing pan, spool, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

I. Containers - Containers for moisture content samples shall made of metal or other suitable materials, with close-fitting lids to prevent loss of moisture prior to or during weighing.

1305.3 SAMPLE (Refer to Sections 1301.4 and .5)

A. If the soil sample is damp when it comes from the field, dry it until it becomes friable under a trowel. Drying may be in air or in a drying apparatus such that the temperature of the sample does not exceed 60 °C (140 °F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the individual particles. **See Section 1301.4 for details.**

B. Sieve an adequate quantity of representative, pulverized soil. Discard the +50mm (2") material. Weigh and discard the portion retained on the 19.0mm (3/4") sieve. Replace the discarded 50 - 19.0mm (2 - 3/4") material with material that passes the 19.0mm (3/4") sieve and is retained on the 4.75mm (#4) sieve that is from the original sample or from another sample having similar characteristics. **See Section 1301.5 for details.**

1305.4 PROCEDURE

A. This test consists of compacting a portion of a soil sample in a mold at different moisture contents ranging from dry to wet. **At least four samples** will be run. The samples will differ in moisture content by one or two percent with the driest sample being about four percentage points below optimum moisture. This would result in two of the samples being below optimum, one near optimum and one over optimum moisture. A valid test will have two points below optimum.

NOTE 3: If heavy clay or organic soils exhibiting flat elongated curves are encountered, the water content increments may be increased to a maximum of 4 percent.

B. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content. A good indication of the soil being nearly right for the first point is if the soil barely forms a "cast" when squeezed.

NOTE 4: Soils that are plastic and cohesive or friable may be (after additional moisture has been added) placed in a suitable covered container to keep from drying out and soaked overnight.

C. After the soil is thoroughly mixed and dampened, push the soil to the edge of the mixing pan to form a circle or ring. Scoop out a portion of the soil ring from four opposite sections. This will provide a good, representative sample for one layer. This should be done for every layer.

D. Form a specimen by compacting the prepared soil in the 101.6mm (4") mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 127mm (5"). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 305mm (12") above the elevation of soil when a sleeve type rammer is used, or from 305mm (12") above the approximate elevation of each finally compacted layer when a stationary mounted type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation.

NOTE 5: The following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete weighing not less than 91kg (200 lbs.), supported by a sound foundation, or a sound concrete floor.

E. Following compaction, the top or final layer should be about 12.5mm (1/2") over the top of the mold when the collar is removed. Carefully trim the excess 12.5mm (1/2") of compacted soil even with the top of the mold by means of the straight edge. Holes developed in the surface by the removal of coarse material shall be filled with finer material hand-pressed into place. Carefully trim around any stones that are at least half buried and solidly seated.

F. Clean all loose material from the mold and then weigh the mold and moist soil in kilograms to the nearest 5 grams or pounds to the nearest 0.01 lb. For molds conforming to tolerances given in 1305.2 and masses recorded in kilograms, multiply the mass of the compacted specimen and mold, minus the mass of the mold by 1059.43, and record the result as wet density, W_1 in kg/m^3. For molds conforming to tolerances in Section 1305.2, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold by 30, and record the results as the wet density, W_1, in lbs/ft of compacted soil.

G. Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, and dry in an oven at 110 ± 5 °C (230 ± 9 °F) for at least 12 hours or to a constant weight to determine the moisture content. The moisture content samples shall weigh not less than 500g. A 12.5 - 19.0mm (1/2 - 3/4") wide section sliced from the center usually provides the 500 grams.

NOTE 6: A representative section must consist of material from all three layers.

H. Thoroughly break up the remainder of the material until it passes a 19.0mm (3/4") sieve and 90% of the soil aggregations will pass a 4.75mm (#4) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points (90 cc, ml, or grams of water will increase the moisture content of 4.5kg [10 lbs.] of material about 2%). Additional water may be needed to replace moisture lost by evaporation during mixing and between points. Repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass, W_1, per cubic meter or cubic ft. of compacted soil.

NOTE 7: In each repetition the material shall be thoroughly mixed before compaction to assure uniform dispersion of the moisture throughout the sample.

1305.5 ALTERNATE PROCEDURE

If the material being tested is fine-grained and cohesive, it is difficult to mix and to break up after compaction; if the material is soft and fragile it may change gradation during compaction. These qualities require slightly different procedures to obtain reliable moisture-density information.

A. Prepare the original sample as outlined in Section 1305.3.

B. Select 11 - 14kg (25 - 30 lbs.) of the prepared material.

C. Moisten or dry the sample to about 4% below the estimated optimum moisture content. At this point when the soil is squeezed in the hand, a "cast" is barely formed. For granular soils (less than 20% passing the 75μm [#200 sieve]) this "cast" should crumble easily when touched.

D. This alternate method requires preparing a separate portion for each compaction test rather than using the same material over again; therefore, divide the sample into 4 or 5 portions, about 2.25kg (5 lbs.) each.

E. Place each portion into a watertight container.

F. Cover and set aside one portion. Mark it "Point #1".

G. Uniformly increasing increments of water shall be mixed with the separate portions to obtain a series of 3 or 4 additional moisture contents beyond Point 1, ranging from dry side to the wet side of optimum moisture.

H. Add enough water to one of the remaining portions to increase the moisture content about 2% over Point #1. Thoroughly mix, cover and mark this portion "Point #2".

NOTE 8: Forty-five cc or grams of water added to 2.25kg (5 lb.) of material will increase the moisture content about 2%.

I. Add 90 cc of water to another portion, thoroughly mix, cover and mark it "Point 3".

J. Add 135 cc of water to another portion, thoroughly mix, cover and mark it "Point 4".

K. Add 180 cc of water to another portion, thoroughly mix, cover and mark it "Point 4".

L. Allow the "points" to soak overnight to permit the moisture to disperse through the soil.

M. Each portion shall then be remixed the following day and compacted following steps B through H of 1305.4.

1305.6 CALCULATIONS

A. MOISTURE CONTENT of the material, as compacted for each trial, calculate as follows:

$$\textbf{Percent Moisture} = \frac{E - F}{F - H} \textbf{ X } 100$$

WHERE:

E = Weight of container and wet soil.

F = Weight of container and dry soil.

H = Weight of container.

In the example (See Section 1305.8):

$$\textbf{Percent Moisture} = \frac{270 - 243}{243 - 13} \textbf{ X } 100 = 11.7$$

B. WET DENSITY (wet weight in pounds per cubic foot of material compacted) calculate as follows:

Wet Density (kg/m ;) = (A - B) **X** 1059.43

WHERE:

A = Weight of wet soil and mold

B = Weight of mold

In the example (See Section 1305.8) the following calculation is made for "Point 1":

Wet Density (kg/m ;) = (7.189 - 5.488) **X** 1059.43 = 1802

C. DRY DENSITY (dry weight in kg/m^3) calculate as follows:

$$\textbf{Dry Density (kg/m}^3\textbf{)} = \frac{\text{Wet Density}}{\text{\% Moisture + 100}} \textbf{ X } 100$$

Using the above calculated values for % Moisture and Wet Density, the following calculation can be made for "Point 1" (See Section 1305.8):

$$\textbf{Dry Density (kg/m}^3\textbf{)} = \frac{1802}{11.7 + 100} \textbf{ X } 100 \textbf{ = } 1613$$

1305.7 MAXIMUM DENSITY and OPTIMUM MOISTURE CONTENT

A. The Maximum Density and Optimum Moisture are determined plotting the information obtained by compacting the sample at various moisture contents. Each moisture content relates to a Wet and a Dry Density.

B. Plot (on the Moisture-Density Relationship graph form, see Section 1305.9) the calculated Dry Densities against the Moisture Contents that were calculated previously and shown in the example (see Section 1305.8). In the examples the following points are plotted:

POINT NUMBER	1	2	3	4
% MOISTURE	11.7	13.8	16.6	18.4
DRY DENSITY	1613	1651	1682	1653

C. Draw a smooth curve through the points.

D. The moisture content corresponding to the peak of the curve shall be termed the "Optimum Moisture Content" of the soil under compaction. In the example, 16.5% is the "Optimum Moisture".

E. The "Maximum Density" also corresponds to the highest point on the "Dry" curve. In the example 1682kg/m^3 is the "Maximum Density".

1305.8 EXAMPLE - COMPUTATION SHEET for the PROCTOR MOISTURE - DENSITY CURVE

	Point Number	1	2	3	4	6	7
A	Weight of Wet Soil + Mold	7.189	7.262	7.339	7.335		
B	Weight of Mold	5.488	5.488	5.488	5.488		
C	Weight of Wet Soil	1.701	1.774	1.851	1.847		
D	Wet Density (kg/m^3)	1802	1879	1961	1956		
	Can Number	**1**	**2**	**3**	**4**		
E	Weight of Wet Soil + Can	270	287	349	376		
F	Weight of Dry Soil +Can	243	254	301	320		
G	Moisture Loss	27	33	48	56		
H	Weight of Can	13	14	11	15		
I	Weight of Dry Soil	230	240	290	305		
K	Percent Moisture	11.7	13.8	16.6	18.4		
	Dry Density (kg/m^3)	1613	1651	1682	1651		

REMARKS:

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