



Standard Test Procedures Manual

Section: SOILS

Subject: MOISTURE - DENSITY PROCTOR

1. SCOPE

1.1. Description of Test

This method describes the procedure for determining the relationship between the moisture content and density of fine-grained or coarse-grained soils.

1.2. Application of Test

Soils are compacted with a 2.5 kg rammer dropped from a height of 304.8 mm. Fine-grained soils are compacted in a 101.6 mm mold and coarse-grained soils in a 152.4 mm mold.

For the purpose of this test method, fine-grained soils include all soil materials having more than 90% of its particles passing a 5.00 mm Canadian Metric Standard sieve.

For the purpose of this test method, coarse grained soils include all soil materials having more than 10% of its particles retained on a 5.0 mm Canadian Metric Standard sieve.

2. APPARATUS AND MATERIALS

2.1. Equipment

A 101.6 mm mold. A cylindrical metal mold with a nominal capacity of 950 cm³ and internal diameter of 101.6 mm and a height of 116.3 mm. The mold will be fitted with a detachable collar and base plate. The exact volume of the mold without the collar but including a lucite liner is determined by weighing the amount of water required to fill it.

A 152.6 mm mold. A cylindrical metal mold with a nominal capacity of 2125 cm³ and internal diameter of 152.4 mm and a height of 116.3 mm. The mold will be fitted with a detachable collar and base plate. The exact volume of the mold without the collar is determined by weighing the amount of water required to fill it.

A metal rammer having a 50.8 mm diameter circular face with a 2.5 kg weight which will drop freely for a distance of 305 mm.

Compaction base. A cube of concrete weighing not less than 45 kg.

A steel straight edge approximately 300 mm in length.

A balance sensitive to 0.1 g.

Canadian Metric Sieves: 5.00 mm, 18.0 mm and 40.0 mm.

Drying apparatus - oven or stove suitable for drying samples.

Mixing tools - four mixing pans, trowel and a water bottle with sprinkler top and a 500 ml graduated cylinder.

3. PROCEDURE

3.1. Sample Preparation

Select a representative sample of sufficient quantity to perform the test; fine-grained soils require approximately 9000 g taken from the portion of sample passing the 5.00 mm sieve; coarse-grained soils required approximately 22,000 g.

Dry samples thoroughly in air or in the oven with a temperature not exceeding 60° C.

Break up aggregations, but do not crush individual particles.

For fine-grained soils, separate material on the 5.00 mm sieve. Regrind the fraction retained and again separate on the 5.00 mm sieve. Combine all ground coarse and fine materials, but if any particles are larger than 18.0 mm replace them with an equal weight of particles passing the 18.00 mm sieve.

For coarse-grained soils, use all the material but replace particles retained on the 40.0 mm sieve with an equal weight of particles passing the 40.0 mm sieve and retained on the 18 mm sieve.

3.2. Test Procedure

3.2.1. Procedure for Fine Grained Soils

Weight out four 2200 g samples in separate mixing pans and label 1, 2, 3 and 4.

Estimate the natural moisture content of the soil.

Estimate the optimum moisture for the soil as well as the amounts of water required to bracket the optimum. Strive for a spread of two percent in moisture

content between samples with two samples below optimum and two above, as shown in the example:

Sample No.	1	2	3	4
Sample Weight (g)	2200	2200	2200	2200
Natural Moisture % (est)	7	7	7	7
Optimum Moisture % (est)	15	15	15	15
Added Water Req'd. %	5	7	9	11
Total Req'd. Moist. %	12	14	16	18
Added Water Req'd. (ml)	110	154	198	242
Round Off ml Water Req'd.	100	150	200	250

Start the addition of water with sample No. 3, mix the required amount of water thoroughly with the soil and examine. If it is not over optimum moisture content, add additional water.

Adjust the amount of water to be added to the remaining samples by an equal amount.

If sample No. 3 (16% in the example) appears to be too far above optimum moisture when the required estimate of water is added, then it may be called sample No. 4. Reduce the quantity of water added to the other samples by an appropriate amount.

Assemble the 101.6 mm mold with collar and base plate attached and insert lucite liner. Place the assembly on the compaction base.

Take the mixed sample and compact in the mold in three equal layers to give a total compacted depth of approximately 127 mm.

Compact each layer with 25 blows from the rammer dropping freely from a height of 305 mm. Avoid bouncing the weight off the handle at the top of the stroke when operating the rammer. Distribute the blows uniformly over the surface of the layer being compacted.

After the specimen has been compacted, remove the collar from the mold and use the straight-edge to trim the compacted soils even with the top.

Remove the mold from the base plate, remove the compacted specimen and remove the liner.

Weigh the specimen and record the weight to the nearest gram.

Slice the sample vertically and remove approximately 100 g of soil from the central section of the test specimen for moisture content determination. Place the sample in a tared aluminum can, weigh and oven dry to a constant weight at 110° C.

Determine the difference between the wet and dry weights and record as weight of moisture for calculation of moisture content.

Repeat the procedure for compacting and moisture content determinations for each of the four samples (ie. two specimens above optimum moisture and two specimens below optimum moisture).

3.2.2. Procedure for Coarse Grained Soils

The procedure to be used is similar to the procedure for fine-grained soil with the following exceptions:

Weigh out four 5500 g samples.

Compact the specimens in the 152.4 mm mold in three equal layers to give a total compacted depth of about 127 mm.

Compact each layer with 56 blows from the rammer dropping freely from a height of 305 mm. Distribute the blows uniformly over the surface.

Remove approximately 500 grams of material from the vertical central section of the test specimen for moisture content determination. Place this sample in a suitable pan and weigh.

Carefully dry the moisture sample on a hot plate or oven at a temperature not exceeding 110° C.

After cooling, weigh the pan and sample and determine the moisture content in a similar manner to that used for fine-grained soils.

4. RESULTS AND CALCULATIONS

4.1. Calculations

The calculations are similar for the fine-grained and coarse-grained test.

Calculate the moisture and density for each of the samples. The following example illustrates the method to be used for each specimen:

Weight of Soil	1966		g
Volume of Mold	945		cm ³
Tare No.	89		
Wet Soil & Tare	141.69		g
Dry Soil & Tare	127.49		g
Weight of Water	14.20		g
Tare Weight	35.86		g
Weight of Dry Soil	91.63		g

$$\begin{aligned} \text{Moisture} &= \frac{\text{weight moisture}}{\text{weight dry soil}} \times 100 \\ &= \frac{14.20}{91.63} \times 100 = 15.5\% \end{aligned}$$

$$\begin{aligned} \text{Wet Density} &= \frac{\text{weight soil g}}{\text{volume mold cm}^3} \times 1000 \\ &= \frac{1966 \times 1000}{945} = 2080 \text{ kg/m}^3 \end{aligned}$$

$$\begin{aligned} \text{Dry Density} &= \frac{\text{wet density}}{100 + \% \text{ moisture}} \times 100 \\ &= \frac{2080 \times 100}{100 + 15.5} = 1800 \text{ kg/m}^3 \end{aligned}$$

4.2. Moisture-Density Plot

Plot the moisture content versus dry density on graph paper with the vertical side representing dry density in kg/m³ and the horizontal side representing moisture content in percentages. Form MR-33 includes a suitable graph paper.

Plot the moistures and corresponding densities as coordinates and draw a "best fit" curve through them in the order of increasing moisture contents to form a parabolic curve.

The moisture content corresponding to the peak of the curve is the "optimum moisture" for the compaction effort used in the test.

If the coordinates on the dry and wet side of the apparent optimum percent are spaced too far apart to properly define the location of the curve at optimum, a fifth density specimen at the required moisture content will be necessary to define the curve properly.

The dry density of the soil at "optimum moisture content" in kilograms per cubic meter will be termed "maximum density" for the compacted effort used in the test.

4.3. Reporting Result

Report the moisture content and maximum density of Form MR-33.

4.4 Mechanical Apparatus

The method described in this Standard Test Procedure does not include mechanical mixing and compaction apparatus. If a laboratory wishes to use equipment or methods other than those described herein it must ensure that specimens prepared using different methods are equal in every respect to those manufactured by this specification.