

State of Nevada
Department of Transportation
Materials Division

**METHOD OF TEST FOR THE DETERMINATION OF MAXIMUM DENSITY AND OPTIMUM
MOISTURE CONTENT OF SOILS USING THE MODIFIED PROCTOR DEVICE**

SCOPE

This test method is intended to determine the relationship between the moisture content and density of soils when compacted in a specified mold using a 4.54 kg (10 lb) rammer with a 457 mm (18 in.) drop. The maximum density and optimum moisture determined by this test shall be used for determining relative percent compaction in the field.

Method A applies to materials that have 40% or less retained on the 4.75 mm (No. 4) sieve. This value may be obtained from results determined per Test Method Nev. T206. Perform Test Method Nev. T206 to determine the percentage of the +4.75 mm (+No. 4) coarse aggregate.

Method D applies to materials that have 30% or less retained on the 19.0 mm (3/4 in.) sieve. This value may be obtained from results determined per Test Method Nev. T206. Perform Test Method Nev. T206 to determine the percentage of the +19.0 mm (+3/4 in.) coarse aggregate.

When both criteria are met for determining “Method A” and “Method D”, “Method A” shall be used.

For materials that do not otherwise require a sieve analysis to be performed, a representative sample shall be obtained, split, dried and screened through both a 4.75 mm (No. 4) and 19.0 mm (3/4 in.) to determine as to whether “Procedure Method A” or “Procedure Method D” is to be performed.

If the specified oversized maximum tolerances are exceeded, other methods of compaction control must be used.

APPARATUS

1. Mold, machined solid-wall metal cylinder having the dimensions as detailed in Table 1 or Table 2, a detachable collar and base plate to which the mold can be fastened to.
2. Rammer, mechanically or manually operated rammer as detailed in Table 1 or Table 2. A manually operated rammer shall be equipped with a suitable guide sleeve to control the path and height of the specified drop. The guide sleeve shall also be equipped with at least four vent holes no smaller than 9.5 mm (3/8 in.). A mechanically operated rammer shall be equipped with a device to uniformly distribute drops at specified heights.
3. Sample Extruder, jack, lever-frame, or other suitable device used for the purpose of extruding compacted specimens from the mold.

4. Balance, with a capacity of 12000 g and sensitive to 0.1 g.
5. Oven, capable of maintaining a temperature of 110 ± 5 °C (230 ± 9 °F).
6. Microwave, electric hot plate or gas stove.
7. Sieves, **Method A** - 4.75 mm (No. 4) or **Method D** - 19.0 mm (3/4 in.)
8. Straightedge, steel straightedge at least 250 mm (10 in.) in length, having one beveled edge and at least one plane surface, used for final trimming of the compacted specimen.
9. Mixing Tools, large mixing bowl, large pan, mixing spoon, scoop, tamper, trowel, spatula, hammer, etc. or other suitable devices for mixing the sample with water.

Table 1 (Metric)
Comparison of Apparatus, Sample, and Procedure

	Method A	Method D
Mold Volume, m ³	0.000943	0.002123
Mold Diameter, mm (Internal)	101.60 ± 0.41	152.40 ± 0.66
Mold Height, mm	116.43 ± 0.13	116.43 ± 0.13
Rammer Diameter, mm	50.80 ± 0.64	50.80 ± 0.64
Rammer Mass, kg	4.54 ± 0.01	4.54 ± 0.01
Lifts	5	5
Blows per Lift	25	56
Material Size, mm	4.75	19.0
Test Sample Size, kg	3.5	11.0
Rammer Drop Height, mm	457	457
Energy, kN-m/m ³	2,693	2,693

Table 2 (English)
Comparison of Apparatus, Sample, and Procedure

	Method A	Method D
Mold Volume, ft ³	0.0333	0.0750
Mold Diameter, in. (Internal)	4.00 ± 0.02	6.00 ± 0.03
Mold Height, in.	4.58 ± 0.01	4.58 ± 0.01
Rammer Diameter, in.	2.00 ± 0.03	2.00 ± 0.03
Rammer Mass, lb	10.0 ± 0.02	10.0 ± 0.02
Lifts	5	5
Blows per Lift	25	56
Material Size, in.	No. 4	¾"
Test Sample Size, lb	7.71	24.25
Rammer Drop Height, in.	18	18
Energy, lb-ft/ft ³	56,250	56,250

PROCEDURE – METHOD A

1. **Method A** - From a thoroughly blended sample as obtained per Test Method Nev. T200, thoroughly screen the blended sample over a 4.75 mm (No. 4) sieve. Split the remaining material passing the 4.75 mm (No. 4) sieve until a 3,500 g ± 350 g sample is obtained.
2. Squeeze a handful of material, and if a mold is formed which can be picked up readily with the thumb and index finger, sufficient moisture is present in the soil to begin the test. If a cast is not formed, add sufficient moisture to the sample at a rate not to exceed 2% of the total weight of the sample (depending on soil consistency) and mix thoroughly until the soil mixture appears uniform (ex. 3,500 g x .02 = 70 mL). Repeat this procedure until a sufficient moisture content for beginning the test is found. Cover the mixing bowl or pan with a damp cloth; keeping it covered throughout the test procedure. If the material is above its optimum moisture, it may be air dried or dried back in an oven not to exceed 60 °C (140 °F)
3. Determine the weight of the clean, dry mold. Include the base plate, but exclude the collar extension and record this weight to the nearest 1 g.
4. Form a specimen by compacting the prepared sample in the mold (with the collar extension attached) in 5 equal lifts. For each lift, uniformly spread the loose material in the mold and tamp it flat with the tamper. Compact each lift with 25 uniformly distributed blows from the rammer, dropping free from a height of 457 mm (18 in.). Make sure the fifth and final lift will leave the compacted soil surface in the collar approximately 6 mm (¼ in.) above the top of the mold.
5. Remove the extension collar using a twisting motion to avoid shearing off the sample below the top of the mold. Trim the compacted specimen even with the top of the mold using the beveled edge of the straightedge.

- Determine the weight of the compacted specimen, mold and base plate and record this weight to the nearest 1 g.
- Determine the weight of the compacted specimen by subtracting the weight of the mold as determined in Step 3 of this procedure.

$$\text{Wet Weight of Specimen} = (\text{Weight of Mold} + \text{Specimen}) - \text{Weight of Mold}$$

$$\text{Wet Density} = \text{Wet Weight of Specimen} / \text{Volume of Mold}$$

- Place the mold in the sample extruder and remove the compacted specimen. Cutting vertically through the center, take a representative sample (approx. 200g – 500g) from the full length and width of the specimen as illustrated in FIGURE 1. Separate the particles of the representative sample; place the sample in a suitable drying container and immediately record the weight of the wet sample to the nearest 0.1 g. Dry the sample in accordance with Test Method Nev. T112.
- Break up the remaining portion of the compacted specimen until it will pass through a 4.75 mm (No. 4) sieve and recombine it with the remaining portion of the sample in the mixing bowl or pan being tested. Thoroughly blend the sample in a mixing bowl or pan and add 2 percent water at 25 ± 5 °C (77 ± 9 °F) NOTE: (1 mL = 1 g).
- Continue to repeat the procedures as outlined in Step 4 thru Step 9 until there is either a decrease or no change in the wet density of the compacted specimen. With moisture additions in increments of 2 %, multiple determinations may be necessary to determine a materials maximum dry density.
- Dry all specimens using one of the methods outlined in Test Method Nev. T112 or by the following microwave oven procedure: Place a 600 mL glass beaker or other suitable container filled with approximately 300 mL of water (maintain water level during drying) into the microwave oven to prevent overheating during the drying process. Place specimen in a microwave safe container, then place in the microwave oven. Dry the sample for 5 minutes, then at 2 minute intervals until a constant weight is achieved. Drying times may be adjusted based on type and size of the microwave oven.
- At the completion of the drying procedure, allow specimens to cool. Weigh and record the dry weight of each specimen to the nearest 0.1 g, then calculate the percent moisture to the nearest 0.1%.

$$\% \text{ Moisture} = [(\text{Wet Weight of Specimen} - \text{Dry Weight of Specimen}) / (\text{Dry})] \times 100$$

$$\text{Dry Density} = [(\text{Wet Density}) / (100 + \% \text{ Moisture})] \times 100$$

PROCEDURE – METHOD D

1. **Method D** - From a thoroughly blended sample as obtained per Test Method Nev. T200, thoroughly screen the blended sample over a 19.0 mm (3/4 in.) sieve. Split the remaining material passing the 19.0 mm (3/4 in.) sieve until an 11,000 g \pm 1,100 g sample is obtained.
2. Squeeze a handful of material, and if a mold is formed which can be picked up readily with the thumb and index finger, sufficient moisture is present in the soil to begin the test. If a cast is not formed, add sufficient moisture to the sample at a rate not to exceed 2% of the total weight of the sample (depending on soil consistency) and mix thoroughly until the soil mixture appears uniform (ex. 11,000 g x .02 = 220 mL). Repeat this procedure until a sufficient moisture content for beginning the test is found. Cover the mixing bowl or pan with a damp cloth; keeping it covered throughout the test procedure. If the material is above its optimum moisture, it may be air dried or dried back in an oven not to exceed 60 °C (140 °F)
3. Determine the weight of the clean, dry mold. Include the base plate, but exclude the collar extension and record this weight to the nearest 1 g.
4. Form a specimen by compacting the prepared sample in the mold (with the collar extension attached) in 5 equal lifts. For each lift, uniformly spread the loose material in the mold and tamp it flat with the tamper. Compact each lift with 56 uniformly distributed blows from the rammer, dropping free from a height of 457 mm (18 in.). Make sure the fifth and final lift will leave the compacted soil surface in the collar approximately 6 mm (1/4 in.) above the top of the mold.
5. Remove the extension collar using a twisting motion to avoid shearing off the sample below the top of the mold. Trim the compacted specimen even with the top of the mold using the beveled edge of the straightedge.
6. Determine the weight of the compacted specimen, mold and base plate and record this weight to the nearest 1 g.
7. Determine the weight of the compacted specimen by subtracting the weight of the mold as determined in Step 3 of this procedure.

$$\text{Wet Weight of Specimen} = (\text{Weight of Mold} + \text{Specimen}) - \text{Weight of Mold}$$

$$\text{Wet Density} = \text{Wet Weight of Specimen} / \text{Volume of Mold}$$

8. Place the mold in the sample extruder and remove the compacted specimen. Cutting vertically through the center, take a representative sample (approx. 200g – 500g) from the full length and width of the specimen as illustrated in FIGURE 1. Separate the particles of the representative sample; place the sample in a suitable drying container and immediately record the weight of the wet sample to the nearest 0.1 g. Dry the sample in accordance with Test Method Nev. T112.
9. Break up the remaining portion of the compacted specimen until it will pass through a 19.0 mm (3/4 in.) sieve and recombine it with the remaining portion of the sample in the mixing bowl or pan being tested. Thoroughly blend the sample in a mixing bowl or pan and add 2 percent water at 25 \pm 5 °C (77 \pm 9 °F) NOTE: (1 mL = 1 g).

10. Continue to repeat the procedures as outlined in Step 4 thru Step 9 until there is either a decrease or no change in the wet density of the compacted specimen. With moisture additions in increments of 2 %, multiple determinations may be necessary to determine a materials maximum dry density.
11. Dry all specimens using one of the methods outlined in Test Method Nev. T112 or by the following microwave oven procedure: Place a 600 mL glass beaker or other suitable container filled with approximately 300 mL of water (maintain water level during drying) into the microwave oven to prevent overheating during the drying process. Place specimen in a microwave safe container, then place in the microwave oven. Dry the sample for 5 minutes, then at 2 minute intervals until a constant weight is achieved. Drying times may be adjusted based on type and size of the microwave oven.
12. At the completion of the drying procedure, allow specimens to cool. Weigh and record the dry weight of each specimen to the nearest 0.1 g, then calculate the percent moisture to the nearest 0.1%.

$$\% \text{ Moisture} = [(\text{Wet Weight of Specimen} - \text{Dry Weight of Specimen}) / (\text{Dry})] \times 100$$

$$\text{Dry Density} = [(\text{Wet Density}) / (100 + \% \text{ Moisture})] \times 100$$

MOISTURE-DENSITY RELATIONSHIP

1. Calculations shall be made to determine a materials wet density (unit mass) and oven-dry density (unit mass). The oven-dry densities of the soil shall be plotted as ordinates (y-axis) and corresponding moisture contents as abscissa (x-axis).
2. When the densities and corresponding moisture contents for the soil sample have been determined and plotted, it shall be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the “optimum moisture content.”
3. The oven-dry density in kilograms per cubic meter or pounds per cubic foot of the soil at optimum moisture content shall be termed “maximum density” under the above compaction.

COARSE AGGREGATE CORRECTION

Method A, When the test specimen contains material exceeding 5 percent by mass retained on the 4.75 mm (No.4) sieve, use the following “Coarse Aggregate Correction” calculations. Use Test Method Nev. T104 to determine the apparent specific gravity of the +4.75 mm (+No. 4) aggregate. Use the percent of +No. 4 aggregate as determined per Test Method Nev. T206.

Method D, When the test specimen contains material exceeding 5 percent by mass retained on the 19.0 mm (3/4 in.) sieve, use the following “Coarse Aggregate Correction” calculations. Use Test Method Nev. T104 to determine the apparent specific gravity of the +19.0 mm (+3/4 in.) aggregate. Use the percent of +3/4 in. aggregate as determined per Test Method Nev. T206.

Correction for the +4.75 mm (+No.4) or +19.0 mm (+3/4 in.) material shall be calculated as follows:

$$D = \frac{dG}{(d)(1-P) + (G)(P)}$$

Example:	D	= Corrected Calculated Max. Density	
	d	= Maximum Dry Density	140.4 lbs/ft ³
	1- P	= Percent +No.4 or +3/4 in. Aggregate	(0.27) 27%
	P	= Percent -No.4 or -3/4 in. Aggregate	(0.73) 73%
		Apparent Specific Gravity of Coarse Aggregate	2.70
	G	= Mass per Volume of Coarse Aggregate: (2.70 x 62.4)	168.5 lb/ft ³

$$D = \frac{(140.4 \text{ lb/ft}^3) \times (168.5 \text{ lb/ft}^3)}{[(140.4 \text{ lb/ft}^3 \times 0.27) + (168.5 \text{ lb/ft}^3 \times 0.73)]}$$

$$D = 147.0 \text{ lb/ft}^3$$

Corrected Optimum Moisture Calculation:

$$[(1-P) \times 2] + [P \times \text{Test Opt. Moisture}]$$

REPORT

Report optimum moisture content or corrected optimum moisture content to the nearest 0.1% and maximum density or corrected maximum density to the nearest 0.1 lb/ft³

NOTES

1. When preparing the initial sample, thoroughly mix with a sufficient amount of water to moisture condition it to approximately three percentage points below the samples optimum moisture content.
2. It's important to place the loose material into the mold and spreading it into a layer of uniform thickness and tamp it with the tamper prior to the compaction of each lift. Do not allow material to build up the sides of the mold between lifts. If this occurs, break down and tamp the material before the final blow is completed or before the next lift is started.
3. When completing a Proctor Compaction Curve Test on gypsum or material blended with recycled asphalt pavement, dry in accordance with Test Method Nev. T112, Method A, under "PROCEDURE", using a temperature of 60 °C (140 °F), to avoid changing the nature of the sample.
4. A valid Modified Proctor Test shall consist of a minimum of three points for the maximum dry density determination consisting of one point below optimum, one near optimum and one over optimum.
5. A new Proctor Curve Test shall be performed whenever results indicate changes to materials, a second re-test is required, test results exceeding 102% compaction or at the discretion of the Resident Engineer.
6. Percentages retained on the +4.75 mm (+No. 4) and +19.0 mm (+3/4 in.) should be determined each time a Proctor Curve is performed to verify that the correct method is being utilized as described in the SCOPE of this Method.
7. In instances where soil materials indicate fragile characteristics (such as the breaking of aggregate) that will reduce significantly by repeated compaction, a separate and new sample shall be used for each compaction test.

When utilizing "Method A", obtain a minimum of three separate samples approximately 2,500 g as described in Step 1 of "PROCEDURE – METHOD A". Each individual sample shall represent one compaction test after it has been properly moisture conditioned in increments of 2%.

When utilizing "Method D", obtain a minimum of three separate samples approximately 5,500 g as described in Step 1 of "PROCEDURE – METHOD D". Each individual sample shall represent one compaction test after it has been properly moisture conditioned in increments of 2%.

8. When developing a compaction curve for free draining soils, such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture sample from the mixing bowl shall be acceptable.

9. Do not use the hammer to extract the material from the mold.

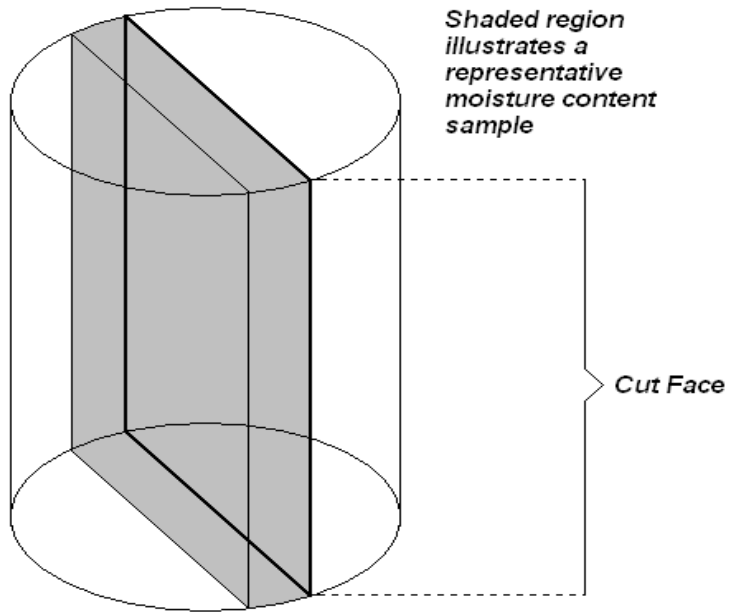


FIGURE 1