State of Nevada
Department of Transportation
Materials Division

# METHOD OF TEST FOR MAXIMUM DENSITY AND RELATIVE COMPACTION OF SOILS USING THE HARVARD MINIATURE COMPACTION DEVICE

## SCOPE

This test method is used to determine the relationship between the moisture content and the density of - 4.75 mm (- No. 4) graded soil when compacted in a specified mold using a spring loaded tamper preset to develop a foot load of 1317 kPa (191.0 psi). The maximum density determined by this test shall be used for determining compaction in the field.

## APPARATUS (See Figure 1 and 2)

1. Mold, metal, machined and polished to the following dimensions:

   | | |
   |---|---|
   | Diameter | 33.34 mm ± 0.05 mm (1.3125 ± 0.002 in.) |
   | Length | 71.52 mm ± 0.05 mm (2.8156 ± 0.002 in.) |
   | Area | 872.99 $mm^2$ (1.3530 $in.^2$) |
   | Volume | 6.24 x $10^{-5} m^3$ (3.8095 $in.^3$) |

   $$6.24 \times 10^{-5} m^3 = 0.0000624\ m^3 \left( \frac{3.8095}{1728}\ in.^3 = 0.0022046\ ft^3 \right)$$

2. Spring loaded tamper, assembled to meet the following requirements:

   | | |
   |---|---|
   | Diameter of Foot | 12.7 mm (0.5 in.) |
   | Area of Foot | 126.68 $mm^2$ (0.19635 $in.^2$) |
   | Spring Load | 17.01 kg (37.5 lb) |
   | Foot Load | 1317 kPa (191.0 psi) |

3. Extruder, lever-frame, used for the purpose of extruding compacted specimens from the mold.

4. Balance, having 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. Electric hot plate or gas stove.

7. Microwave oven.

8. Sieve, 4.75 mm (No. 4).

9. Large mixing bowl, teaspoon (tsp), fork, large mixing spoon, straight edge spatula, 100 mL graduated plastic cylinder, plastic syringe, cloth and a steel rod with a smooth end approximately 25.4 mm (1 in.) in diameter.

**PROCEDURE**

1. Split and screen sufficient material passing the 4.75 mm (No. 4) sieve until a 1500 g sample is obtained. Place this material in the mixing bowl. Squeeze a handful of material, and if a cast 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 a maximum of 30 mL of water (depending on soil consistency) and mix thoroughly until the soil mixture appears uniform. Repeat this procedure until the suitable moisture content for beginning the test is found. Mix and adjust the sample weight to 1500 g of material and perform the test. If the material is too wet, dry back the material slightly, using the oven method in accordance with Test Method Nev. T112 stirring every 5 minutes. Mix and adjust the sample to 1500 g and perform the test. Cover material in the mixing bowl with a damp cloth and keep covered throughout this test procedure.

2. Level out the material in the mixing bowl, remove approximately 10 mL (2 tsp) of material from a single location and place it in the mold. Tamp 25 times moving the tamping foot after each tamp to give uniform coverage over the surface area of the soil in the mold. Proper tamping has been achieved when the handle and the nut at the top of the tamper separates slightly. Repeat this process for three additional lifts making sure the fourth and final lift will leave the compacted soil surface in the collar above the top of the mold. Obtain the soil for each lift from a single location of material in the bowl so that when the specimen is compacted there will be four source holes providing a double check on the number of lifts per specimen. Place the 25.4 mm (1 in.) steel rod on the compacted soil surface, apply slight pressure downward with one hand and with the other hand, turn and lift the collar vertically to remove. Carefully trim the top surface of the compacted soil specimen so that it is flush with the top of the mold and is free of any voids. Place the mold with compacted specimen in the sample extruder and pull the handle down to extrude specimen. Weigh the specimen plus any portion separated during the extrusion operation to the nearest 0.1 g. Record the wet weight in grams divided by 62.4 = $Mg/m^3$ (weight in grams is the net weight in $lbs/ft^3$). Place the specimen in a suitable container for drying in an oven capable of maintaining 110 ± 5°C (230 ± 9°F), electric hotplate, gas stove or microwave oven (separate the specimen particles during the process for more thorough drying).

3. Add 2 percent water at 25 ± 5°C (77 ± 9°F) in mL (1 mL = 1 g) to the soil remaining in the mixing bowl (weigh the material in mixing bowl after each specimen to obtain 2 percent moisture; or by adding 28 mL to the second specimen, 26 mL to the third specimen and continue as more specimens are molded). Repeat the process outlined in paragraph 2 above. Initial moisture additions are controlled by the weight of the material available for the test. (Weight of material x 0.02 = mL or grams of water to be added). (Hint: Moisture addition will decrease approximately 2 mL or grams with each additional specimen).

4. Continue and repeat the procedures as outlined in paragraphs 2 and 3 above until the highest dry density is established. The following three scenarios are indicators that the highest dry density has been achieved:

   a. When the last compacted specimen fails to gain more than 1.4 g (wet).

   b. When free water, or a thin ribbon of plastic material, is extruded at the bottom of the mold and the base plate connection.

   c. When the spring loaded tamping foot penetrates the specimen in excess of 6.35 mm (0.25 in.) on the top lift of the specimen, when the total load of 17.01 kg (37.5 lbs) is carefully applied. To check this, carefully trim the top surface of the soil specimen so that it is flush with the top of the mold. Place the mold and specimen back in the mold holder, and apply the spring loaded tamper to the center of the sample. If the penetration exceeds 6.35 mm (0.25 in.), the moisture content is above optimum, and this specimen will not be used as the maximum dry density (even if it is the highest dry weight).

   If any of the scenarios described in 4.a. to 4.c. occur prior to the third specimen, the material shall be dried back before continuing the test procedure. Refer to No. 1 under PROCEDURE for drying back or split another 1500 g sample and start the test over.

5. 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.

6. 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%. Record the weight in grams divided by 62.4 = Mg/m$^3$ (weight in grams is in lbs/ft$^3$) for each respective specimen. The weight of the specimen having the greatest dry density is the maximum density for this particular - 4.75 mm (- No. 4) soil fraction. After all specimens have been dried, and the dry weight is still increasing, the curve is not complete, and additional specimens must be produced (unless the highest specimen was due to 4.c. above). EXCEPTION: The only time you do not use the highest dry density from the Harvard Miniature Curve Test is if that specimen had excessive penetration as described in 4.c. above. If this occurs, place an asterisk next to this specimen, and note “*penetration in excess of 6.35 mm (0.25 in.)”.

## MOISTURE CONTROL

1. The optimum moisture content of the Harvard Miniature Curve Test can only be used as a moisture control in the field on the - 4.75 mm (- No. 4) fraction of the material. If the total material contains + 4.75 mm (+ No. 4) material, then an approximate optimum moisture content will be calculated after first determining the percent + 4.75 mm (+ No. 4) = (1-P) and percent - 4.75 mm (- No. 4) = (P). The following equation shall be used for this calculation:

   Total Sample Approximate Optimum Moisture = [(1-P) x 2] + [P x Test Optimum Moisture]

   Where: 1-P = Decimal equivalent of % + 4.75 mm (+ No. 4)

   Where: P = Decimal equivalent of % - 4.75 mm (- No. 4)

## COMPACTION CONTROL

1. Compaction control of any material having a suitable range of moisture content may be achieved by the appropriate use of one of the following three methods that meet the gradation limits of the material to be compacted:

   a. Maximum size 100 mm (4 in.) or less with the percent passing the 4.75 mm (No. 4) sieve within the following limits:

| Sieve Designation | Percent Passing 4.75 mm (No. 4) Sieve |
|---|---|
| 100 mm (4 in.) | 21.5 to 100 |
| 90 mm (3 1/2 in.) | 23.0 to 100 |
| 75 mm (3 in.) | 24.8 to 100 |
| 63 mm (2 1/2 in.) | 27.2 to 100 |
| 50 mm (2 in.) | 30.4 to 100 |
| 37.5 mm (1 1/2 in.) | 35.1 to 100 |
| 25.0 mm (1 in.) | 43.0 to 100 |
| 19.0 mm (3/4 in.) | 49.7 to 100 |

   Sieve Designation is determined by the smallest sieve that will pass at least 90% of the sample being tested.

The Calculated Maximum Density of the above sized material within their respective gradation limits shall be calculated as follows:

$$D = GK(1-P) + Pd(1.03)$$

D = Calculated Maximum Density, $Mg/m^3$ (pcf)

G = Apparent Specific Gravity of the coarse aggregate + 4.75 mm (+ No. 4), Test Method Nev. T104

K = 0.90 (56.16), rock correction factor

P = Percent of fine aggregate - 4.75 mm (- No. 4) expressed as a decimal

d = Maximum Dry Density of the fine aggregate - 4.75 mm (- No. 4) as determined by the Harvard Miniature Curve Test

b. Maximum size 100 mm (4 in.) or less with gradation limits outside of those shown for sized material in paragraph 1.a. above: A Calculated Maximum Density Curve for field use will be determined by the Materials Division. Contact the Geotechnical Lab for sample sizes and requirements.

c. Maximum size larger than 100 mm (4 in.) in sufficient quantities as determined by the Engineer: No field density tests will be performed for this type of material, as adequate compaction can best be controlled by means of a proof rolling test by following the conditions as set forth in the specifications for proof rolling.

2. Relative Compaction is defined as the ratio of the in-place field density dry of a soil or aggregate to its Calculated Maximum Density. The percent compaction is computed from the following formula:

$$\text{Percent Compaction} = \left(\frac{\text{Field Density Dry}}{\text{Calculated Maximum Density}}\right) \times 100$$

**REPORT**

Report percent compaction to the nearest whole percent.

NOTES

1. It is important to leave the material loose in the mold prior to tamping each lift. If the material is even slightly pre-tamped with the rod or finger, a bridging condition may develop during the compaction procedure, and the bottom of that lift will show a considerable amount of voids resulting in weight less than should be obtained.

2. Densities too high will result when any of the following discrepancies occur:

   a. Excessive compression of the spring during the tamping process.

   b. Excessive number of tamps per lift.

   c. Excessive number of lifts per specimen.

   d. Excessive mold wear increasing the inside diameter of the mold.

3. Specimens over optimum moisture may not support the 1317 kPa (191.0 psi) spring load, and the foot will penetrate through the soil layer resulting the excessive penetration, displacing the soil upward around the spring loaded tamping foot. Continue performing the specimen and remaining lifts, lessen the required load to the spring loaded tamper. Compact such a specimen by allowing 6.35 mm (0.25 in.) or less penetration (hand tamping) by the spring loaded tamping foot and a suitable specimen will be produced.

4. A valid Harvard Miniature Curve Test shall consist of a minimum of three points for the maximum density determination (one below optimum, one at optimum and one over optimum).

5. A new Harvard Miniature Curve Test shall be performed whenever the material changes, a second re-test is required, test results exceed 102 percent compaction, and for every tenth compaction test on the same material.

6. When completing a Harvard Miniature 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.

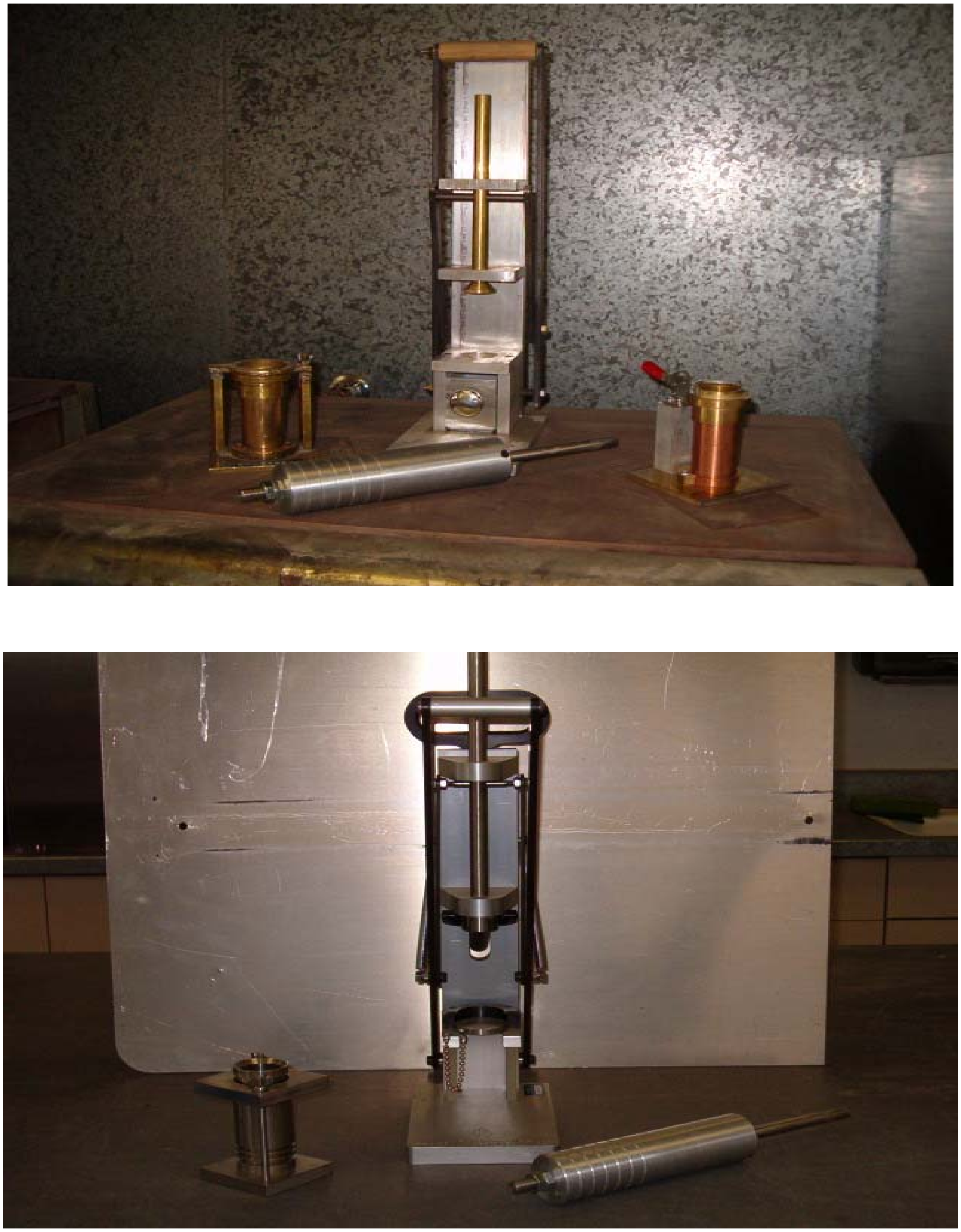

FIGURE 1

FIGURE 2