

Recommend Approval: <u>Vladimir Tanchev</u> 04/16/2024 Assistant Division Chief Date <u>Antikhab Haider</u> 04/29/2024 Division Chief Date	Maryland Department of Transportation State Highway Administration Office of Materials Technology MARYLAND STANDARD METHOD OF TESTS	
Approved: <u>Eric M. Frempong</u> 05/02/2024 Director Date	IN-PLACE DENSITY OF EMBANKMENT, SUBBASE, BASE, SURFACE AND SHOULDER MATERIALS	MSMT 350

SCOPE:

These procedures are used to determine the in-place density of embankments, base, subbase, surface, and shoulder materials.

REFERENCE DOCUMENTS:

M 231 Weighing Devices Used in the Testing of Materials.

T 191 Density of Soil In-Place by the Sand-Cone Method.

MSMT 351 Field Determination of Moisture Density Relations of Soils.

MATERIALS:

1. 80 lb bag of density sand.

EQUIPMENT:

1. Cylindrical compaction mold, 1/30 ft³.
2. Cylindrical compaction mold, $\frac{1}{13.33}$ ft³.
3. Compaction rammer, 10 lb.
4. Compaction rammer, 5.5 lb.
5. 12 in. straightedge.
6. Scale or balance conforming to M 231, Class G 100, having a minimum capacity of 100 lb.
7. Scale or balance conforming to M 231, Class G 2.
8. Two 10 in. pie pans.
9. 12 in. frying pan.

10. 12 in. rocker set complete with pan, frame and dust ring.
11. 12 in. square sieve, with 2 in. openings.
12. 12 in. square sieve, with 3/4 in. openings.
13. 12 in. square sieve, with No. 4 openings.
14. 12 in. square sieve, with No. 10 opening.
15. Field density plate with recess to accommodate sand cone apparatus.
16. Steel pan, 12 x 30 in.
17. Electric or gas hot plate.
18. Soil density pick.
19. Calibrated sand cone density apparatus.
20. 3 in. spatula.
21. Two water pails.
22. Stencil brush.
23. Bench brush.
24. Sprinkling can.
25. Large spoon.
26. Compaction Report forms.

TEST SITE PREPARATION:

Follow the procedures below in preparing the test area, excavating the density hole, and determining the volume of the hole by either the Sand Cone (Method A) or Sand Bucket (Method B) methods. The method used will be determined by the type of construction and type of material.

DENSITY HOLE

1. Determine the location to be tested. Remove all loose material and clear a test area about 2 ft x 2 ft. Use a straightedge and level the area until the surface is smooth and firm.
2. Place a field density plate on the prepared surface and leave in place until the test is completed.

3. Use a soil density pick to excavate a hole sized to yield a representative sample of the material being tested. The size of this sample is given under the appropriate case for the particular material. Remain inside the base plate circle when digging the test hole. Extend the depth of the hole to the bottom of the layer being tested.
4. Remove the material from the hole, place in a suitable container, and cover to prevent loss of moisture.
5. Remove all loose material, and then smooth the bottom of the hole.

IN-PLACE DENSITY TEST PROCEDURES:

Follow the procedures below to test the material excavated from the density hole and for computing the various results in determining the in-place density. Each type of construction is covered under a separate heading.

It will not be necessary to reclaim the sand from the test hole due to possible contamination of the density sand.

METHOD A - SAND CONE (Soils and GAB)

Sand Calibration. Calibrate the sand used to measure the volume of the density hole before each test. The technician performing the calibration shall also perform the in-place density test. The volume of the sand cone apparatus will be calibrated by laboratory personnel in conformance with T 191. The volume will remain constant as long as the jar and cone attachment is in the same relative position. Match marks are provided to ensure proper reassembly.

Calibrate the sand on a vibration-free work platform to avoid erroneous results. Care should be taken to ensure no heavy equipment is operating in the area during testing to avoid vibration of the sand. Calibrate the sand to determine the field density as follows:

1. Sieve the loose, dry sand through a No. 10 sieve and discard the material retained.
2. Weigh the empty sand cone apparatus.
3. Place the empty apparatus upright on a firm level surface, close the petcock, and fill the cone with sand.
4. Open the petcock and fill the apparatus, keeping the cone at least half full of sand. Close the petcock sharply after the sand stops flowing and empty the excess sand remaining in the cone.
5. Weigh the filled apparatus and determine the net weight of sand by subtracting the weight of the empty apparatus.

6. Determine the weight of sand required to fill the cone by seating the inverted apparatus filled with sand on a clean, level, plane surface. Place a field density plate on the level surface and seat the inverted apparatus.
7. Open the petcock and leave it open until the sand stops flowing.
8. Close the petcock sharply and weigh the apparatus and remaining sand to determine the loss. This loss represents the weight of sand required to fill the cone.
9. Replace the sand removed in the cone determination and close the petcock.
10. Compute the loose weight per ft³ of sand and the weight of the sand in the cone as shown in the CALCULATIONS Section.
11. Repeat Steps 1 through 10 a minimum of three times and average the density results. The maximum variation between any one determination and the average shall not exceed 1%. If the variation is larger than that, the test needs to be repeated.
12. Enter the density of the loose, dry sand on the appropriate line of the Compaction Report Form.
13. Enter the weight of sand in the cone on the appropriate line of the Compaction Report Form.

TEST PROCEDURE:

1. Weigh the apparatus refilled with sand from Step 8 above to the nearest 0.01 lb.
2. Invert the jar and place the cone over the density hole. Make certain the rim fits perfectly with the level ground so no sand escapes from under the edge of the cone.
3. Open the petcock and let the sand flow until there is no further movement of the sand in the jar. Avoid vibrating or jarring the cone to avoid affecting the flow. Close the petcock, remove the apparatus and weigh to the nearest 0.01 lb.
4. Determine the weight of the sand in the hole and the total volume of the hole as shown under the CALCULATIONS Section.
5. Dry then weigh all excavated material to determine the moisture content.

**METHOD B - SAND BUCKET
(GAB Only)**

Sand Calibration. Calibrate the sand used to measure the volume of the test hole once a day, whenever new sand is used, or after six tests have been performed. The calibration shall be performed by the technician performing the in-place density test.

Calibrate the sand on a vibration-free work platform to avoid erroneous results. Care should be taken to ensure no heavy equipment is operating in the area during testing to avoid vibration of the sand. Calibrate the sand to determine the field density as follows:

1. Fill the sprinkling can with sand to approximately 3/4 full.
2. Weigh a 6 in. diameter mold without the collar to the nearest 0.01 lb.
3. Place the mold on a level surface. Lift the sprinkling can and tilt it so the spout is about 2 to 3 in. above the rim of the mold. Pour the sand slowly and smoothly to fill the mold uniformly until it begins to overflow. Strike off the excess with a straightedge in one sweeping motion to even the sand with the top of the mold. Avoid any vibrating or jarring the mold to negate any settlement of the sand during the filling or strike off operations.
4. Brush away all excess sand from the mold and weigh to the nearest 0.01 lb.
5. Calculate the density of the sand as shown in CALCULATIONS Section.
6. Repeat Steps 1 through 5 a minimum of three times and average the density results. The maximum variation between any one determination and the average shall not exceed 1%. If the variation is larger than that, the test needs to be repeated.
7. Enter the average density on the appropriate line of the Compaction Report Form.

TEST PROCEDURE:

1. Fill the sprinkling can with calibrated sand to approximately 3/4 full and weigh to the nearest 0.01 lb.
2. Pour the sand into the center of the excavated test hole. Keep the spout of the sprinkling can about 2 to 3 in. above the test hole. Pour the sand into the test hole in the same manner as used in calibrating the sand. Pour only enough sand to just fill the hole and do not waste any by overfilling the hole or by spillage. Under fill the hole to avoid the risk disturbing the loose sand by having to remove the excess. Move the straightedge across the hole at different angles and level the sand to the original ground. Avoid any vibrating or jarring the mold to negate any settlement of the sand during the filling or strike off operations.
3. Weigh the sand remaining in the bucket to the nearest 0.01 lb.
4. Determine the weight of the sand in the hole and the total volume of the hole as shown in CALCULATIONS.
5. Dry then weigh all excavated material to determine the moisture content.

EMBANKMENTS AND SUBGRADES

The Laboratory will furnish a Typical Curve Chart covering most of the anticipated soil types for embankment and subgrade compaction control. There will be instances, however, where additional curves must be run in the field for soil types not included on the Typical Curve Chart. These curves shall be determined as specified in MSMT 351, Method 5.

Special Provisions will apply for the following procedure if the Contract Documents dictate a method other than MSMT 351, Method 1. Record the date and results obtained from the in-place density on the appropriate Lab Form.

PROCEDURE:

1. Prepare the test area, excavate the test hole, and determine its volume as described in METHOD A - SAND CONE. Obtain a sample of approximately 11 to 13 lb.
2. Prepare a representative 6 lb sample of material passing the 3/4 in. sieve from the sample obtained from the test hole and perform a one step moisture-density in conformance with MSMT 351, Method 1.
3. Perform a one step moisture-density test on samples containing more than 35 percent coarse material retained on the No. 4 sieve, in conformance MSMT 351, Method 2.
4. Plot the wet density obtained in the one step test at the percent moisture on the Typical Curve Chart.
5. Plot the maximum dry density of this curve if this point falls directly on one of the curves.
6. If this point falls between two curves and to the left of the maximum dry density-optimum moisture line, the maximum dry density shall be interpolated as follows:
 - a. Project the point upwards and to the right, keeping it proportionately the same distance between the two guide curves.
 - b. Continue this projection until it intersects the maximum dry density-optimum moisture line on the chart.
 - c. This point of intersection represents the maximum dry density and optimum moisture content for the particular soil.
 - d. If the plotted point falls above, or to the right of, the maximum dry density-optimum moisture line, dry the material then perform another one step moisture density test in conformance with MSMT 351, Method 1. The new results are then plotted as detailed in Steps 4, 5 and 6.
7. Compute the percent compaction as shown in CALCULATIONS.

CHEMICAL STABILIZED SUBGRADE

The Laboratory will furnish moisture-density curves for chemical stabilized subgrade compaction control based on samples which represent specific sections of subgrade. These curves can also be developed by the Contractor in conformance with MSMT 351, Method 1 or 3.

PROCEDURE:

1. Prepare the test area, excavate the test hole, and determine its volume as described in METHOD A - SAND CONE
2. Use the moisture-density curve furnished by the Laboratory or determined in the field corresponding to the section being tested.
3. Determine the maximum dry density from the curve. Compute the percent compaction as shown in CALCULATIONS.
4. There is no field determination of the maximum density using the Typical Curve Chart for this procedure.

PLAIN AND STABILIZED GRADED AGGREGATE BASE

The laboratory will furnish only one compaction curve for graded aggregate stabilized with portland cement or asphalt emulsion. This curve will be based on the approved Job Mix Formula from an approved source of supply.

PROCEDURE:

1. Prepare the test area, excavate the test hole, and determine its volume as described in METHOD B - SAND BUCKET.
2. Make certain that the sample is completely dried by using a hot plate at the highest temperature range for at least one hour when determining the moisture content of graded aggregate stabilized with asphalt emulsion.
3. Then, weigh the sample at one minute intervals until there is no change in weight between two consecutive weighings.
4. Record the maximum dry density from the curve furnished by the Laboratory.
5. Compute the percent compaction as shown in CALCULATIONS.

It should be noted that the optimum moisture content for graded aggregate stabilized with asphalt emulsion includes the water in the emulsion.

GRAVEL BASE, SUBBASE, SHOULDER, AND SURFACE

The Laboratory will furnish a chart showing the moisture-density relations of material corresponding to the upper and lower gradation bands given in the Specifications and the gradation of the material in the pit for gravel base, subbase, shoulder, and surface compaction control. These relations are based on the material passing the 3/4 in. sieve with adjustment for the percentages retained on this sieve. All one point density determinations, and any additional curves required, will be made by the Engineer as specified in MSMT 351, Method 5.

PROCEDURE:

1. Prepare the test area, excavate the test hole, and determine its volume as described in METHOD B - SAND BUCKET. Obtain a sufficient quantity of additional material from the area immediately adjacent to the test area to adequately perform the operation stated in Step 3.
2. Plot the wet density obtained in the one step test and the percent moisture on the Gravel Compaction Chart.
3. Use the procedure stated in Case A, Embankments and Subgrades, Steps 5 and 6, to determine the maximum dry density and optimum moisture of this material.
4. Compute the percent compaction as shown in CALCULATIONS.

SOIL CEMENT BASES

The Laboratory will furnish the specific gravity of the material retained on the 3/4 in. sieve and a one moisture-density curve for soil cement compaction control; which shall be used only as a guide for evaluating field test results. The Engineer will determine the wet density in the field as specified in MSMT 351, Method 3 and the following procedures.

PROCEDURE:

1. Obtain a representative sample of the soil cement mixture from the roadway where the in-place density will be determined. Take a sample, immediately before compaction, weighing approximately 16 lb. Record the exact location where the sample was taken.
2. Reduce the sample by quartering to approximately 8 lb and sieve over a 3/4 in. sieve. Discard the material retained on the 3/4 in. sieve.
3. Perform a one step moisture-density test as specified in MSMT 351, Method 3 using the material passing the 3/4 in. sieve.
4. Prepare a test area at the same location where the sample in Step 1 was taken after compaction of the roadway course. Excavate the hole so that it extends for the full depth of the soil cement course being tested; then determine the volume.

5. Compute the in-place wet density as shown in CALCULATIONS.
6. Compute the percent compaction as shown in CALCULATIONS.
7. Steps 1 through 4 of this procedure will not be required for the retest if the percent compaction fails to conform to the minimum requirement.

CALCULATIONS:

All the calculations required for determining the in-place density results have been given in conjunction with ON SITE TEST PROCEDURES and FIELD LABORATORY TEST PROCEDURES with specific reference to the operations indicated on the report forms for individual material types.

1. Calculate the density of the sand using the sand cone method as follows:

$$D = \frac{W_2 - W_1}{V}$$

where:

D = density of loose, dry sand, lb/ft³,

W₁ = weight of empty apparatus,

W₂ = weight of apparatus filled with sand, and

V = predetermined volume of sand cone apparatus.

2. Calculate the density of the sand using the sand bucket method as follows:

$$D = (W_1 - W_2) A$$

where:

D = density of loose, dry sand, lb/ft³,

W₁ = weight of mold and sand,

W₂ = weight of mold, and

A = predetermined volume of 6 in. diameter mold without collar.

3. Calculate the moisture content as follows:

$$M = \frac{C - D}{D} \times 100$$

where:

M = percent of moisture content,

C = weight of wet material, and

D = weight of dry material.

4. Calculate the weight of sand in test hole as follows:

$$S_w = (W_1 - W_2) - W_3$$

where:

S_w = total weight of sand in test hole,

W_1 = initial weight of loose, dry sand and container,

W_2 = final weight of loose, dry sand and container, and

W_3 = weight of dry sand in cone.

5. Calculate the volume of the test hole as follows:

$$V = \frac{S_w}{D}$$

where:

V = volume of test hole, ft³,

S_w = total weight of sand in test hole, and

D = predetermined density of loose, dry sand, lb/ft³.

6. Calculate the in-place wet density of the material from the test hole as follows:

$$D_w = \frac{A - B}{V}$$

where:

D_w = in-place wet density, lb/ft³,

A = weight of wet material from test hole,

B = weight of container, and

V = volume of test hole, ft³.

7. Calculate the in-place dry density of the material as follows:

$$D_d = \frac{D_w}{(100 + M)} \times 100$$

where:

D_d = in-place dry density, lb/ft³,

D_w = in-place wet density, lb/ft³, and

M = percent moisture content.

8. Calculate the percent compaction of the material as follows:

$$C = \frac{D_d}{D_m} \times 100$$

where:

C = percent compaction obtained,

D_d = in-place dry density, lb/ft³, and

D_m = maximum dry density from Typical Curve Chart, lb/ft³.

9. Calculate the percent retained on the 3/4 in. sieve as follows:

$$R = \frac{E}{F} \times 100$$

where:

R = percent retained on the 3/4 in. sieve,

E = dry weight of material retained on the 3/4 in. sieve, and

F = total dry weight of material.

10. Calculate the maximum wet density of a soil cement mix as follows:

$$M_d = \frac{(100 - R) D_w + RS}{100}$$

where:

M_d = maximum wet density of mix, containing material retained on the 3/4 in. sieve, lb/ft³,

R = percent of gravel retained on the 3/4 in. sieve,

D_w = wet density of the molded material, lb/ft³, and

S = specific gravity x 1000 lb/ft³.

11. Calculate the percent of compaction of a soil cement mix as follows:

$$S_c = \frac{D_w}{M_d}$$

where:

S_c = percent of compaction of soil cement mix,

D_w = wet density of the molded material, lb/ft³, and

M_d = maximum wet density of mix, containing material retained on the 3/4 in. sieve, lb/ft³.

REPORTS:

Reports for in-place density test results consist of the appropriate form for a specific material. Record all pertinent data on the form including the date, exact location of the density hole, and characteristics of the material tested. Report all percentages to the nearest whole percent.