LABORATORY THEORETICAL MAXIMUM DRY DENSITY OF GRANULAR SOIL AND SOIL/ AGGREGATE
WAQTC TM 15

Scope

This method is used to establish the theoretical maximum dry density of granular and non-granular soil-aggregate. Use Procedure 1 for material with more than 30 percent retained on the 4.75 mm (No. 4) sieve or Procedure 2 for material with more than 30 percent retained on the 19.0 mm (¾ in.) sieve.

Terminology

- Fine aggregate portion – material passing the 4.75 mm (No. 4) Sieve.
- Coarse aggregate portion – material retained on the 4.75 mm (No. 4) sieve.

Significance

A theoretical maximum dry density chart and curve are developed by determining a laboratory maximum dry density of a representative sample of material passing the 4.75 mm (No. 4) and the material retained on the 4.75 mm (No. 4), and their respective apparent specific gravities (G_{ab}). The theoretical maximum dry density chart and curve address the range of theoretical maximum dry densities due to fluctuations in coarse and fine aggregate of a given material.

To determine the laboratory maximum dry density of the fine aggregate portion, this method allows for use of the FOP for AASHTO T 99/T 180 or by vibratory compactor covered in the method.

This method is for use on granular materials having 30 to 70 percent passing the 4.75 mm (No. 4) or 19.0 mm (3/4 in.) sieve.

Apparatus

- A vibratory spring-loaded compactor – D G Parrott & Son Humphres Maximum Density machine, or equivalent.
- Molds: solid wall rigid inflexible metal cylinders.
  - — Small mold: volume approximately 0.003 m^3 (0.1 $ft.^3$) with an inside diameter of 150 mm ± 5 mm (6 ± 0.15 in.) and a height of 200 ± 5 mm (8 ± 0.1 in.) with base.
  - — Large mold: volume approximately 0.014 m^3 (0.5 $ft.^3$) with a height 85 to 150 percent of the inside diameter.
- Cap: rigid, inflexible metal cap fitting inside the mold with 1.5 mm (1/16 in.) max. space between piston and mold wall.
- Spacer blocks: of varying heights compatible with the compactor and pistons.

- Measuring device: minimum length 150 mm (6 in.), accurate and readable to 2.5 mm (0.01 in.)
- Sieves: 75 mm (3 in.), 19 mm (¾ in.), and a 4.75 mm (No. 4) conforming to the FOP for AASHTO T 27/T 11
- Balance or Scale: Capacity sufficient for the principle sample mass, readable to 0.1 percent or 0.1 g, and meeting the requirements of AASHTO M 231
- Tamping rod: straight steel, 16 mm (5/8 in.) in diameter and approximately 400 mm (24 in.) long having at least one end rounded to a hemispherical tip
- Straight edge: at least 25 mm (1 in.) longer than the diameter of the mold
- A stopwatch or timer readable to 1 second

Determining Laboratory Maximum Dry Density

Select the proper method for determining the laboratory maximum dry density of the fine aggregate portion of the sample, refer to Table 1, or as directed by the agency.

Select the proper method for determining the laboratory maximum dry density of the coarse aggregate portion of the sample, refer to Table 2.

Table 1
Fine Aggregate Portion Laboratory Maximum Dry Density Method

Estimated Soil Type	Recommended Test Method
Sandy, non-plastic, permeable soil or non-cohesive soil.	WAQTC TM 15 Vibratory Compactor
Silt, some plasticity, low permeability.	FOP for AASTHO T 99/T 180, T 99 Method A
Sandy/silt, some plasticity, permeable.	WAQTC TM 15 and FOP for AASHTO T 99/T 180, T 99 Method A (use highest results)

Table 2
Coarse Aggregate Portion Laboratory Maximum Dry Density Method

Coarse Aggregate Amount	Test Method
No more than 15 percent by weight of the original aggregate specimen exceeds 19 mm (¾ in.)	WAQTC TM 15 Vibratory Compactor Procedure 1
15 percent or more by weight of the original aggregate specimen is greater than 19 mm (¾ in) but does not exceed 75 mm (3 in.)	WAQTC TM 15 Vibratory Compactor Procedure 2

Sample Preparation

1. Obtain a representative sample according to the FOP for AASHTO R 90, minimum 180 kg. (400 lbs.).

2. Reduce according to the FOP for AASHTO R 76 to a sufficient size to yield amounts required in steps 7 and 8.

3. If the sample is damp, dry until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus maintained at a temperature not exceeding 60°C (140°F).

4. Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.

5. Remove the material retained on the 75 mm (3 in.) sieve.

6. Separate into coarse and fine aggregate portions by passing the remainder of the sample through the 4.75 mm (No. 4) sieve.

7. Fine aggregate –

    a. Obtain a representative sample as described in the FOP for AASHTO T 99/T 180, T 99 Method A, or

    b. Obtain at least three representative test samples of approximately 6 kg (13 lb.) each for the fine aggregate vibratory compactor method.

8. Coarse aggregate – obtain a representative sample for one of the following:

    a. 19 mm (¾ in) to 4.75 mm (No. 4) – approximately 5 kg (11 lb.) for coarse aggregate vibratory compactor Procedure 1; or

    b. 75 mm (3 in) to 4.75 mm (No. 4) – approximately 20 kg (45 lb.) for coarse aggregate vibratory compactor Procedure 2.

Laboratory Maximum Dry Density of Fine Aggregate Portion

Determine laboratory maximum dry density of the fine aggregate portion according to the FOP for AASHTO T 180/T 99, T 99 Method A, or the following vibratory compactor method. Refer to Table 1.

Vibratory Compactor Method

1. Determine and record the mass of the clean dry small mold to the nearest 5 g (0.01 lb.). Designate this mass as the M_m.

2. Add enough water to one of the fine aggregate portions to saturate the sample, approximately optimum moisture. Do not over saturate (Note 1).

Note 1: The sample is considered saturated when one to two drops of free water are visible at the base of the mold at the end of the first 2-minute load cycle, Table 3. Refer to Step 11.

3. Mix until homogenous.

4. Place approximately one third of the sample in the mold.

5. Consolidate with 25 strokes of the tamping rod, distribute evenly over the surface, and 25 blows of the manually operated rammer.

6. Repeat Steps 4 and 5 for two subsequent lifts. The surface of the top lift should be finished as level as possible.

7. Place the cap on top of the molded specimen and mount the mold on the jack platform in the compactor. Use spacers between the load spring assembly and cap to adjust the elevation of the mold so the hammers strike near the center of the mass of material in the mold.

8. Elevate the mold with the jack until the load spring assembly seats on top of the cap and apply an initial seating load of approximately 100 lb_f. on the sample.

9. Start the compactor hammers. Continue to elevate the mold, applying the load gradually over the time stated in the Table 3.

Table 3
Load Application Rate

Load lb_f	Time
0 to 500	1 min.
500 to 1,000	30 sec.
1,000 to 2,000	30 sec.

10. Upon reaching 2,000 lb_f at the end of the 2-minute cycle, stop the hammer, release the load on the jack, and return to zero pressure.

11. Determine apparent moisture.

    a. If the material is pumping around the mold cap or excessive amounts of water are seeping from the mold, prepare a new sample and begin the test again at Step 1.

    b. If the base of the mold is dry or there is a small amount of water, repeat Steps 7 through 10, four additional times.

12. Remove the mold assembly from the compactor.

13. Measure the height of the compacted specimen.

    a. Lay the straight edge across the mold.

    b. Using the measuring device, measure from the bottom of the straight edge to the top of the cap and spacers to the nearest 0.1 mm (0.01 in.). Designate as D.

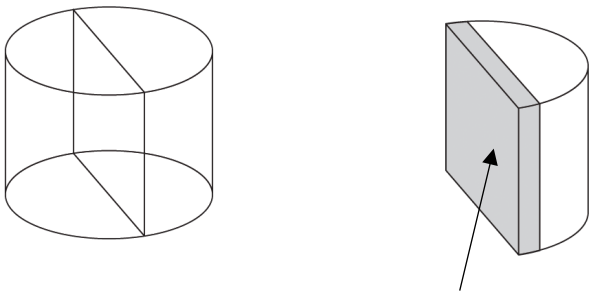
    c. Calculate and record the height, h_s, of the compacted specimen, subtract D and the T, from Annex A, from the height of the mold.

14. Determine and record the mass of the mold and specimen, M_{ms}, to the nearest 5 g (0.01 lb.).

15. Determine and record the mass of the specimen, M_s, by subtracting M_m from M_{ms}.

16. Remove the specimen from the mold.

17. Use the entire specimen for a moisture content sample or obtain a representative sample by slicing vertically through the center of the specimen. Obtain at least 500 g. (1.1 lb.) from one of the cut faces, ensuring that all the layers are represented. If a vertical face does not exist, take a representative sample.



Slice through the center **Representative moisture content sample**

18. Determine and record the moisture content, w, according to the FOP for AASHTO T 255/T 265.

19. Calculate and record the wet density, ρ_w, of the fine aggregate portion.

20. Calculate and record the laboratory dry density, ρ_d, of the fine aggregate portion.

Laboratory Maximum Dry Density of the Coarse Portion

Vibratory Compactor Method

Note 2: Procedure 1 uses the small mold, this procedure is not recommended for material with aggregate larger than 9.3 mm (3/4 in.).

Procedure 1

1. Determine and record the mass of the small mold to the nearest 5 g (0.01 lb.). Designate this mass as the M_m.

2. Determine and record the mass of the coarse aggregate portion to the nearest 5 g (0.01 lb.). Designate this mass as the M_s. See Note 3.

Note 3: If all the coarse aggregate portion does not fit in the mold or there is some indication that material may have been lost, perform alternate Step 15 to determine M_s.

3. Determine amount of water to add to the coarse aggregate portion by multiplying the mass determined in Step 2 by 0.025 (2.5 percent).

4. Add water to coarse aggregate portion, mix thoroughly.

5. Place approximately one third of the sample in the mold.

6. Tamp the surface lightly with the manually operated rammer to consolidate material and achieve a level surface.

7. Repeat Steps 5 and 6 for two subsequent lifts. Ensure all of the coarse aggregate portion is placed in the mold.

8. Place the cap on top of the molded specimen and mount the mold on the jack platform in the compactor. Use spacers between the load spring assembly and cap to adjust the elevation of the mold so the hammers strike near the center of the mass of material in the mold.

9. Elevate the mold with the jack until the loading spring assembly seats on top of the cap and spacers.

10. Apply an initial seating load of approximately 100 lb_f on the sample.

11. Start the compactor hammers. Continue to elevate the mold, applying the load gradually over the time stated in the Table 3.

12. Upon reaching the 2,000 lb_f load at the end of the 2-minute cycle, stop the hammer, release the load on the jack, and return to zero pressure.

13. Repeat Steps 10 through 12 four additional times.

14. Remove the mold assembly from the compactor.

15. Measure the height of the compacted specimen.

    a. Lay the straight edge across the mold.

    b. Using the measuring device, measure from the bottom of the straight edge to the top of the cap and spacers to the nearest 0.1 mm (0.01 in.). Designate as D.

    c. Calculate and record the height of the compacted specimen, h_s, by subtracting D and T (thickness of the cap) from the height of the mold h_m. See Annex A.

16. Alternate method of determining M_s

    a. Remove the specimen from the mold.

    b. Determine the dry mass according to the FOP for AASHTO T 255. Designate as M_s.

17. Calculate and record the laboratory dry density, ρ_d, of the coarse aggregate portion.

Procedure 2

1. Determine and record the mass of the large mold and cap to the nearest 5 g (0.01 lb.). Designate this mass as the M_m.

2. Determine and record the mass of the coarse aggregate portion to the nearest 5 g (0.01 lb.). Designate this mass as the M_s.

Note 4: If all the coarse aggregate portion does not fit in the mold or there is some indication that material may have been lost, perform alternate Step 14 to determine M_s.

3. Place approximately one fifth of the sample in the mold.

4. Tamp the surface lightly with the manually operated rammer to consolidate material and achieve a level surface.

5. Place the cap on top of the molded specimen and mount the mold on the jack platform in the compactor. Use spacers between the load spring assembly and cap to adjust the elevation of the mold so the hammers strike near the center of the mass of material in the mold.

6. Elevate the mold with the jack until the loading spring assembly seats on top of the cap.

7. Apply an initial seating load of approximately 100 lb_f on the sample.

8. Start the compactor hammers. Continue to elevate the mold, applying the load gradually over the time stated in the Table 3.

9. Upon reaching the 2,000 lb_f load at the end of the 2-minute cycle, stop the hammer, release the load on the jack, and return to zero pressure.

10. Repeat Steps 3 through 9 four additional times. Ensure all of the coarse aggregate portion is placed in the mold on the final lift.

11. Remove the mold assembly from the compactor.

12. Measure the height of the compacted specimen.

    a. Lay the straight edge across the mold.

    b. Using the measuring device, measure from the bottom of the straight edge to the top of the cap and spacers to the nearest 0.1 mm (0.01 in.). Designate as D.

    c. Calculate and record the height of the compacted specimen, h_s, by subtracting D and T (thickness of cap) from the height of the mold, h_s. See Annex A.

13. Alternate method of determining M_s

    a. Remove the specimen from the mold.

    b. Determine the dry mass of the specimen according to the FOP for AASHTO T 255. Designate as M_s.

14. Calculate and record the laboratory dry density, ρ_d, of the coarse aggregate portion.

Apparent Specific Gravity of the Fine and Coarse Portions

1. Determine the apparent specific gravity, G_{ab}, of the minus 4.75mm (No. 4) sieve according to AASHTO T 84 or Annex B.

2. Determine the apparent specific gravity, G_{ab}, of the plus 4.75 mm (No. 4) sieve according to the FOP for AASHTO T 85 or Annex B.

Calculations

Height of specimen in mold (fine or coarse aggregate portion)

$$h_s = h_m - D - T$$

where:

h_s = height of specimen in mold, 0.1 mm (0.01 in.)

h_m = height of mold, 0.1 mm (0.01 in.), Annex A

D = measured distance from the mold top to the cap, 0.1 mm (0.01 in.)

T = thickness of the cap, 0.1 mm (0.01 in.), Annex A

Volume of the specimen in the mold (fine or coarse aggregate portion)

$$V_s = \frac{h_s \times \pi \times \left(\frac{d}{2}\right)^2}{1e^9\, mm^3/_{m^3}\ or\ 1728\, in^3/_{ft^3}}$$

where:

V_s = volume of specimen in mold m^3 (ft^3)

d = inside diameter of the mold, 0.1 mm (0.01 in.), Annex A

Mass of fine aggregate portion in the mold

$$M_s = M_{ms} - M_m$$

where:

M_s = mass of specimen in mold, 0.005 kg (0.01 lb.)

M_{ms} = mass of mold and specimen, 0.005 kg (0.01 lb.)

M_m = mass of mold, 0.005 kg (0.01 lb.)

Wet Density of fine aggregate portion

$$\rho_w = \frac{M_s}{V_s}$$

Where:

ρ_w = wet density, kg/m^3 (lb/ft^3)

M_s = mass of specimen in the mold, 0.005 kg (0.01 lb.)

Laboratory maximum dry density fine aggregate portion

$$\rho_d = \left(\frac{\rho_w}{w + 100}\right) \times 100 \quad or \quad \rho_d = \frac{\rho_w}{\left(\frac{w}{100}\right) + 1}$$

Where:

ρ_d = dry density, kg/m^3 (lb/ft^3)

w = moisture content, as a percentage (FOP for AASHTO T 255)

Laboratory maximum dry density of coarse aggregate portion

$$\rho_d = \left(\frac{M_s}{V_s}\right) \times 100$$

Where:

ρ_d = dry density, kg/m^3 (lb/ft^3)

M_s = mass of specimen in the mold, 0.005 kg (0.01 lb.)

V_s = volume of specimen in mold m^3 (ft^3)

Example

Example for small mold fine aggregate portion

Wet mass, M_w	=	6.470 kg (14.26 lb)
Moisture content, w	=	11.3%
Height of mold, h_m	=	203.7 mm (8.02 in.)
Inside diameter of mold, d	=	153.4 mm (6.04 in.)
Measurement from top of mold to cap, D	=	44.5 mm (1.75 in.)
Thickness of the cap, T	=	3.6 mm (0.14 in.)
Mass of specimen and mold, M_{ms}	=	6.400 kg (14.11 lb)
Mass of mold, M_m	=	0.280 kg (0.62 lb)

Height of fine aggregate portion in mold

$$h_s = h_m - D - T$$

$$h_s = 203.7\ mm - \ 44.5\ mm - 3.6\ mm = 155.6\ mm$$

$$h_s = 8.02\ in. - 1.75\ mm - 0.14\ in. = 6.13\ in.$$

Volume of the fine aggregate in the mold

$$V_s = \frac{h_s \times \pi \times \left(\frac{d}{2}\right)^2}{1e^9\ mm^3/_{m^3}\ or\ \ 1728\ in^3/_{ft^3}}$$

$$V_s = \frac{155.6\ mm\ \ \times \pi \times \left(\frac{153.4\ mm}{2}\right)^2}{1{,}000{,}000{,}000\ mm^3/_{m^3}} = 0.002876\ m^3$$

Or

$$V_s = \frac{6.13\ in.\ \ \times \pi \times \left(\frac{6.04\ in.}{2}\right)^2}{1728\ in^3/_{ft^3}} = 0.1016\ ft^3$$

Mass of fine aggregate portion in the mold

$$M_s = M_{ms} - M_m$$

$$M_s = 6.400\ kg\ - 0.280\ kg = 6.119\ kg$$

$$M_s = 14.11\ lb - 0.62\ lb = 13.49\ lb$$

Wet density of fine aggregate portion

$$\rho_w = \frac{M_s}{V_s}$$

$$\rho_w = \frac{6.119\ kg}{0.002876\ m^3} = 2128\ {}^{kg}/_{m^3}$$

$$\rho_w = \frac{13.49\ lb}{0.1016\ ft^3} = 132.8\ {}^{lb}/_{ft^3}$$

Where:

ρ_w = wet density, kg/m^3 (lb/ft^3)

M_s = mass of specimen in the mold

Laboratory maximum dry density of the fine aggregate portion

$$\rho_d = \left(\frac{\rho_w}{w + 100}\right) \times 100 \quad or \quad \rho_d = \frac{\rho_w}{\left(\frac{w}{100}\right) + 1}$$

$$\rho_d = \left(\frac{2128\, kg/m^3}{11.3\% + 100}\right) \times 100 = 1912\ kg/m^3 \quad \rho_d = \left(\frac{132.8\ lb/ft^3}{11.3\% + 100}\right) \times 100 = 119.3\, lb/ft^3$$

Or

$$\rho_d = \left(\frac{2128\, kg/m^3}{\frac{11.3\%}{100} + 1}\right) = 1912\, kg/m^3 \quad \rho_d = \left(\frac{132.8\ lb/ft^3}{\frac{11.3\%}{100} + 1}\right) = 119.3\, lb/ft^3$$

Example for small mold coarse aggregate portion (Procedure 1)

Calculations will be the same for Procedure 2

Height of mold, h_m	=	203.7 mm (8.02 in.)
Inside diameter of mold, d	=	153.4 mm (6.04 in.)
Measurement from top of mold to cap, D	=	42.4 mm (1.67 in.)
Thickness of the cap, T	=	3.6 mm (0.14 in.)
Mass of coarse aggregate in the mold, M_s	=	4.985 kg (10.99 lb)

Height of coarse aggregate portion in mold

$$h_s = h_m - D - T$$

$$h_s = 203.7\ mm - 42.4\ mm - 3.6\ mm = 157.7\ mm$$

$$h_s = 8.02\ in. - 1.67\ in. - 0.14\ in. = 6.21\ in.$$

Volume of the coarse aggregate portion in the mold

$$V_s = \frac{h_s \times \pi \times \left(\frac{d}{2}\right)^2}{1e^9\, mm^3/_{m^3}\ or\ 1728\, in^3/_{ft^3}}$$

$$V_s = \frac{157.7\, mm \times \pi \times \left(\frac{153.4\, mm}{2}\right)^2}{1{,}000{,}000{,}000\, mm^3/_{m^3}} = 0.002915\, m^3$$

$$V_s = \frac{6.21\, in.\ \times\ \pi \times \left(\frac{6.04\, in.}{2}\right)^2}{1728\, in^3/_{ft^3}} = 0.1030\, ft^3$$

Laboratory maximum dry density of coarse aggregate portion

$$\rho_d = \left(\frac{M_s}{V_s}\right) \times 100$$

$$\rho_d = \left(\frac{4.985\, kg}{0.002915\, m^3}\right) \times 100 = \ 1710\ {}^{kg}/_{m^3}$$

$$\rho_d = \left(\frac{10.99\, lb}{0.1030\, ft^3}\right) \times 100 = \ 106.7\ {}^{lb}/_{ft^3}$$

Where:

ρ_d = dry density, kg/m^3 (lb/ft^3)
M_s = mass of specimen in the mold, 0.005 kg (0.01 lb.)
V_s = volume of specimen in mold m^3 (ft^3)

Theoretical Maximum Density Curve Development

Enter the following data into an approved spreadsheet to develop the maximum density chart and maximum density curve.

- Laboratory maximum dry density, ρ_d, of the coarse aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Laboratory maximum dry density, ρ_d, of the fine aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the nearest 0.1 percent if the FOP for AASTHO T 99/T 180, T 99 Method A was used for the fine portion.
- Coarse aggregate apparent specific gravity, G_{ab}, to the nearest 0.001
- Fine aggregate portion apparent specific gravity, G_{ab}, to the nearest 0.001

Example

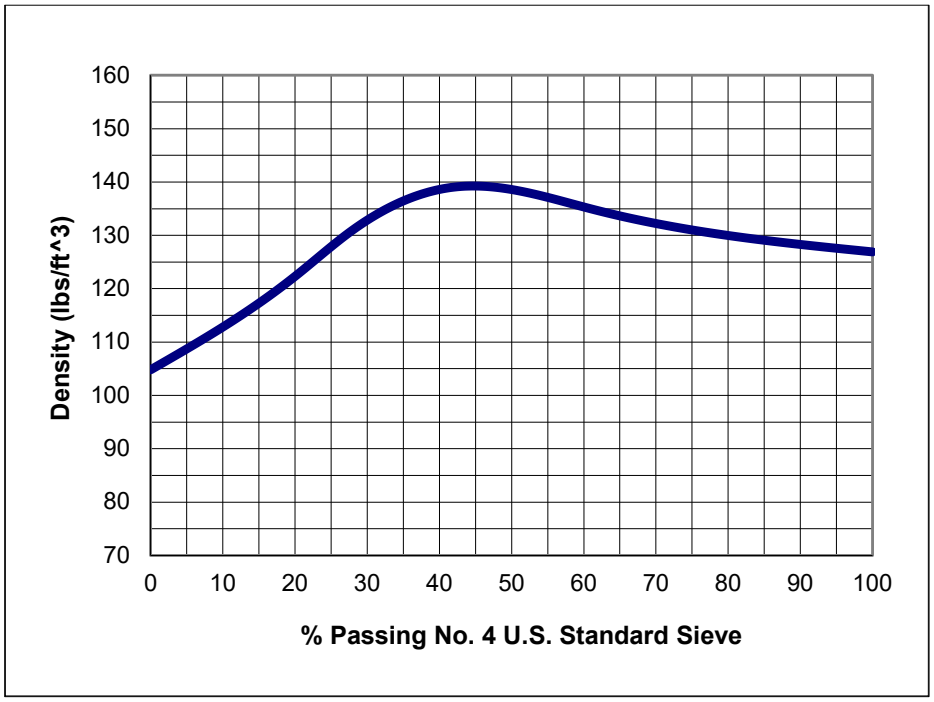
Theoretical Maximum Dry Density Chart

Density Curves			
Pass #4	Maximum	Pass #4	Maximum
0.0	104.8	31.0	133.7
1.0	105.6	32.0	134.5
2.0	106.4	33.0	135.2
3.0	107.1	34.0	135.8
4.0	107.9	35.0	136.4
5.0	108.7	36.0	137.0
6.0	109.5	37.0	137.5
7.0	110.3	38.0	137.9
8.0	111.1	39.0	138.3
9.0	112.0	40.0	138.6
10.0	112.8	41.0	138.9
11.0	113.7	42.0	139.0
12.0	114.5	43.0	139.2
13.0	115.4	44.0	139.2
14.0	116.4	45.0	139.2
15.0	117.3	46.0	139.2
16.0	118.2	47.0	139.1
17.0	119.2	48.0	139.0
18.0	120.2	49.0	138.8
19.0	121.3	50.0	138.6
20.0	122.3	51.0	138.3
21.0	123.4	52.0	138.1
22.0	124.5	53.0	137.8
23.0	125.6	54.0	137.5
24.0	126.8	55.0	137.1
25.0	127.9	56.0	136.8
26.0	129.0	57.0	136.4
27.0	130.0	58.0	136.0
28.0	131.0	59.0	135.7
29.0	132.0	60.0	135.3
30.0	132.8	61.0	135.0

Density Curves			
Pass #4	Maximum	Pass #4	Maximum
62.0	134.6	82.0	129.6
63.0	134.3	83.0	129.4
64.0	134.0	84.0	129.3
65.0	133.6	85.0	129.1
66.0	133.3	86.0	128.9
67.0	133.1	87.0	128.8
68.0	132.8	88.0	128.6
69.0	132.5	89.0	128.4
70.0	132.2	90.0	128.3
71.0	132.0	91.0	128.1
72.0	131.7	92.0	128.0
73.0	131.5	93.0	127.9
74.0	131.2	94.0	127.7
75.0	131.0	95.0	127.6
76.0	130.8	96.0	127.4
77.0	130.6	97.0	127.3
78.0	130.4	98.0	127.2
79.0	130.2	99.0	127.0
80.0	130.0	100.0	126.9
81.0	129.8		

Control Points for Density Curves		
Pass #4	Maximum	Loose
0.0	104.8	87.6
20.5	122.8	99.6
27.4	130.4	103.8
42.5	139.1	105.4
61.1	134.9	96.7
100.0	126.9	81.9

Theoretical Maximum Dry Density Curve



Report

- Results on standard agency forms
- Sample ID
- Laboratory maximum dry density of the coarse aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Laboratory maximum dry density of the fine aggregate portion to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Optimum moisture content to the nearest 0.1 percent (when using the FOP for AASTHO T 99/T 180, T 99 Method A for the fine aggregate portion)
- Coarse aggregate apparent specific gravity (G_{ab}) to the nearest 0.001
- Fine aggregate apparent specific gravity (G_{ab}) to the nearest 0.001
- Theoretical maximum dry density chart
- Theoretical maximum dry density curve

ANNEX A STANDARDIZATION OF THE MOLD

(Mandatory Information)

Apparatus

- Calipers having a range sufficient to measure the diameter of the measure being checked and readable to at least 0.1 mm (0.01 in.)
- Inside diameter caliper, 300 mm (12 in.) range
- Straight edge at least 25 mm (1 in.) larger than the mold
- Ruler readable to 0.1 mm (0.01 in.)

Procedure

Determine the height of the mold (h_m)

1. Place the straight edge across the top of the mold.
2. Using the caliper measure from the bottom of the straight edge to the center mold to the nearest 0.1 mm (0.01 in.)
3. Turn the straight edge 90 degrees.
4. Repeat Step 2.
5. Average the two measurements.
6. Designate as h_m

Determine the thickness of the cap and spacers (T)

1. Place cap and spacers inside the mold.
2. Place the straight edge across the top of the mold.
3. Using the caliper measure from the bottom of the straight edge to the center of the top of the cap to the nearest 0.1 mm (0.01 in.).
4. Turn the straight edge 90 degrees.
5. Repeat Step 3.
6. Average the two measurements.
7. Subtract the average measurement from h_m
8. Designate as T.

Determine the inside diameter of the mold (d)

1. Using the caliper measure the inside diameter of the mold to the nearest 0.1 mm (0.01 in.).
2. Turn the mold 90 degrees.
3. Repeat Step 1.
4. Average the two measurements.

5. Designate as d.

ANNEX B APPARENT SPECIFIC GRAVITY (G_{ab}) DETERMINATION

(Mandatory Information)

This procedure covers the determination of apparent specific of coarse and fine aggregate by means of a pycnometer. When the soil is composed of material both larger and smaller than the 4.75 mm (No. 4) sieve, the sample is separated on the 4.75 mm (No. 4) sieve.

Apparatus

- Pycnometer: A flask or other suitable container in which the volume can be reproduced within ±0.1 ml. The volume of the flask shall be at least 50 percent greater than required for the test sample.
- Pycnometer / volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening
- Balance: A balance of sufficient capacity, readable to 0.1 g. Meeting AASHTO M 231, Class G2.
- Oven: Capable of maintaining a temperature of 110 ±5°C (230 ±9°F) for drying the specimens to a constant mass.
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum: Capable of evacuating air from the container to a partial vacuum of 13.33 kPa (100 mmHg) or less absolute pressure
- Manometer or vacuum gauge: Capable of measuring the vacuum being applied at the source of the vacuum
- Water bath: A constant-temperature water bath (optional)
- Thermometers: Thermometric devices accurate to 0.5°C (1°F)
- Bleeder valve to adjust vacuum
- Timer

Sample Preparation

1. Sample and reduce the aggregate in accordance with the FOPs for AASHTO R 90 and R 76.
2. Dry the sample sufficiently to obtain a clean separation of fine and coarse material in the sieving operation.
3. Sieve the sample in accordance with the FOP for AASHTO T 27/ T 11 over the 4.75 mm (No. 4) sieve.

Coarse test sample

a. Split or quarter approximately 1000 g of material from the portion retained on the 4.75 mm (No. 4) sieve.

b. Dry to constant mass according to the FOP for AASHTO T 255 at 110 ±5°C (230 ±9°F).

c. Cool to room temperature.

Fine test sample

a. Split or quarter approximately 500 g of material from the portion passing the 4.75 mm (No. 4) sieve.

b. Dry to constant mass according to the FOP for AASHTO T 255/T 265 at 110 ±5°C (230 ±9°F).

c. Cool to room temperature.

Procedure

The procedure is performed on fine and coarse aggregate separately.

1. Determine and record the mass of the dry test sample. Designate as A.
2. Place the test sample in the pycnometer.
3. Add water at approximately 20°C (68°F) until the pycnometer is about ¾ full.
4. Connect the pycnometer to the vacuum system.
5. Apply partial vacuum, 30 mmHg or less absolute pressure, for 20 ± 1 min.
6. Agitate the pycnometer and contents, either continuously by mechanical device or manually by vigorous shaking, at 2-minute intervals. This agitation facilitates the removal of entrapped air.
7. Release vacuum and disconnect the hoses.
8. Fill the pycnometer with water without reintroducing air. Water temperature should be maintained as close to 20 ±0.5°C (68 ±1°F) as possible throughout the procedure.

Note 1: It may be necessary to place the pycnometer in a water bath for 10 minutes after the release of vacuum to stabilize at 20 ±0.5°C (68 ±1°F).

   a. Metal pycnometer (coarse test sample only) – Fill the pycnometer with to 20 ±0.5°C (68 ±1°F) water according to manufacturer's instructions and dry the outside.

   b. Glass pycnometer (fine or coarse test samples) – Completely fill the pycnometer with to 20 ±0.5°C (68 ±1°F) water, slide the calibrated glass plate over the mouth of the pycnometer making sure there are no air bubbles trapped under the plate. Dry the outside.

9. Determine and record the mass of the pycnometer, sample, and water. Designate as C.

Calculation

Calculate the G_{ab} to three decimal places as follows:

$$G_{ab} = \frac{A}{A + B - C}$$

Where:

A = Mass of dry sample in air, g

B = Mass of pycnometer filled with water at 20°C (68°F), g, determined during the Standardization of Pycnometer procedure

C = Mass of pycnometer, water, and the test sample at to 20 ±0.5°C (68 ±1°F), g

Coarse example:

$$G_{ab} = \frac{2200.3\ g}{2200.3\ g + 7502.5\ g - 8812.0\ g} = 2.470$$

Given:

A = 2200.3 g

B = 7502.5 g

C = 8812.0 g

Report

- Report on standard agency forms.
- Report apparent specific gravities, G_{ab}, to the nearest 0.001

Standardization of Pycnometer

The pycnometer shall be standardized periodically in conformance with procedures established by the agency.

1. Fill the pycnometer with water at approximately 20°C (68°F).
2. Place the metal or plastic cover, or a glass plate on the pycnometer and eliminate all air.

Note B1: When using a metal pycnometer and cover, place the cover on the pycnometer and push down slowly, forcing excess water out of the hole in the center of the cover. Use care when filling the pycnometer to avoid reintroducing air into the water.

3. Stabilize the pycnometer at 20 ± 0.5ºC (68 ± 1ºF) for 10 ± 1 min.
4. Towel dry the outside of the pycnometer and cover.
5. Determine and record the mass of the pycnometer, water, and lid.
6. Repeat Steps 2 through 5 two more times for a total of three determinations.
7. If the variation of the three masses is within 0.3 g, average the three masses. Designate as “B.”
8. If the variation of the masses is greater than 0.3 g, take corrective action and perform the “Standardization of Pycnometer” again.