

INSERT TAB

AASHTO

Bulk Density (“Unit Weight”) and Voids in Aggregate

AASHTO Designation: T 19/T 19-22

ASTM Designation: C29/C 29M-07

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Oregon

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November 30, 2017

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 22**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- The use of unbonded caps as defined by ASTM C1231/C1231M-15, for compressive strength determination, is an allowable option.

Compressive Strength of Cylindrical Concrete Specimens

AASHTO Designation: T 22-22

ASTM Designation: C39/C 39M-05

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October 31, 2022

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 27/11**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- Under procedure Method A, step 1, the initial dry mass of the sample may be determined utilizing a companion moisture sample (this is an option not a requirement).
- Perform the moisture test according to T 255/ T 265.
- Under procedures (A, B and C) Delete the $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) temperature reference for drying.
- Shaking time for all methods will be a minimum of 10 minutes.
- Use the following formula to adjust the wet mass of the sample to the initial dry mass:

$$\text{Initial Dry Mass} = \left\{ \frac{WM}{1 + \left(\frac{\% M}{100} \right)} \right\}$$

Where: WM = Initial Wet Mass of T 27/11 sample.

%M = Moisture content of companion moisture sample.

- Document the Initial Wet Mass of the sample when utilizing a companion moisture.

**SIEVE ANALYSIS OF FINE AND COARSE AGGREGATES
FOP FOR AASHTO T 27
MATERIALS FINER THAN 75 μM (NO. 200) SIEVE IN MINERAL AGGREGATE
BY WASHING
FOP FOR AASHTO T 11**

Scope

A sieve analysis, or ‘gradation,’ measures distribution of aggregate particle sizes within a given sample.

Accurate determination of the amount of material smaller than 75 μm (No. 200) cannot be made using just AASHTO T 27. If quantifying this material is required, use AASHTO T 11 in conjunction with AASHTO T 27.

This FOP covers sieve analysis in accordance with AASHTO T 27-22 and materials finer than 75 μm (No. 200) in accordance with AASHTO T 11-22 performed in conjunction with AASHTO T 27. The procedure includes three methods: A, B, and C.

Apparatus

- Balance or scale: Capacity sufficient for the masses shown in Table 1, accurate to 0.1 percent of the sample mass or readable to 0.1 g, and meeting the requirements of AASHTO M 231
- Sieves: Meeting the requirements of ASTM E11
- Mechanical sieve shaker: Meeting the requirements of AASHTO T 27
- Suitable drying equipment (refer to FOP for AASHTO T 255)
- Containers and utensils: A pan or vessel of sufficient size to contain the sample covered with water and permit vigorous agitation without loss of material or water
- Optional
 - Mechanical washing device
 - Mallet: With a rubber or rawhide head having a mass of 0.57 ± 0.23 kg (1.25 ± 0.5 lb)

Sample Sieving

- In all procedures, the sample is shaken in nested sieves. Sieves are selected to furnish information required by specification. Intermediate sieves are added for additional information or to avoid overloading sieves, or both.
- The sieves are nested in order of increasing size from the bottom to the top, and the sample, or a portion of the sample, is placed on the top sieve.
- The loaded sieves are shaken in a mechanical shaker for approximately 10 minutes, refer to Annex A, *Time Evaluation*.

- Care must be taken so that sieves are not overloaded, refer to Annex B, *Overload Determination*. The sample may be sieved in increments and the mass retained for each sieve added together from each sample increment to avoid overloading sieves.

Sample Preparation

Obtain samples according to the FOP for AASHTO R 90 and reduce to sample size, shown in Table 1, according to the FOP for AASHTO R 76.

TABLE 1
Sample Sizes for Aggregate Gradation Test

Nominal Maximum Size* mm (in.)	Minimum Dry Mass g (lb)
125 (5)	300,000 (660)
100 (4)	150,000 (330)
90 (3 1/2)	100,000 (220)
75 (3)	60,000 (130)
63 (2 1/2)	35,000 (77)
50 (2)	20,000 (44)
37.5 (1 1/2)	15,000 (33)
25.0 (1)	10,000 (22)
19.0 (3/4)	5000 (11)
12.5 (1/2)	2000 (4)
9.5 (3/8)	1000 (2)
6.3 (1/4)	1000 (2)
4.75 (No. 4)	500 (1)

*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps between specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Sample sizes in Table 1 are standard for aggregate sieve analysis, due to equipment restraints samples may need to be divided into several “subsamples.” For example, a gradation that requires 100 kg (220 lbs.) of material would not fit into a large tray shaker all at once.

Some agencies permit reduced sample sizes if it is proven that doing so is not detrimental to the test results. Some agencies require larger sample sizes. Check agency guidelines for required or permitted sample sizes.

Selection of Procedure

Agencies may specify which method to perform. If a method is not specified, perform Method A.

Overview**Method A**

- Determine original dry mass of the sample
- Wash over a 75 μ m (No. 200) sieve
- Determine dry mass of washed sample
- Sieve washed sample
- Calculate and report percent retained and passing each sieve

Method B

- Determine original dry mass of the sample
- Wash over a 75 μ m (No. 200) sieve
- Determine dry mass of washed sample
- Sieve sample through coarse sieves, 4.75 mm (No. 4) sieves and larger
- Determine mass of fine material, minus 4.75 mm (No. 4)
- Reduce fine material
- Determine mass of reduced portion
- Sieve reduced portion
- Calculate and report percent retained and passing each sieve

Method C

- Determine original dry mass of the sample
- Sieve sample through coarse sieves, 4.75 mm (No. 4) sieves and larger
- Determine mass of fine material, minus 4.75 mm (No. 4)
- Reduce fine material
- Determine mass of reduced portion
- Wash reduced portion over a 75 μ m (No. 200) sieve
- Determine dry mass of washed reduced portion
- Sieve washed reduced portion
- Calculate and report percent retained and passing each sieve

Procedure Method A

1. Dry the sample to constant mass $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) according to the FOP for AASHTO T 255. Cool to room temperature.
2. Determine and record the original dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

When the specification does not require the amount of material finer than $75\ \mu\text{m}$ (No. 200) be determined by washing, skip to Step 11.

3. Nest a sieve, such as a 2.0 mm (No. 10), above the $75\ \mu\text{m}$ (No. 200) sieve.
4. Place the sample in a container and cover with water.

Note 1: A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the $75\ \mu\text{m}$ (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

5. Agitate vigorously to ensure complete separation of the material finer than $75\ \mu\text{m}$ (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.

Note 2: Washing longer than 10 minutes in a mechanical washer has been shown to cause significant amounts of degradation depending upon aggregate type.

6. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the $75\ \mu\text{m}$ (No. 200) sieve.
7. Add water to cover material remaining in the container, agitate, and repeat Step 5. Continue until the wash water is reasonably clear.
8. Remove the upper sieve and return material retained to the washed sample.
9. Rinse the material retained on the $75\ \mu\text{m}$ (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
10. Return all material retained on the $75\ \mu\text{m}$ (No. 200) sieve to the container by rinsing into the washed sample.

Note 3: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the $75\ \mu\text{m}$ (No. 200) sieve to prevent loss of fines.

11. Dry the washed sample to constant mass at $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) according to the FOP for AASHTO T 255. Cool to room temperature.
12. Determine and record the dry mass of the sample.
13. Select sieves required by the specification and those necessary to avoid overloading as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the $75\ \mu\text{m}$ (No. 200).
14. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place sieves in mechanical shaker and shake for the

minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

Note 4: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

15. Determine and record the individual or cumulative mass retained for each sieve and in the pan. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

Note 5: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

Note 6: In the case of coarse / fine aggregate mixtures, distribute the minus 4.75 mm (No. 4) among two or more sets of sieves to prevent overloading of individual sieves.

16. Perform the *Check Sum* calculation – Verify the *total mass after sieving* compared to the *dry mass before sieving* is not more than 0.3 percent. The *dry mass before sieving* is the dry mass after wash or the original dry mass (*M*) if performing the sieve analysis without washing. Do not use test results for acceptance if the *Check Sum* result is more than 0.3 percent.

17. Calculate the total percentages passing, and the individual or cumulative percentages retained to the nearest 0.1 percent by dividing the individual sieve masses or cumulative sieve masses by the original dry mass (*M*) of the sample.

18. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Method A Calculations

Check Sum

$$\text{Check Sum} = \frac{\text{dry mass before sieving} - \text{total mass after sieving}}{\text{dry mass before sieving}} \times 100$$

Percent Retained

$$\text{IPR} = \frac{\text{IMR}}{M} \times 100 \quad \text{or} \quad \text{CPR} = \frac{\text{CMR}}{M} \times 100$$

Where:

IPR	=	Individual Percent Retained
CPR	=	Cumulative Percent Retained
M	=	Original dry mass of the sample
IMR	=	Individual Mass Retained
CMR	=	Cumulative Mass Retained

Percent Passing (PP)

$$PP = PPP - IPR \quad \text{or} \quad PP = 100 - CPR$$

Where:

PP = Percent Passing

PPP = Previous Percent Passing

Method A Example Individual Mass Retained

Original dry mass of the sample (<i>M</i>):	5168.7 g
Dry mass of the sample after washing:	4911.3 g
Total mass after sieving equals	
Sum of Individual Masses Retained (IMR), including minus 75 μm (No. 200) in the pan:	4905.9 g
Amount of 75 μm (No. 200) minus washed out (5168.7 g – 4911.3 g):	257.4 g

Check Sum

$$Check\ Sum = \frac{4911.3\ g - 4905.9\ g}{4911.3\ g} \times 100 = 0.1\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

Individual Percent Retained (IPR) for 9.5 mm (3/8 in.) sieve:

$$IPR = \frac{619.2\ g}{5168.7\ g} \times 100 = 12.0\%$$

Percent Passing (PP) 9.5 mm (3/8 in.) sieve:

$$PP = 86.0\% - 12.0\% = 74.0\%$$

Reported Percent Passing = 74%

**Method A Individual
Gradation on All Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine IPR by dividing IMR by <i>M</i> and multiplying by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from previous PP	Percent Passing (PP)	Reported Percent Passing*
19.0 (3/4)	0		0		100.0	100
12.5 (1/2)	724.7	$\frac{724.7}{5168.7} \times 100 =$	14.0	$100.0 - 14.0 =$	86.0	86
9.5 (3/8)	619.2	$\frac{619.2}{5168.7} \times 100 =$	12.0	$86.0 - 12.0 =$	74.0	74
4.75 (No. 4)	1189.8	$\frac{1189.8}{5168.7} \times 100 =$	23.0	$74.0 - 23.0 =$	51.0	51
2.36 (No. 8)	877.6	$\frac{877.6}{5168.7} \times 100 =$	17.0	$51.0 - 17.0 =$	34.0	34
1.18 (No. 16)	574.8	$\frac{574.8}{5168.7} \times 100 =$	11.1	$34.0 - 11.1 =$	22.9	23
0.600 (No. 30)	329.8	$\frac{329.8}{5168.7} \times 100 =$	6.4	$22.9 - 6.4 =$	16.5	17
0.300 (No. 50)	228.5	$\frac{228.5}{5168.7} \times 100 =$	4.4	$16.5 - 4.4 =$	12.1	12
0.150 (No. 100)	205.7	$\frac{205.7}{5168.7} \times 100 =$	4.0	$12.1 - 4.0 =$	8.1	8
0.075 (No. 200)	135.4	$\frac{135.7}{5168.7} \times 100 =$	2.6	$8.1 - 2.6 =$	5.5	5.5
minus 0.075 (No. 200) in the pan	20.4					
Total mass after sieving = sum of sieves + mass in the pan = 4905.9 g						
Original dry mass of the sample (<i>M</i>): 5168.7g						

* Report total percent passing to 1 percent except report the 75 μm (No. 200) sieve to 0.1 percent.

Method A Example Cumulative Mass Retained

Original dry mass of the sample (<i>M</i>):	5168.7 g
Dry mass of the sample after washing:	4911.3 g
Total mass after sieving equals Final Cumulative Mass Retained (FCMR) (includes minus 75 µm (No. 200) from the pan):	4905.9 g
Amount of 75µm (No. 200) minus washed out (5168.7 g – 4911.3 g):	257.4 g

Check Sum

$$\text{Check Sum} = \frac{4911.3 \text{ g} - 4905.9 \text{ g}}{4911.3 \text{ g}} \times 100 = 0.1\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR) for 9.5 mm (3/8 in.) sieve:

$$\text{CPR} = \frac{1343.9 \text{ g}}{5168.7 \text{ g}} \times 100 = 26.0\%$$

Percent Passing (PP) 9.5 mm (3/8 in.) sieve:

$$\text{PP} = 100.0\% - 26.0\% = 74.0\%$$

Reported Percent Passing = 74%

**Method A Cumulative
Gradation on All Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Determine CPR by dividing CMR by M and multiplying by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Reported Percent Passing*
19.0 (3/4)	0		0.0		100.0	100
12.5 (1/2)	724.7	$\frac{724.7}{5168.7} \times 100 =$	14.0	$100.0 - 14.0 =$	86.0	86
9.5 (3/8)	1343.9	$\frac{1343.9}{5168.7} \times 100 =$	26.0	$100.0 - 26.0 =$	74.0	74
4.75 (No. 4)	2533.7	$\frac{2533.7}{5168.7} \times 100 =$	49.0	$100.0 - 49.0 =$	51.0	51
2.36 (No. 8)	3411.3	$\frac{3411.3}{5168.7} \times 100 =$	66.0	$100.0 - 66.0 =$	34.0	34
1.18 (No. 16)	3986.1	$\frac{3986.1}{5168.7} \times 100 =$	77.1	$100.0 - 77.1 =$	22.9	23
0.600 (No. 30)	4315.9	$\frac{4315.9}{5168.7} \times 100 =$	83.5	$100.0 - 83.5 =$	16.5	17
0.300 (No. 50)	4544.4	$\frac{4544.4}{5168.7} \times 100 =$	87.9	$100.0 - 87.9 =$	12.1	12
0.150 (No. 100)	4750.1	$\frac{4750.1}{5168.7} \times 100 =$	91.9	$100.0 - 91.9 =$	8.1	8
0.075 (No. 200)	4885.5	$\frac{4885.5}{5168.7} \times 100 =$	94.5	$100.0 - 94.5 =$	5.5	5.5
FCMR	4905.9					
Total mass after sieving: 4905.9 g						
Original dry mass of the sample (M): 5168.7 g						

* Report total percent passing to 1 percent except report the 75 μ m (No. 200) sieve to 0.1 percent.

Procedure Method B

1. Dry the sample to constant mass at $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) according to the FOP for AASHTO T 255. Cool to room temperature.
2. Determine and record the original dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as *M*.

When the specification does not require the amount of material finer than $75\ \mu\text{m}$ (No. 200) be determined by washing, skip to Step 11.

3. Nest a protective sieve, such as a 2.0 mm (No. 10), above the $75\ \mu\text{m}$ (No. 200) sieve.
4. Place the sample in a container and cover with water.

Note 1: A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the $75\ \mu\text{m}$ (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

5. Agitate vigorously to ensure complete separation of the material finer than $75\ \mu\text{m}$ (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.

Note 2: Washing longer than 10 minutes in a mechanical washer has been shown to cause significant amounts of degradation depending upon aggregate type.

6. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the $75\ \mu\text{m}$ (No. 200) sieve.
7. Add water to cover material remaining in the container, agitate, and repeat Step 5. Continue until the wash water is reasonably clear.
8. Remove the upper sieve and return material retained to the washed sample.
9. Rinse the material retained on the $75\ \mu\text{m}$ (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
10. Return all material retained on the $75\ \mu\text{m}$ (No. 200) sieve to the container by rinsing into the washed sample.

Note 3: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the $75\ \mu\text{m}$ (No. 200) sieve to prevent loss of fines.

11. Dry the washed sample to constant mass at $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) according to the FOP for AASHTO T 255. Cool to room temperature.
12. Determine and record the dry mass after wash.
13. Select sieves required by the specification and those necessary to avoid overloading as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4).
14. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place the sieves in the mechanical shaker and shake for the

minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

Note 4: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

15. Determine and record the individual or cumulative mass retained for each sieve. Ensure that all particles trapped in full openings of the sieve are removed and included in the mass retained.

Note 5: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 μm (No. 30) and larger sieves, and soft hair bristle for smaller sieves.

16. Determine and record the mass of the minus 4.75 mm (No. 4) material in the pan. Designate this mass as M_1 .
17. Perform the *Coarse Check Sum* calculation – Verify the *total mass after coarse sieving* compared to the *dry mass before sieving* to not more than 0.3 percent. The *dry mass before sieving* is the dry mass after wash or the original dry mass (M) if performing the sieve analysis without washing. Do not use test results for acceptance if the *Check Sum* result is more than 0.3 percent.
18. Reduce the minus 4.75 mm (No. 4) according to the FOP for AASHTO R 76 to produce a sample with a minimum mass of 500 g. Determine and record the mass of the minus 4.75 mm (No. 4) split, designate this mass as M_2 .
19. Select sieves required by the specification and those necessary to avoid overloading as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 75 μm (No. 200) up to, but not including, the 4.75 mm (No. 4) sieve.
20. Place the sample portion on the top sieve and place the sieves in the mechanical shaker. Shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).
21. Determine and record the individual or cumulative mass retained for each sieve and in the pan. Ensure that all particles trapped in full openings of the sieve are removed and included in the mass retained. (See Note 5.)
22. Perform the *Fine Check Sum* calculation – Verify the *total mass after sieving* compared to the *dry mass before sieving* (M_2) is not more than 0.3 percent. Do not use test results for acceptance if the *Check Sum* result is more than 0.3 percent.
23. Calculate to the nearest 0.1 percent, the Individual Mass Retained (IMR) or Cumulative Mass Retained (CMR) of the size increment of the reduced sample and the original sample.
24. Calculate the total percent passing.
25. Report total percent passing to 1 percent except report the 75 μm (No. 200) sieve to 0.1 percent.

Method B Calculations**Check Sum**

$$\text{Coarse Check Sum} = \frac{\text{dry mass before sieving} - \text{total mass after coarse sieving}}{\text{dry mass before sieving}} \times 100$$

$$\text{Fine Check Sum} = \frac{M_2 - \text{total mass after fine sieving}}{M_2} \times 100$$

Percent Retained for 4.75 mm (No. 4) and larger

$$IPR = \frac{IMR}{M} \times 100 \quad \text{or} \quad CPR = \frac{CMR}{M} \times 100$$

Where:

IPR	=	Individual Percent Retained
CPR	=	Cumulative Percent Retained
M	=	Original dry mass of the sample
IMR	=	Individual Mass Retained
CMR	=	Cumulative Mass Retained

Percent Passing (PP) for 4.75 mm (No. 4) and larger

$$PP = PPP - IPR \quad \text{or} \quad PP = 100 - CPR$$

Where:

PP	=	Percent Passing
PPP	=	Previous Percent Passing

Minus 4.75mm (No. 4) adjustment factor (R)

The mass of material retained for each sieve is multiplied by the adjustment factor, the total mass of the minus 4.75 mm (No. 4) from the pan, M_1 , divided by the mass of the reduced split of minus 4.75 mm (No. 4), M_2 . For consistency, this adjustment factor is carried to three decimal places.

$$R = \frac{M_1}{M_2}$$

where:

- R = minus 4.75 mm (No. 4) adjustment factor
- M_1 = total mass of minus 4.75 mm (No. 4) before reducing
- M_2 = mass of the reduced split of minus 4.75 mm (No. 4)

Total Individual Mass Retained (TIMR):

$$TIMR = R \times B$$

where:

- TIMR = Total Individual Mass Retained
- R = minus 4.75 mm (No. 4) adjustment factor
- B = individual mass of the size increment in the reduced portion sieved

Total Cumulative Mass Retained (TCMR)

$$TCMR = (R \times B) + D$$

where:

- TCMR = Total Cumulative Mass Retained
- R = minus 4.75 mm (No. 4) adjustment factor
- B = cumulative mass of the size increment in the reduced portion sieved
- D = cumulative mass of plus 4.75mm (No. 4) portion of sample

Method B Example Individual Mass Retained

Dry mass of total sample, before washing:	3214.0 g
Dry mass of sample after washing:	3085.1 g
Total mass after sieving	
Sum of Individual Masses Retained (IMR) plus the minus 4.75 mm (No. 4) from the pan:	3085.0 g
Amount of 75 µm (No. 200) minus washed out (3214.0 g – 3085.1 g):	128.9 g

Coarse Check Sum

$$\text{Coarse Check Sum} = \frac{3085.1 \text{ g} - 3085.0 \text{ g}}{3085.1 \text{ g}} \times 100 = 0.0\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

Individual Percent Retained (IPR) for 9.5 mm (3/8 in.) sieve

$$\text{IPR} = \frac{481.4 \text{ g}}{3214.0 \text{ g}} \times 100 = 15.0\%$$

Percent Passing (PP) for 9.5 mm (3/8 in.) sieve:

$$\text{PP} = 95.0\% - 15.0\% = 80.0\%$$

Reported Percent Passing = 80%

**Method B Individual
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine IPR by dividing IMR by M and multiplying by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from previous PP	Percent Passing (PP)
16.0 (5/8)	0		0		100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0
9.50 (3/8)	481.4	$\frac{481.4}{3214.0} \times 100 =$	15.0	$95.0 - 15.0 =$	80.0
4.75 (No. 4)	475.8	$\frac{475.8}{3214.0} \times 100 =$	14.8	$80.0 - 14.8 =$	65.2
Minus 4.75 (No. 4) in the pan	1966.7 (M_1)				
Total mass after sieving: sum of sieves + mass in the pan = 3085.0 g					
Original dry mass of the sample (M): 3214.0 g					

Fine Sample

The minus 4.75 mm (No. 4) from the pan, M_1 (1966.7 g), was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **512.8 g**. This is M_2 .

The reduced mass was sieved.

Total mass after sieving equals

Sum of Individual Masses Retained (IMR) including
minus 75 μ m (No. 200) in the pan 511.8 g

Fine Check Sum

$$\text{Fine Check Sum} = \frac{512.8 \text{ g} - 511.8 \text{ g}}{512.8 \text{ g}} \times 100 = 0.2\%$$

The result is not more than an 0.3 percent therefore the results can be used for acceptance purposes.

Adjustment Factor (*R*) for Total Individual Mass Retained (TIMR) on minus 4.75 (No. 4) sieves

The mass of material retained for each sieve is multiplied by the adjustment factor (*R*) carried to three decimal places.

$$R = \frac{M_1}{M_2} = \frac{1,966.7 \text{ g}}{512.8 \text{ g}} = 3.835$$

where:

- R = minus 4.75 mm (No. 4) adjustment factor
- M₁ = total mass of minus 4.75 mm (No. 4) from the pan
- M₂ = mass of the reduced split of minus 4.75 mm (No. 4)

Each “individual mass retained” on the fine sieves must be multiplied by *R* to obtain the *Total Individual Mass Retained (TIMR)*.

Total Individual Mass Retained (TIMR) for 2.00 mm (No. 10) sieve

$$\text{TIMR} = 3.835 \times 207.1 \text{ g} = 794.2 \text{ g}$$

Individual Percent Retained (IPR) for 2.00 mm (No. 10) sieve:

$$\text{IPR} = \frac{794.2 \text{ g}}{3214.0 \text{ g}} \times 100 = 24.7\%$$

Percent Passing (PP) 2 mm (No. 10) sieve:

$$PP = 65.2\% - 24.7\% = 40.5\%$$

Reported Percent Passing = 41%

**Method B Individual
Gradation on Fine Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine TIMR by multiplying IMR by $R \left(\frac{M_1}{M_2}\right)$	Total Individual Mass Retained (TIMR)
2.00 (No. 10)	207.1	$207.1 \times 3.835 =$	794.2
0.425 (No. 40)	187.9	$187.9 \times 3.835 =$	720.6
0.210 (No. 80)	59.9	$59.9 \times 3.835 =$	229.7
0.075 (No. 200)	49.1	$49.1 \times 3.835 =$	188.3
minus 0.075 (No. 200) in the pan	7.8		
Total mass after sieving: sum of fine sieves + the mass in the pan = 511.8 g			

**Method B Individual
Final Gradation on All Sieves**

Sieve Size mm (in.)	Total Individual Mass Retained g (TIMR)	Determine IPR by dividing TIMR by M and multiplying by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from previous PP	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0		0		100	100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0	95
9.50 (3/8)	481.4	$\frac{481.4}{3214.0} \times 100 =$	15.0	$95.0 - 15.0 =$	80.0	80
4.75 (No. 4)	475.8	$\frac{475.8}{3214.0} \times 100 =$	14.8	$80.0 - 14.8 =$	65.2	65
2.00 (No. 10)	794.2	$\frac{794.2}{3214.0} \times 100 =$	24.7	$65.2 - 24.7 =$	40.5	41
0.425 (No. 40)	720.6	$\frac{720.6}{3214.0} \times 100 =$	22.4	$40.5 - 22.4 =$	18.1	18
0.210 (No. 80)	229.7	$\frac{229.7}{3214.0} \times 100 =$	7.1	$18.1 - 7.1 =$	11.0	11
0.075 (No. 200)	188.3	$\frac{188.3}{3214.0} \times 100 =$	5.9	$11.0 - 5.9 =$	5.1	5.1
minus 0.075 (No. 200) in the pan	29.9					
Original dry mass of the sample (M): 3214.0 g						

* Report total percent passing to 1 percent except report the 75 μ m (No. 200) sieve to 0.1 percent.

Method B Example Cumulative Mass Retained

Original dry mass of the sample (<i>M</i>):	3214.0 g
Dry mass of sample after washing:	3085.1 g
Total mass after sieving equals	
Cumulative Mass Retained (CMR) on the 4.75 (No. 4) plus the minus 4.75 mm (No. 4) in the pan:	3085.0 g
Amount of 75 μm (No. 200) minus washed out (3214.0 g – 3085.1 g):	128.9 g

Coarse Check Sum

$$\text{Coarse Check Sum} = \frac{3085.1 \text{ g} - 3085.0 \text{ g}}{3085.1 \text{ g}} \times 100 = 0.0\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR) for 9.5 mm (3/8 in.) sieve

$$\text{CPR} = \frac{642.5 \text{ g}}{3214.0 \text{ g}} \times 100 = 20.0\%$$

Percent Passing (PP) for 9.5 mm (3/8 in.) sieve

$$\text{PP} = 100.0\% - 20.0\% = 80.0\%$$

Reported Percent Passing = 80%

**Method B Cumulative
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Determine CPR by dividing CMR by M and multiplying by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)
16.0 (5/8)	0		0		100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0
9.50 (3/8)	642.5	$\frac{642.5}{3214.0} \times 100 =$	20.0	$100.0 - 20.0 =$	80.0
4.75 (No. 4)	1118.3 (D)	$\frac{1118.3}{3214.0} \times 100 =$	34.8	$100.0 - 34.8 =$	65.2
Minus 4.75 (No. 4) in the pan	1966.7 (M _I)				
CMR: 1118.3 + 1966.7 = 3085.0					
Original dry mass of the sample (M): 3214.0 g					

Fine Sample

The mass of minus 4.75 mm (No. 4) material in the pan, M_I (1966.7 g), was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **512.8 g**. This is M_2 .

The reduced mass was sieved.

Total mass after fine sieving equals

Final Cumulative Mass Retained (FCMR) (includes minus
75 μ m (No. 200) from the pan): 511.8 g

Fine Check Sum

$$\text{Fine Check Sum} = \frac{512.8 \text{ g} - 511.8 \text{ g}}{512.8 \text{ g}} \times 100 = 0.2\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

The cumulative mass of material retained for each sieve is multiplied by the adjustment factor (R) carried to three decimal places to obtain the *Adjusted Cumulative Mass Retained (ACMR)* and added to the cumulative mass retained on the 4.75 mm (No. 4) sieve, D , to obtain the *Total Cumulative Mass Retained (TCMR)*.

Adjustment factor (R) for Adjusted Cumulative Mass Retained (ACMR) in minus 4.75 (No. 4) sieves.

$$R = \frac{M_1}{M_2} = \frac{1,966.7 \text{ g}}{512.8 \text{ g}} = 3.835$$

where:

- R = minus 4.75 mm (No. 4) adjustment factor
- M_1 = total mass of minus 4.75 mm (No. 4) from the pan
- M_2 = mass of the reduced split of minus 4.75 mm (No. 4)

Adjusted Cumulative Mass Retained (ACMR) for the 2.00 mm (No. 10) sieve

$$ACMR = 3.835 \times 207.1 \text{ g} = 794.2 \text{ g}$$

Total Cumulative Mass Retained (TCMR) for the 2.00 mm (No. 10) sieve

$$TCMR = 794.2 \text{ g} + 1118.3 \text{ g} = 1912.5 \text{ g}$$

Cumulative Percent Retained (CPR) for 2.00 mm (No. 10) sieve:

$$CPR = \frac{1912.5 \text{ g}}{3214.0 \text{ g}} \times 100 = 59.5\%$$

Percent Passing (PP) 2.00 mm (No. 10) sieve:

$$PP = 100.0\% - 59.5\% = 40.5\%$$

Reported Percent Passing = 41%

**Method B Cumulative
Gradation on Fine Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Determine TCMR by multiplying CMR by $R \left(\frac{M_1}{M_2} \right)$ and adding D	Total Cumulative Mass Retained (TCMR)
2.00 (No. 10)	207.1	$207.1 \times 3.835 + 1118.3 =$	1912.5
0.425 (No. 40)	395.0	$395.0 \times 3.835 + 1118.3 =$	2633.1
0.210 (No. 80)	454.9	$454.9 \times 3.835 + 1118.3 =$	2862.8
0.075 (No. 200)	504.0	$504.0 \times 3.835 + 1118.3 =$	3051.1
FCMR	511.8		
Total: sum of masses on fine sieves + minus 75 μm (No. 200) in the pan = 511.8			

**Method B Cumulative
Final Gradation on All Sieves**

Sieve Size mm (in.)	Total Cumulative Mass Retained g (TCMR)	Determine CPR by dividing CMR by M and multiplying by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0		0		100.0	100
12.5 (1/2)	161.1	$\frac{161.1}{3214.0} \times 100 =$	5.0	$100.0 - 5.0 =$	95.0	95
9.5 (3/8)	642.5	$\frac{642.5}{3214.0} \times 100 =$	20.0	$100.0 - 20.0 =$	80.0	80
4.75 (No. 4)	1118.3 (D)	$\frac{1118.3}{3214.0} \times 100 =$	34.8	$100.0 - 34.8 =$	65.2	65
2.00 (No. 10)	1912.5	$\frac{1912.5}{3214.0} \times 100 =$	59.5	$100.0 - 59.5 =$	40.5	41
0.425 (No. 40)	2633.1	$\frac{2633.1}{3214.0} \times 100 =$	81.9	$100.0 - 81.9 =$	18.1	18
0.210 (No. 80)	2862.8	$\frac{2862.8}{3214.0} \times 100 =$	89.1	$100.0 - 89.1 =$	10.9	11
0.075 (No. 200)	3051.1	$\frac{3051.1}{3214.0} \times 100 =$	94.9	$100.0 - 94.9 =$	5.1	5.1
FCMR	3081.1					
Original dry mass of the sample (M): 3214.0 g						

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Procedure Method C

1. Dry the sample to constant mass at $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) according to the FOP for AASHTO T 255. Cool to room temperature.
2. Determine and record the original dry mass of the sample to the nearest 0.1 percent or 0.1 g. Designate this mass as M .
3. Break up any aggregations or lumps of clay, silt, or adhering fines to pass the 4.75 mm (No. 4) sieve.
4. Select sieves required by the specification and those necessary to avoid overloading as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 4.75 mm (No. 4) sieve.
5. Place the sample, or a portion of the sample, on the top sieve. Sieves may already be in the mechanical shaker, if not place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

Note 1: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

6. Determine and record the cumulative mass retained for each sieve. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

Note 2: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening sieving over a full opening. Use coarse wire brushes to clean the 600 μm (No. 30) and larger sieves, and soft bristle brush for smaller sieves.

7. Determine and record the mass of the minus 4.75 mm (No. 4) material in the pan. Designate this mass as M_1 .
8. Perform the *Coarse Check Sum* calculation –Verify the *total mass after coarse sieving* compared to the *original dry mass (M)* is not more than 0.3 percent.
9. Reduce the minus 4.75 mm (No. 4) according to the FOP for AASHTO R 76, to produce a sample with a minimum mass of 500 g.
10. Determine and record the mass of the minus 4.75 mm (No. 4) split, designate this mass as M_3 .
11. Nest a protective sieve, such as a 2.0 mm (No. 10), above the 75 μm (No. 200) sieve.
12. Place the sample in a container and cover with water.

Note 3: A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75 μm (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.

13. Agitate vigorously to ensure complete separation of the material finer than 75 μm (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device.

Note 4: Washing longer than 10 minutes in a mechanical washer has been shown to cause significant amounts of degradation depending upon aggregate type.

14. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 μm (No. 200) sieve.
15. Add water to cover material remaining in the container, agitate, and repeat Step 12. Repeat until the wash water is reasonably clear.
16. Remove the upper sieve and return material retained to the washed sample.
17. Rinse the material retained on the 75 μm (No. 200) sieve until water passing through the sieve is reasonably clear and detergent or dispersing agent is removed, if used.
18. Return all material retained on the 75 μm (No. 200) sieve to the container by flushing into the washed sample.

Note 5: Excess water may be carefully removed with a bulb syringe; the removed water must be discharged back over the 75 μm (No. 200) sieve to prevent loss of fines.

19. Dry the washed sample portion to constant mass at $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$) according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the dry mass, designate this mass as *dry mass before sieving*.
20. Select sieves required by the specification and those necessary to avoid overloading as described in Annex B. With a pan on bottom, nest the sieves increasing in size starting with the 75 μm (No. 200) sieve up to, but not including the 4.75 mm (No. 4) sieve.
21. Place the sample portion on the top sieve. Place the sieves in the mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

Note 6: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

22. Determine and record the cumulative mass retained for each sieve. Ensure that all material trapped in full openings of the sieve are removed and included in the mass retained.

Note 7: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 μm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

23. Perform the *Fine Check Sum* calculation – Verify the *total mass after fine sieving* compared to the *dry mass before sieving* is not more than 0.3 percent. Do not use test results for acceptance if the *Check Sum* is more than 0.3 percent.
24. Calculate the Cumulative Percent Retained (CPR) and Percent Passing (PP) for the 4.75 mm (No. 4) and larger.
25. Calculate the Cumulative Percent Retained (CPR-#4) and the Percent Passing (PP-#4) for minus 4.75 mm (No. 4) split and Percent Passing (PP) for the minus 4.75 mm (No. 4).
26. Report total percent passing to 1 percent except report the 75 μm (No. 200) sieve to 0.1 percent.

Method C Calculations

Check Sum

$$\text{Coarse check sum} = \frac{M - \text{total mass after coarse sieving}}{M} \times 100$$

$$\text{Fine check sum} = \frac{\text{dry mass before sieving} - \text{total mass after fine sieving}}{\text{dry mass before sieving}} \times 100$$

where:

M = Original dry mass of the sample

Cumulative Percent Retained (CPR) for 4.75 mm (No. 4) sieve and larger

$$CPR = \frac{CMR}{M} \times 100$$

where:

CPR = Cumulative Percent Retained of the size increment for the total sample

CMR = Cumulative Mass Retained of the size increment for the total sample

M = Total dry sample mass before washing

Percent Passing (PP) 4.75 mm (No. 4) sieve and larger

$$PP = 100 - CPR$$

where:

PP = Percent Passing of the size increment for the total sample

CPR = Cumulative Percent Retained of the size increment for the total sample

Or calculate PP for sieves larger than 4.75 mm (No. 4) sieve without calculating CPR

$$\frac{M - CMR}{M} \times 100$$

Cumulative Percent Retained (CPR_{#4}) for minus 4.75 mm (No. 4) split

$$CPR_{\#4} = \frac{CMR_{\#4}}{M_3} \times 100$$

where:

- CPR_{#4} = Cumulative Percent Retained for the sieve sizes of M₃
 CMR_{#4} = Cumulative Mass Retained for the sieve sizes of M₃
 M₃ = Total mass of the minus 4.75 mm (No. 4) split before washing

Percent Passing (PP_{#4}) for minus 4.75 mm (No. 4) split

$$PP_{\#4} = 100 - CPR_{\#4}$$

where:

- PP_{#4} = Percent Passing for the sieve sizes of M₃
 CPR_{#4} = Cumulative Percent Retained for the sieve sizes of M₃

Percent Passing (PP) for sieves smaller than 4.75 mm (No. 4) sieve

$$PP = \frac{(PP_{\#4} \times \#4 PP)}{100}$$

where:

- PP = Total Percent Passing
 PP_{#4} = Percent Passing for the sieve sizes of M₃
 #4 PP = Total Percent Passing the 4.75 mm (No. 4) sieve

Or calculate PP for sieves smaller than 4.75 mm (No. 4) sieve without calculating CPR_{#4} and PP_{#4}

$$PP = \frac{\#4 PP}{M_3} \times (M_3 - CMR_{\#4})$$

where:

- PP = Total Percent Passing
- #4 PP = Total Percent Passing the 4.75 mm (No. 4) sieve
- M₃ = Total mass of the minus 4.75 mm (No. 4) split before washing
- CMR_{#4} = Cumulative Mass Retained for the sieve sizes of M₃

Method C Example

Original dry mass of the sample (*M*): 3304.5 g

Total mass after sieving equals

Cumulative Mass Retained (CMR) on the 4.75 (No. 4) plus the minus 4.75 mm (No. 4) from the pan: 3085.0 g

Coarse Check Sum

$$Coarse Check Sum = \frac{3304.5 g - 3304.5 g}{3304.5 g} \times 100 = 0.0\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR) for the 9.5 mm (3/8 in.) sieve:

$$CPR = \frac{604.1 g}{3304.5 g} \times 100 = 18.3\%$$

Percent Passing (PP) for the 9.5 mm (3/8 in.) sieve:

$$PP = 100.0\% - 18.3\% = 81.7\%$$

Reported Percent Passing = 82%

Example for Alternate Percent Passing (PP) formula for the 9.5 mm (3/8 in.) sieve:

$$PP = \frac{3304.5 - 604.1}{3304.5} \times 100 = 81.7\%$$

Reported Percent Passing = 82%

**Method C Cumulative
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Determine CPR by dividing CMR by M and multiplying by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0		0.0		100.0	100
12.5 (1/2)	125.9	$\frac{125.9}{3304.5} \times 100 =$	3.8	$100.0 - 3.8 =$	96.2	96
9.50 (3/8)	604.1	$\frac{604.1}{3304.5} \times 100 =$	18.3	$100.0 - 18.3 =$	81.7	82
4.75 (No. 4)	1295.6	$\frac{1295.6}{3304.5} \times 100 =$	39.2	$100.0 - 39.2 =$	60.8 (#4 PP)	61
Mass in pan	2008.9					
CMR: 1295.6 + 2008.9 = 3304.5						
Original dry mass of the sample (M): 3304.5						

Fine Sample

The pan (2008.9 g) was reduced according to the FOP for AASHTO R 76, to at least 500 g. In this case, the reduced mass was determined to be **527.6 g**. This is M_3 .

Dry mass of minus 4.75mm (No. 4) reduced portion before wash (M_3): 527.6 g

Dry mass of minus 4.75mm (No. 4) reduced portion after wash: 495.3 g

Total mass after fine sieving equals

Final Cumulative Mass Retained (FCMR)
(includes minus 75 μm (No. 200) from the pan): 495.1 g

Fine Check Sum

$$\text{Fine Check Sum} = \frac{495.3 \text{ g} - 495.1 \text{ g}}{495.3 \text{ g}} \times 100 = 0.0\%$$

The result is not more than 0.3 percent therefore the results can be used for acceptance purposes.

Cumulative Percent Retained (CPR_{#4}) for minus 4.75 mm (No. 4) for the 2.0 mm (No. 10) sieve:

$$CPR_{\#4} = \frac{194.3 \text{ g}}{527.6 \text{ g}} \times 100 = 36.8\%$$

Percent Passing (PP_{#4}) for minus 4.75 mm (No. 4) for the 2.0 mm (No. 10) sieve:

$$PP_{\#4} = 100.0\% - 36.8\% = 63.2\%$$

**Method C Cumulative
Gradation on Fine Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR _{#4})	Determine CPR _{#4} by dividing CMR by M ₃ and multiplying by 100	Cumulative Percent Retained _{#4} (CPR _{#4})	Determine PP _{#4} by subtracting CPR _{#4} from 100.0	Percent Passing _{#4} (PP _{#4})
2.0 (No. 10)	194.3	$\frac{194.3}{527.6} \times 100 =$	36.8	$100.0 - 36.8 =$	63.2
0.425 (No. 40)	365.6	$\frac{365.6}{527.6} \times 100 =$	69.3	$100.0 - 69.3 =$	30.7
0.210 (No. 80)	430.8	$\frac{430.8}{527.6} \times 100 =$	81.7	$100.0 - 81.7 =$	18.3
0.075 (No. 200)	484.4	$\frac{484.4}{527.6} \times 100 =$	91.8	$100.0 - 91.8 =$	8.2
FCMR	495.1				
Dry mass of minus 4.75mm (No. 4) reduced portion before wash (M ₃): 527.6 g					
Dry mass after washing: 495.3 g					

Percent Passing (PP) for the 2.0 mm (No. 10) sieve for the entire sample:

#4 PP (Total Percent Passing the 4.75 mm (No. 4) sieve) = 60.8%

$$PP = \frac{63.2\% \times 60.8\%}{100} = 38.4\%$$

Reported Percent Passing = 38%

**Method C Cumulative
Final Gradation on All Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Cumulative Percent Retained (CPR)	Percent Passing (PP -#4)	Determine PP by multiplying PP-#4 by #4 PP and dividing by 100	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0	0.0			100.0	100
12.5 (1/2)	125.9	3.8			96.2	96
9.5 (3/8)	604.1	18.3			81.7	82
4.75 (No. 4)	1295.6	39.2			60.8 (#4 PP)	61
2.0 (No. 10)	194.3	36.8	63.2	$\frac{63.2 \times 60.8}{100} =$	38.4	38
0.425 (No. 40)	365.6	69.3	30.7	$\frac{30.7 \times 60.8}{100} =$	18.7	19
0.210 (No. 80)	430.8	81.7	18.3	$\frac{18.3 \times 60.8}{100} =$	11.1	11
0.075 (No. 200)	484.4	91.8	8.2	$\frac{8.2 \times 60.8}{100} =$	5.0	5.0
FCMR	495.1					

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Example for Alternate Percent Passing (PP) for the 4.75 mm (No. 4) sieve for the entire sample:

#4 PP (Total Percent Passing the 4.75 mm (No. 4) sieve) = 60.8%

$$PP = \frac{60.8\%}{527.6} \times (527.6 - 194.3) = 38.4\%$$

Reported Percent Passing = 38%

**Alternate Method C Cumulative
Gradation on Coarse Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained, g (CMR)	Determine PP by subtracting CMR from M, and dividing the result by M then multiplying by 100	Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)	0.0		100.0	100
12.5 (1/2)	125.9	$\frac{3304.5 - 125.9}{3304.5} \times 100 =$	96.2	96
9.5 (3/8)	604.1	$\frac{3304.5 - 604.1}{3304.5} \times 100 =$	81.7	82
4.75 (No. 4)	1295.6	$\frac{3304.5 - 1295.6}{3304.5} \times 100 =$	60.8 (#4 PP)	61
Mass in Pan	2008.9			
Cumulative sieved mass: $1295.6 + 2008.9 = 3304.5$				
Original dry mass of the sample (M): 3304.5				

**Alternate Method C Cumulative
Gradation on Fine Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR _{#4})	Determine PP _{#4} by subtracting CMR _{#4} from M ₃ , dividing result by M ₃ and multiplying by 100	Percent Passing _{#4} (PP _{#4})
2.0 (No. 10)	194.3	$\frac{527.6 - 194.3}{527.6} \times 100 =$	63.2
0.425 (No. 40)	365.6	$\frac{527.6 - 365.6}{527.6} \times 100 =$	30.7
0.210 (No. 80)	430.8	$\frac{527.6 - 430.8}{527.6} \times 100 =$	18.3
0.075 (No. 200)	484.4	$\frac{527.6 - 484.4}{527.6} \times 100 =$	8.2
FCMR	495.1		
Dry mass of minus 4.75mm (No. 4) reduced portion before wash (M ₃): 527.6 g			
Dry mass after washing: 495.3 g			

**Alternate Method C Cumulative
Final Gradation on All Sieves**

Sieve Size mm (in.)	Percent Passing _{#4} (PP _{#4})	Determine PP by multiplying PP _{#4} by #4 PP and dividing by 100	Determined Percent Passing (PP)	Reported Percent Passing*
16.0 (5/8)			100.0	100
12.5 (1/2)			96.2	96
9.5 (3/8)			81.7	82
4.75 (No. 4)			60.8 (#4 PP)	61
2.0 (No. 10)	63.2	$\frac{63.2 \times 60.8}{100} =$	38.4	38
0.425 (No. 40)	30.7	$\frac{30.7 \times 60.8}{100} =$	18.7	19
0.210 (No. 80)	18.3	$\frac{18.3 \times 60.8}{100} =$	11.1	11
0.075 (No. 200)	8.2	$\frac{8.2 \times 60.8}{100} =$	5.0	5.0

* Report total percent passing to 1 percent except report the 75 μm (No. 200) sieve to 0.1 percent.

FINENESS MODULUS

Fineness Modulus (FM) is used in determining the degree of uniformity of the aggregate gradation in PCC mix designs. It is an empirical number relating to the fineness of the aggregate. The higher the FM the coarser the aggregate. Values of 2.40 to 3.00 are common for fine aggregate in PCC.

The sum of the cumulative percentages retained on specified sieves in the following table divided by 100 gives the FM.

Sample Calculation

	Example A				Example B		
	Percent				Percent		
		Retained				Retained	
Sieve Size mm (in)	Passing		On Spec'd Sieves*		Passing		On Spec'd Sieves*
75*(3)	100	0	0		100	0	0
37.5*(11/2)	100	0	0		100	0	0
19*(3/4)	15	85	85		100	0	0
9.5*(3/8)	0	100	100		100	0	0
4.75*(No.4)	0	100	100		100	0	0
2.36*(No.8)	0	100	100		87	13	13
1.18*(No.16)	0	100	100		69	31	31
0.60*(No.30)	0	100	100		44	56	56
0.30*(No.50)	0	100	100		18	82	82
0.15*(100)	0	100	100		4	96	96
			$\Sigma = 785$				$\Sigma = 278$
			FM = 7.85				FM = 2.78

In decreasing size order, each * sieve is one-half the size of the preceding * sieve.

Report

- On forms approved by the agency
- Sample ID
- Percent passing for each sieve
- Individual mass retained for each sieve
- Individual percent retained for each sieve
- or
- Cumulative mass retained for each sieve
- Cumulative percent retained for each sieve
- FM to the nearest 0.01

Report percentages to the nearest 1 percent except for the percent passing the 75 μm (No. 200) sieve, which shall be reported to the nearest 0.1 percent.

ANNEX A**Time Evaluation**

(Mandatory information)

The sieving time for each mechanical sieve shaker shall be checked at least annually to determine the time required for complete separation of the sample by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.
2. Provide a snug-fitting pan and cover for each sieve and hold in a slightly inclined position in one hand.
3. Hand shake each sieve by striking the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes.

Note A1: A mallet may be used instead of the heel of the hand if comparable force is used.

If more than 0.5 percent by mass of the total sample before sieving passes any sieve after one minute of continuous hand shaking adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.

ANNEX B**Overload Determination**

(Mandatory information)

Additional sieves may be necessary to keep from overloading sieves or to provide other information, such as fineness modulus. The sample may also be sieved in increments to prevent overloading.

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m^2 (4 g/in^2) of sieving surface.
- For sieves with openings 4.75 mm (No. 4) and larger, the mass, in grams shall not exceed the product of $2.5 \times (\text{sieve opening in mm}) \times (\text{effective sieving area})$. See Table B1.

TABLE B1

Maximum Allowable Mass of Material Retained on a Sieve, g
Nominal Sieve Size, mm (in.)
Exact size is smaller (see AASHTO T 27)

Sieve Size		203 dia	305 dia	305 by 305	350 by 350	372 by 580
mm (in.)		(8)	(12)	(12 × 12)	(14 × 14)	(16 × 24)
		Sieving Area m ²				
		0.0285	0.0670	0.0929	0.1225	0.2158
90	(3 1/2)	*	15,100	20,900	27,600	48,500
75	(3)	*	12,600	17,400	23,000	40,500
63	(2 1/2)	*	10,600	14,600	19,300	34,000
50	(2)	3600	8400	11,600	15,300	27,000
37.5	(1 1/2)	2700	6300	8700	11,500	20,200
25.0	(1)	1800	4200	5800	7700	13,500
19.0	(3/4)	1400	3200	4400	5800	10,200
16.0	(5/8)	1100	2700	3700	4900	8600
12.5	(1/2)	890	2100	2900	3800	6700
9.5	(3/8)	670	1600	2200	2900	5100
6.3	(1/4)	440	1100	1500	1900	3400
4.75	(No. 4)	330	800	1100	1500	2600
-4.75	(-No. 4)	200	470	650	860	1510



Oregon

Kate Brown, Governor

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October 31, 2021

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 30**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Delete Mass Verification Section**
- **Under Procedure step 2 – delete this step.**
- **Under Procedure step 4 – Dispersing agents or wetting solutions are optional.**
- **Under Procedure step 9 – delete this step**
- **Under Procedure step 13 - Shaking time will be a minimum of 10 minutes.**
- **Under Procedure step 17 – Aggregate Correction Factors are at the option of the Engineer.**
- **Under Reporting section, 3rd bullet - Aggregate Correction Factors are at the option of the Engineer.**

MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE FOP FOR AASHTO T 30

Scope

This procedure covers mechanical analysis of aggregate recovered from asphalt mix samples in accordance with AASHTO T 30-21. This FOP uses the aggregate recovered from the ignition furnace used in AASHTO T 308. AASHTO T 30 was developed for analysis of extracted aggregate and thus includes references to extracted bitumen and filter element, which do not apply in this FOP.

Sieve analyses determine the gradation or distribution of aggregate particles within a given sample to determine compliance with design and production standards.

Apparatus

- Balance or scale: Capacity sufficient for the sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g and conforming to AASHTO M 231.
- Sieves, meeting the requirements of FOP for AASHTO T 27/T 11.
- Mechanical sieve shaker, meeting the requirements of FOP for AASHTO T 27/T 11.
- Mechanical Washing Apparatus (optional).
- Suitable drying equipment, meeting the requirements of the FOP for AASHTO T 255.
- Containers and utensils: A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.
- Wetting Agent: Any dispersing agent, such as dishwashing detergent, that will promote separation of the fine materials.

Sample Sieving

- In this procedure, it is required to shake the sample over nested sieves. Sieves are selected to furnish information required by specification. Intermediate sieves are added for additional information or to avoid overloading sieves, or both.
- The sieves are nested in order of increasing size from the bottom to the top, and the test sample, or a portion of the test sample, is placed on the top sieve.
- The loaded sieves are shaken in a mechanical shaker for approximately 10 minutes, refer to Annex A; *Time Evaluation*.

Mass Verification

The aggregate sample mass, $M_{(T30)}$, determined in this method, shall agree with the mass of the aggregate remaining after ignition, M_f from the FOP for AASTHO T 308, within 0.10 percent. If the variation exceeds 0.10 percent, the results cannot be used for acceptance.

Procedure

1. Determine and record the mass of the sample that was removed from the basket in the FOP for AASHTO T 308 to 0.1 g. Designate this mass as $M_{(T30)}$.
 2. Verify the mass of the sample is within 0.10 percent by subtracting $M_{(T30)}$ from $M_{(T308)}$ dividing by $M_{(T308)}$ and multiply by 100 (see *Mass Verification Calculation* and example).

If the variation exceeds 0.10 percent, the sieve analysis results cannot be used for acceptance.
 3. Nest a sieve, such as a 2.0 mm (No. 10) or 1.18 mm (No. 16), above the 75 μ m (No. 200) sieve.
 4. Place the test sample in a container and cover with water. Add a wetting agent to the water to assure a thorough separation of the material finer than the 75 μ m (No. 200) sieve from the coarser particles. There should be enough wetting agent to produce a small amount of suds when the sample is agitated. Excessive suds may overflow the sieves and carry material away with them.
 5. Agitate vigorously to ensure complete separation of the material finer than 75 μ m (No. 200) from coarser particles and bring the fine material into suspension above the coarser material. Avoid degradation of the sample when using a mechanical washing device. Maximum agitation is 10 min.
- Note 1:* When mechanical washing equipment is used, the introduction of water, agitating, and decanting may be a continuous operation. Use care not to overflow or overload the 75 μ m (No. 200) sieve.
6. Immediately pour the wash water containing the suspended material over the nested sieves; be careful not to pour out the coarser particles or over fill the 75 μ m (No. 200) sieve.
 7. Add water to cover material remaining in the container, agitate, and repeat Step 6. Continue until the wash water is reasonably clear.
 8. Remove the upper sieve, return material retained to the washed sample.
 9. Rinse the material retained on the 75 μ m (No. 200) sieve until water passing through the sieve is reasonably clear and wetting agent is removed.
 10. Return all material retained on the 75 μ m (No. 200) sieve to the washed sample by rinsing into the washed sample.
 11. Dry the washed test sample to constant mass according to the FOP for AASHTO T 255. Cool to room temperature. Determine and record the “dry mass after washing.”
 12. Select sieves required by the specification and those necessary to avoid overloading. (See Annex B.) With a pan on bottom, nest the sieves increasing in size starting with the 75 μ m (No. 200).
 13. Place the test sample, or a portion of the test sample, on the top sieve. Place sieves in mechanical shaker and shake for the minimum time determined to provide complete separation for the sieve shaker being used (approximately 10 minutes, the time determined by Annex A).

Note 2: Excessive shaking (more than 10 minutes) may result in degradation of the sample.

14. Determine and record the individual or cumulative mass retained for each sieve including the pan. Ensure that all material trapped in full openings of the sieves are removed and included in the mass retained.

Note 3: For sieves 4.75 mm (No. 4) and larger, check material trapped in less than a full opening by sieving over a full opening. Use coarse wire brushes to clean the 600 µm (No. 30) and larger sieves, and soft bristle brushes for smaller sieves.

15. Perform the *Check Sum* calculation – Verify the *total mass after sieving* of material compared to the *dry mass after washing* is not more than 0.2 percent. Do not use test results for acceptance if the *Check Sum* result is more than 0.2 percent.

16. Calculate the total percentages passing, and the individual or cumulative percentages retained, to the nearest 0.1 percent by dividing the individual sieve masses or cumulative sieve masses by the total mass of the initial dry sample.

17. Apply the Aggregate Correction Factor (ACF) to the calculated percent passing, as required in the FOP for AASHTO T 308 “Correction Factor,” to obtain the reported percent passing.

18. Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Calculations

Mass verification

$$\text{Mass verification} = \frac{M_{f(T308)} - M_{(T30)}}{M_{f(T308)}} \times 100$$

Where:

$M_{f(T308)}$ = Mass of aggregate remaining after ignition from the FOP for AASHTO T 308

$M_{(T30)}$ = Mass of aggregate sample obtained from the FOP for AASHTO T 308

Check Sum

$$\text{check sum} = \frac{\text{dry mass after washing} - \text{total mass after sieving}}{\text{dry mass after washing}} \times 100$$

Percent Retained**Individual**

$$IPR = \frac{IMR}{M_{T30}} \times 100$$

Cumulative

$$CPR = \frac{CMR}{M_{T30}} \times 100$$

Where:

IPR	=	Individual Percent Retained
CPR	=	Cumulative Percent Retained
M_{T30}	=	Total dry sample mass before washing
IMR	=	Individual Mass Retained
CMR	=	Cumulative Mass Retained

Percent Passing**Individual**

$$PP = PCP - IPR$$

Cumulative

$$PP = 100 - CPR$$

Where:

PP	=	Calculated Percent Passing
PCP	=	Previous Calculated Percent Passing

Reported Percent Passing

$$RPP = PP + ACF$$

Where:

RPP = Reported Percent Passing

ACF = Aggregate Correction Factor (if applicable)

Example

Mass verification

$$Mass\ verification = \frac{2422.5\ g - 2422.3\ g}{2422.5\ g} \times 100 = 0.01\%$$

Given:

$$M_{R(T308)} = 2422.5\ g$$

$$M_{(T30)} = 2422.3\ g$$

Dry mass of total sample, before washing (M_{T30}):	2422.3 g
Dry mass of sample, after washing out the 75 μ m (No. 200) minus:	2296.2 g
Amount of 75 μ m (No. 200) minus washed out ($2422.3\ g - 2296.2\ g$):	126.1 g

Check sum

$$check\ sum = \frac{2296.2\ g - 2295.3\ g}{2296.2\ g} \times 100 = 0.0\%$$

This is not more than 0.2 percent therefore the results can be used for acceptance purposes.

Percent Retained for the 75 µm (No. 200) sieve

$$IPR = \frac{63.5 \text{ g}}{2422.3 \text{ g}} \times 100 = 2.6\%$$

or

$$CPR = \frac{2289.6 \text{ g}}{2422.3 \text{ g}} \times 100 = 94.5\%$$

Percent Passing using IPR and PCP for the 75 µm (No. 200) sieve

$$PP = 8.1\% - 2.6\% = 5.5\%$$

Percent Passing using CPR for the 75 µm (No. 200) sieve

$$PP = 100.0\% - 94.5\% = 5.5\%$$

Reported Percent Passing

$$RPP = 5.5\% + (-0.6\%) = 4.9\%$$

**Individual
Gradation on All Sieves**

Sieve Size mm (in.)	Individual Mass Retained g (IMR)	Determine IPR by dividing IMR by <i>M</i> and multiplying by 100	Individual Percent Retained (IPR)	Determine PP by subtracting IPR from Previous PP	Percent Passing (PP)	Agg. Corr. Factor from T 308 (ACF)	Reported Percent Passing*
19.0 (3/4)	0		0		100.0		100
12.5 (1/2)	346.9	$\frac{346.9}{2422.3} \times 100 =$	14.3	$100.0 - 14.3 =$	85.7		86
9.5 (3/8)	207.8	$\frac{207.8}{2422.3} \times 100 =$	8.6	$85.7 - 8.6 =$	77.1		77
4.75 (No. 4)	625.4	$\frac{625.4}{2422.3} \times 100 =$	25.8	$77.1 - 25.8 =$	51.3		51
2.36 (No. 8)	416.2	$\frac{416.2}{2422.3} \times 100 =$	17.2	$51.3 - 17.2 =$	34.1		34
1.18 (No. 16)	274.2	$\frac{274.2}{2422.3} \times 100 =$	11.3	$34.1 - 11.3 =$	22.8		23
0.600 (No. 30)	152.1	$\frac{152.1}{2422.3} \times 100 =$	6.3	$22.8 - 6.3 =$	16.5		17
0.300 (No. 50)	107.1	$\frac{107.1}{2422.3} \times 100 =$	4.4	$16.5 - 4.4 =$	12.1		12
0.150 (No. 100)	96.4	$\frac{96.4}{2422.3} \times 100 =$	4.0	$12.1 - 4.0 =$	8.1		8
0.075 (No. 200)	63.5	$\frac{63.5}{2422.3} \times 100 =$	2.6	$8.1 - 2.6 =$	5.5	-0.6 (5.5 - 0.6 =)	4.9
minus 75 µm (No. 200) in the pan	5.7						
Total mass after sieving = sum of sieves + mass in the pan = 2295.3 g							
Dry mass of total sample, before washing (M _{T30}): 2422.3g							

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

**Cumulative
Gradation on All Sieves**

Sieve Size mm (in.)	Cumulative Mass Retained g (CMR)	Determine CPR by dividing CMR by M and multiplying by 100	Cumulative Percent Retained (CPR)	Determine PP by subtracting CPR from 100.0	Percent Passing (PP)	Agg. Corr. Factor from T 308 (ACF)	Reported Percent Passing*
19.0 (3/4)	0		0.0		100.0		100
12.5 (1/2)	346.9	$\frac{346.9}{2422.3} \times 100 =$	14.3	$100.0 - 14.3 =$	85.7		86
9.5 (3/8)	554.7	$\frac{554.7}{2422.3} \times 100 =$	22.9	$100.0 - 22.9 =$	77.1		77
4.75 (No. 4)	1180.1	$\frac{1180.1}{2422.3} \times 100 =$	48.7	$100.0 - 48.7 =$	51.3		51
2.36 (No. 8)	1596.3	$\frac{1596.3}{2422.3} \times 100 =$	65.9	$100.0 - 65.9 =$	34.1		34
1.18 (No. 16)	1870.5	$\frac{1870.5}{2422.3} \times 100 =$	77.2	$100.0 - 77.2 =$	22.8		23
0.600 (No. 30)	2022.6	$\frac{2022.6}{2422.3} \times 100 =$	83.5	$100.0 - 83.5 =$	16.5		17
0.300 (No. 50)	2129.7	$\frac{2129.7}{2422.3} \times 100 =$	87.9	$100.0 - 87.9 =$	12.1		12
0.150 (No. 100)	2226.1	$\frac{2226.1}{2422.3} \times 100 =$	91.9	$100.0 - 91.9 =$	8.1		8
0.075 (No. 200)	2289.6	$\frac{2289.6}{2422.3} \times 100 =$	94.5	$100.0 - 94.5 =$	5.5	-0.6 (5.5 - 0.6 =)	4.9
minus 75 µm (No. 200) in the pan	2295.3						
Total mass after sieving = 2295.3 g							
Dry mass of total sample, before washing (M _{T30}): 2422.3g							

* Report total percent passing to 1 percent except report the 75 µm (No. 200) sieve to 0.1 percent.

Report

- On forms approved by the agency
- Sample ID
- Depending on the agency, this may include:
 - Individual mass retained on each sieve
 - Individual percent retained on each sieve
 - Cumulative mass retained on each sieve
 - Cumulative percent retained on each sieve
 - Aggregate Correction Factor for each sieve from AASHTO T 308
 - Calculated percent passing each sieve to 0.1 percent
- Percent passing to the nearest 1 percent, except 75 μm (No. 200) sieve to the nearest 0.1 percent.

ANNEX A TIME EVALUATION

(Mandatory Information)

The minimum time requirement should be evaluated for each shaker at least annually by the following method:

1. Shake the sample over nested sieves for approximately 10 minutes.
2. Provide a snug-fitting pan and cover for each sieve and hold in a slightly inclined position in one hand.
3. Hand-shake each sieve by striking the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turning the sieve about one sixth of a revolution at intervals of about 25 strokes.

If more than 0.5 percent by mass of the total sample before sieving passes any sieve after one minute of continuous hand sieving adjust shaker time and re-check.

In determining sieving time for sieve sizes larger than 4.75 mm (No. 4), limit the material on the sieve to a single layer of particles.

ANNEX B OVERLOAD DETERMINATION

(Mandatory Information)

- For sieves with openings smaller than 4.75 mm (No. 4), the mass retained on any sieve shall not exceed 7 kg/m² (4 g/in²) of sieving surface.
- For sieves with openings 4.75 mm (No. 4) and larger, the mass (in kg) shall not exceed the product of 2.5 x (sieve opening in mm) x (effective sieving area). See Table B1.

Additional sieves may be necessary to keep from overloading the specified sieves. The sample may also be sieved in increments or sieves with a larger surface area.

TABLE B1
Maximum Allowable Mass of Material Retained on a Sieve, g
Nominal Sieve Size, mm (in.)
Exact size is smaller (see AASHTO T 27)

Sieve Size	203 mm	254 mm	305 mm
mm (in.)	(8 in.)	(10 in.)	(12 in.)
	dia.	dia.	dia.
	Sieving Area m ² (in ²)		
	0.0285	0.0457	0.0670
	(44.2)	(70.8)	(103.5)
50 (2)	3600	5700	8400
37.5 (1 1/2)	2700	4300	6300
25.0 (1)	1800	2900	4200
19.0 (3/4)	1400	2200	3200
16.0 (5/8)	1100	1800	2700
12.5 (1/2)	890	1400	2100
9.5 (3/8)	670	1100	1600
6.3 (1/4)	440	720	1100
4.75 (No. 4)	330	540	800
-4.75 (-No. 4)	200	320	470

Specific Gravity and Absorption of Fine Aggregate

AASHTO Designation: T 84-22

ASTM Designation: C 128-12

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SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE FOP FOR AASHTO T 85

Scope

This procedure covers the determination of specific gravity and absorption of coarse aggregate in accordance with AASHTO T 85-22. Specific gravity may be expressed as bulk specific gravity (G_{sb}), bulk specific gravity, saturated surface dry (G_{sb} SSD), or apparent specific gravity (G_{sa}). G_{sb} and absorption are based on aggregate after soaking in water. This procedure is not intended to be used with lightweight aggregates.

Terminology

Absorption – the increase in the mass of aggregate due to water being absorbed into the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry mass. The aggregate is considered “dry” when it has been maintained at a temperature of $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) for sufficient time to remove all uncombined water.

Saturated Surface Dry (SSD) – condition of an aggregate particle when the permeable voids are filled with water, but no water is present on exposed surfaces.

Specific Gravity – the ratio of the mass, in air, of a volume of a material to the mass of the same volume of gas-free distilled water at a stated temperature.

Apparent Specific Gravity (G_{sa})– the ratio of the mass, in air, of a volume of the impermeable portion of aggregate to the mass of an equal volume of gas-free distilled water at a stated temperature.

Bulk Specific Gravity (G_{sb})– the ratio of the mass, in air, of a volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) to the mass of an equal volume of gas-free distilled water at a stated temperature.

Bulk Specific Gravity (SSD) (G_{sb} SSD) – the ratio of the mass, in air, of a volume of aggregate, including the mass of water within the voids filled to the extent achieved by submerging in water for 15 to 19 hours (but not including the voids between particles), to the mass of an equal volume of gas-free distilled water at a stated temperature.

Apparatus

- Balance or scale: with a capacity of 5 kg, sensitive to 0.1 g. Meeting the requirements of AASHTO M 231.
- Sample container: a wire basket of 3.35 mm (No. 6) or smaller mesh, with a capacity of 4 to 7 L (1 to 2 gal) to contain aggregate with a nominal maximum size of 37.5 mm (1 1/2 in.) or smaller; or a larger basket for larger aggregates, or both.
- Water tank: watertight and large enough to completely immerse aggregate and basket, equipped with an overflow valve to keep water level constant.

- Suspension apparatus: wire used to suspend apparatus shall be of the smallest practical diameter.
- Sieves: 4.75 mm (No. 4) or other sizes as needed, meeting the requirements of FOP for AASHTO T 27/T 11.
- Large absorbent towel

Sample Preparation

1. Obtain the sample in accordance with the FOP for AASHTO R 90 (see Note 1).
2. Mix the sample thoroughly and reduce it to the approximate sample size required by Table 1 in accordance with the FOP for AASHTO R 76.
3. Reject all material passing the appropriate sieve by dry sieving.
4. Thoroughly wash sample to remove dust or other coatings from the surface.
5. Dry the test sample to constant mass according to the FOP for AASHTO T 255/T 265 at a temperature of 110 ±5°C (230 ±9°F) and cool in air at room temperature for 1 to 3 hours.

Note 1: Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant mass may be eliminated, and, if the surfaces of the particles in the sample have been kept continuously wet until test, the 15-to-19-hour soaking may also be eliminated.

6. Re-screen the sample over the appropriate sieve. Reject all material passing that sieve.
7. The sample shall meet or exceed the minimum mass given in Table 1.

Note 2: If this procedure is used only to determine the G_{sb} of oversized material for the FOP for AASHTO T 99 / T 180, the material can be rejected over the appropriate sieve. For T 99 / T 180 Methods A and B, use the 4.75 mm (No. 4) sieve; T 99 / T 180 Methods C and D use the 19 mm (3/4 in).

Table 1

Nominal Maximum Size* mm (in.)	Minimum Mass of Test Sample, g (lb)
12.5 (1/2) or less	2000 (4.4)
19.0 (3/4)	3000 (6.6)
25.0 (1)	4000 (8.8)
37.5 (1 1/2)	5000 (11)
50 (2)	8000 (18)
63 (2 1/2)	12,000 (26)
75 (3)	18,000 (40)

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure

1. Immerse the aggregate in water at room temperature for a period of 15 to 19 hours.

Note 3: When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more subsamples, and then combine the values obtained.

2. Place the empty basket into the water bath and attach to the balance. Inspect the immersion tank to ensure the water level is at the overflow outlet height and basket is fully submerged. Tare the balance with the empty basket attached in the water bath.
3. Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. If the test sample dries past the SSD condition, immerse in water for 30 min, and then resume the process of surface-drying.

Note 4: A moving stream of air may be used to assist in the drying operation but take care to avoid evaporation of water from aggregate pores.

4. Determine the SSD mass of the sample, and record this and all subsequent masses to the nearest 0.1 g or 0.1 percent of the sample mass, whichever is greater. Designate this mass as "B."
5. Immediately place the SSD test sample in the sample container and weigh it in water maintained at $23.0 \pm 1.7^{\circ}\text{C}$ ($73.4 \pm 3^{\circ}\text{F}$). Shake the container to release entrapped air before recording the weight. Re-inspect the immersion tank to ensure the water level is at the overflow outlet height and basket is fully submerged. Designate this submerged weight as "C."

Note 5: The container should be immersed to a depth sufficient to cover it and the test sample during mass determination. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

6. Remove the sample from the basket. Ensure all material has been removed. Place in a container of known mass.
7. Dry the test sample to constant mass according to the FOP for AASHTO T 255 / T 265 at $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) and cool in air at room temperature for 1 to 3 hours.
8. Determine and record the dry mass. Designate this mass as "A."

Calculations

Perform calculations and determine values using the appropriate formula below.

Bulk specific gravity (G_{sb})

$$G_{sb} = \frac{A}{B - C}$$

Bulk specific gravity, SSD ($G_{sb} SSD$)

$$G_{sb}SSD = \frac{B}{B - C}$$

Apparent specific gravity (G_{sa})

$$G_{sa} = \frac{A}{A - C}$$

Absorption

$$\text{Absorption} = \frac{B - A}{A} \times 100$$

Where:

- A = oven dry mass, g
- B = SSD mass, g
- C = weight in water, g

Sample Calculations

Sample	A	B	C	B - C	A - C	B - A
1	2030.9	2044.9	1304.3	740.6	726.6	14.0
2	1820.0	1832.5	1168.1	664.4	651.9	12.5
3	2035.2	2049.4	1303.9	745.5	731.3	14.2

Sample	G _{sb}	G _{sb} SSD	G _{sa}	Absorption
1	2.742	2.761	2.795	0.7
2	2.739	2.758	2.792	0.7
3	2.730	2.749	2.783	0.7

These calculations demonstrate the relationship between G_{sb}, G_{sb} SSD, and G_{sa}. G_{sb} is always lowest since the volume includes voids permeable to water. G_{sb} SSD is always intermediate. G_{sa} is always highest since the volume does not include voids permeable to water. When running this test, check to make sure the values calculated make sense in relation to one another.

Report

- On forms approved by the agency
- Sample ID
- Specific gravity values to the nearest 0.001
- Absorption to the nearest 0.1 percent

EMBANKMENT AND BASE
IN-PLACE DENSITY

WAQTC

FOP AASHTO T 85 (22)

Observe the following for Base Aggregate applications:

- **Use T 99 Method A and perform the Coarse Particle Correction according to ODOT TM 223. This Process shall be used for Dense Graded Base Aggregate Separated Stockpile sizes of 1" – 0 and smaller. Dense Graded Base Aggregate with Separated Stockpile sizes larger than 1" – 0 and Open graded Base Aggregates are non-density testable and should be evaluated according to the appropriate specifications contained in the project contract documents.**
- **Measures may be taken to reduce or eliminate seepage of moisture from between the mold and the base plate which do not affect the mold's volume.**
- **Moisture content of individual points will be determined using the entire molded sample.**

Annex A Section

Earthwork and other graded Aggregates, except Base Aggregate Applications, use the following Oversize Particle Correction guidelines:

- **Less than 10% plus No. 4 (Method A), no coarse particle correction is required.**
- **10%-- 40% plus No. 4 (Method A), a coarse particle correction is required.**
- **Over 40% plus No. 4 (Method A), re-screen material and perform T 99 method D.**
- **Less than 10% plus 3/4 in. (Method D), no coarse particle correction is required.**
- **10%-- 30% plus 3/4 in. (Method D), a coarse particle correction is required.**
- **Over 30% plus 3/4 in. (Method D), the material is non-density testable and should be evaluated according to the earthwork or appropriate aggregate specifications contained in the project contract documents.**
- ***Percentage of coarse particles can be determined in the wet state.***

Observe the following for other Graded Aggregates:

- **If during crushing operations process control data is available for the No. 4 and/or 3/4 in. screen use the average values to compute the coarse particle correction.**



Oregon

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October 31, 2018

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 99 and T 180**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Methods B & C are not allowed on ODOT contracts.**
- **Use T 99 Methods A or D for earthwork applications and other graded materials, except Base Aggregate, based on the following criteria:**
 1. **The soil or soil/aggregate mixture will first be analyzed according to Method A. If the amount of material retained on the No. 4 screen exceeds 40% then use Method D.**
 2. **If the amount of material retained on the 3/4" screen exceeds 30% then the material is non-density testable and should be evaluated according to the appropriate specifications contained in the project contract documents.**
- **Under Section Apparatus, Mold, determination of the mold volume is not required according to Annex B, if the wet density is computed using the mold volume based on Table 2.**
- **Under Section Apparatus, Balances or Scales for the standard or modified proctor, change the scale sensitivity to 5 g or better.**
- **Under procedure, step 15; delete the second and third sentence. Add the following: *(Note: For proper curve development a minimum of 3 points representing the dry side and 2 points representing the wet side of the curve is considered best practice).***
- **Under the Calculations Section, wet density may be computed using the molds volume in Table 2 or a "Mold Factor" can be used as a multiplier based on the following: Mass determination in lbs., 4" diameter mold (30) and in grams (0.06614) and 6" diameter mold in lbs. (13.33) and in grams (0.02939).**

(See Next Page)

**MOISTURE-DENSITY RELATIONS OF SOILS:
USING A 2.5 KG (5.5 LB) RAMMER AND A 305 MM (12 IN.) DROP**

FOP FOR AASHTO T 99

USING A 4.54 KG (10 LB) RAMMER AND A 457 MM (18 IN.) DROP

FOP FOR AASHTO T 180

Scope

This procedure covers the determination of the moisture-density relations of soils and soil-aggregate mixtures in accordance with two similar test methods:

- AASHTO T 99-22: Methods A, B, C, and D
- AASHTO T 180-22: Methods A, B, C, and D

This test method applies to soil mixtures having 40 percent or less retained on the 4.75 mm (No. 4) sieve for methods A or B, or 30 percent or less retained on the 19 mm ($\frac{3}{4}$ in.) sieve with methods C or D. The retained material is defined as oversize (coarse) material. If no minimum percentage is specified, 5 percent will be used. Samples that contain oversize (coarse) material that meet percent retained criteria should be corrected by using *Annex A, Correction of Maximum Dry Density and Optimum Moisture for Oversized Particles*. Samples of soil or soil-aggregate mixture are prepared at several moisture contents and compacted into molds of specified size, using manual or mechanical rammers that deliver a specified quantity of compactive energy. The moist masses of the compacted samples are multiplied by the appropriate factor to determine wet density values. Moisture contents of the compacted samples are determined and used to obtain the dry density values of the same samples. Maximum dry density and optimum moisture content for the soil or soil-aggregate mixture is determined by plotting the relationship between dry density and moisture content.

Apparatus

- Mold – Cylindrical mold made of metal with the dimensions shown in Table 1 or Table 2. If permitted by the agency, the mold may be of the “split” type, consisting of two half-round sections, which can be securely locked in place to form a cylinder. Determine the mold volume according to *Annex B, Standardization of the Mold*.
- Mold assembly – Mold, base plate, and a detachable collar.
- Rammer – Manually or mechanically operated rammers as detailed in Table 1 or Table 2. A manually operated rammer shall be equipped with a guide sleeve to control the path and height of drop. The guide sleeve shall have at least four vent holes no smaller than 9.5 mm ($\frac{3}{8}$ in.) in diameter, spaced approximately 90 degrees apart and approximately 19 mm ($\frac{3}{4}$ in.) from each end. A mechanically operated rammer will uniformly distribute blows over the sample and will be calibrated with several soil types, and be adjusted, if necessary, to give the same moisture-density results as with the manually operated rammer. For additional information concerning calibration, see AASHTO T 99 and T 180.

- Sample extruder – A jack, lever frame, or other device for extruding compacted specimens from the mold quickly and with little disturbance.
- Balance(s) or scale(s) of the capacity and sensitivity required for the procedure used by the agency.
 - A balance or scale with a capacity of 11.5 kg (25 lb) and a sensitivity of 1 g for obtaining the sample, meeting the requirements of AASHTO M 231, Class G 5.
 - A balance or scale with a capacity of 2 kg and a sensitivity of 0.1 g is used for moisture content determinations done under both procedures, meeting the requirements of AASHTO M 231, Class G 2.
- Drying apparatus – A thermostatically controlled drying oven, capable of maintaining a temperature of $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$) for drying moisture content samples in accordance with the FOP for AASHTO T 255/T 265.
- Straightedge – A steel straightedge at least 250 mm (10 in.) long, with one beveled edge and at least one surface plane within 0.1 percent of its length, used for final trimming.
- Sieve(s) – 4.75 mm (No. 4) and/or 19.0 mm (3/4 in.), meeting the requirements of FOP for AASHTO T 27/T 11.
- Mixing tools – Miscellaneous tools such as a mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device, for mixing the sample with water.
- Containers with close-fitting lids to prevent gain or loss of moisture in the sample.

Table 1
Comparison of Apparatus, Sample, and Procedure – Metric

	T 99	T 180
Mold Volume, m ³	Methods A, C: 0.000943 ±0.000014	Methods A, C: 0.000943 ±0.000014
	Methods B, D: 0.002124 ±0.000025	Methods B, D: 0.002124 ±0.000025
Mold Diameter, mm	Methods A, C: 101.60 ±0.40	Methods A, C: 101.60 ±0.4
	Methods B, D: 152.40 ±0.70	Methods B, D: 152.40 ±0.70
Mold Height, mm	116.40 ±0.50	116.40 ±0.50
Detachable Collar Height, mm	50.80 ±0.64	50.80 ±0.64
Rammer Diameter, mm	50.80 ±0.25	50.80 ±0.25
Rammer Mass, kg	2.495 ±0.009	4.536 ±0.009
Rammer Drop, mm	305 ±2	457 ±2
Layers	3	5
Blows per Layer	Methods A, C: 25	Methods A, C: 25
	Methods B, D: 56	Methods B, D: 56
Material Size, mm	Methods A, B: 4.75 minus	Methods A, B: 4.75 minus
	Methods C, D: 19.0 minus	Methods C, D: 19.0 minus
Test Sample Size, kg	Method A: 3 Method C: 5 (1)	Method B: 7 Method D: 11(1)
Energy, kN-m/m ³	592	2,693

(1) This may not be a large enough sample depending on your nominal maximum size for moisture content samples.

Table 2
Comparison of Apparatus, Sample, and Procedure – English

	T 99	T 180
Mold Volume, ft ³	Methods A, C: 0.0333 ±0.0005	Methods A, C: 0.0333 ±0.0005
	Methods B, D: 0.07500 ±0.0009	Methods B, D: 0.07500 ±0.0009
Mold Diameter, in.	Methods A, C: 4.000 ±0.016	Methods A, C: 4.000 ±0.016
	Methods B, D: 6.000 ±0.026	Methods B, D: 6.000 ±0.026
Mold Height, in.	4.584 ±0.018	4.584 ±0.018
Detachable Collar Height, in.	2.000 ±0.025	2.000 ±0.025
Rammer Diameter, in.	2.000 ±0.025	2.000 ±0.025
Rammer Mass, lb	5.5 ±0.02	10 ±0.02
Rammer Drop, in.	12 ±0.06	18 ±0.06
Layers	3	5
Blows per Layer	Methods A, C: 25	Methods A, C: 25
	Methods B, D: 56	Methods B, D: 56
Material Size, in.	Methods A, B: No. 4 minus	Methods A, B: No.4 minus
	Methods C, D: 3/4 minus	Methods C, D: 3/4 minus
Test Sample Size, lb	Method A: 7 Method C: 12 ₍₁₎	Method B: 16 Method D: 25 ₍₁₎
Energy, lb-ft/ft ³	12,375	56,250

(1) This may not be a large enough sample depending on your nominal maximum size for moisture content samples.

Sample

If the sample is damp, dry it 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). Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.

Obtain a representative test sample of the mass required by the agency by passing the material through the sieve required by the agency. See Table 1 or Table 2 for test sample mass and material size requirements.

In instances where the material is prone to degradation, i.e., granular material, a compaction sample with differing moisture contents should be prepared for each point.

If the sample is plastic (clay types), it should stand for a minimum of 12 hours after the addition of water to allow the moisture to be absorbed. In this case, several samples at different moisture contents should be prepared, put in sealed containers, and tested the next day.

Note 1: Both T 99 and T 180 have four methods (A, B, C, D) that require different masses and employ different sieves.

Procedure

During compaction, rest the mold firmly on a dense, uniform, rigid, and stable foundation, or base. This base shall remain stationary during the compaction process.

1. Determine the mass of the clean, dry mold. Include the base plate but exclude the extension collar. Record the mass to the nearest 1 g (0.005 lb).
2. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 to 8 percentage points below optimum moisture content. For many materials, this condition can be identified by forming a cast by hand.
 - a. Prepare individual samples of plastic or degradable material, increasing moisture contents 1 to 2 percent for each point.
 - b. Allow samples of plastic soil to stand for 12 hrs.
3. Form a specimen by compacting the prepared soil in the mold assembly in approximately equal layers. For each layer:
 - a. Spread the loose material uniformly in the mold.

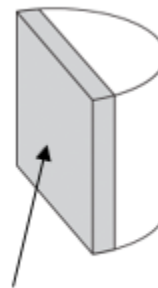
Note 2: It is recommended to cover the remaining material with a non-absorbent sheet or damp cloth to minimize loss of moisture.

- b. Lightly tamp the loose material with the manual rammer or other similar device, this establishes a firm surface.
 - c. Compact each layer with uniformly distributed blows from the rammer. See Table 1 for mold size, number of layers, number of blows, and rammer specification for the various test methods. Use the method specified by the agency.
 - d. Trim down material that has not been compacted and remains adjacent to the walls of the mold and extends above the compacted surface.

4. Remove the extension collar. Avoid shearing off the sample below the top of the mold. The material compacted in the mold should not be over 6 mm (¼ in.) above the top of the mold once the collar has been removed.
5. Trim the compacted soil even with the top of the mold with the beveled side of the straightedge.
6. Clean soil from exterior of the mold and base plate.
7. Determine and record the mass of the mold, base plate, and wet soil to the nearest 1 g (0.005 lb).
8. Determine and record the wet mass (M_w) of the sample by subtracting the mass in Step 1 from the mass in Step 7.
9. Calculate the wet density (ρ_w), in kg/m^3 (lb/ft^3), by dividing the wet mass by the measured volume (V_m).
10. Extrude the material from the mold. For soils and soil-aggregate mixtures, slice vertically through the center and remove one of the cut faces for a representative moisture content sample. For granular materials, a vertical face will not exist. Take a representative sample ensuring that all layers are represented. This sample must meet the sample size requirements of the test method used to determine moisture content.



Extruded material



**Representative moisture
content sample**

Note 3: When developing a 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 content from the mixing bowl may be preferred in order to determine the amount of moisture available for compaction.

11. Determine and record the moisture content (w) of the sample in accordance with the FOP for AASHTO T 255 / T 265.
12. If the material is degradable or plastic, return to Step 3 using a prepared individual sample. If not, continue with Steps 13 through 15.
13. Thoroughly break up the remaining portion of the molded specimen until it will again pass through the sieve, as judged by eye, and add to the remaining portion of the sample being tested.
14. Add sufficient water to increase the moisture content of the remaining soil by 1 to 2 percentage points and repeat steps 3 through 11.

15. Continue determinations until there is either a decrease or no change in the wet mass.
There will be a minimum of three points on the dry side of the curve and two points on the wet side. For non-cohesive, drainable soils, one point on the wet side is sufficient.

Calculations

Wet Density

$$\rho_w = \frac{M_w}{V_m}$$

Where:

$$\begin{aligned} \rho_w &= \text{wet density, kg/m}^3 \text{ (lb/ft}^3\text{)} \\ M_w &= \text{wet mass} \\ V_m &= \text{volume of the mold, Annex B} \end{aligned}$$

Dry Density

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

Where:

$$\begin{aligned} \rho_d &= \text{dry density, kg/m}^3 \text{ (lb/ft}^3\text{)} \\ w &= \text{moisture content, as a percentage} \end{aligned}$$

Example for 4-inch mold, Methods A or C

$$\begin{aligned} \text{Wet mass, } M_w &= 1.928 \text{ kg (4.25 lb)} \\ \text{Moisture content, } w &= 11.3\% \\ \text{Measured volume of the mold, } V_m &= 0.000946 \text{ m}^3 \text{ (0.0334 ft}^3\text{)} \end{aligned}$$

Wet Density

$$\rho_w = \frac{1.928 \text{ kg}}{0.000946 \text{ m}^3} = 2038 \text{ kg/m}^3 \quad \rho_w = \frac{4.25 \text{ lb}}{0.0334 \text{ ft}^3} = 127.2 \text{ lb/ft}^3$$

Dry Density

$$\rho_d = \left(\frac{2038 \text{ kg/m}^3}{11.3 + 100} \right) \times 100 = 1831 \text{ kg/m}^3 \quad \rho_d = \left(\frac{127.2 \text{ lb/ft}^3}{11.3 + 100} \right) \times 100 = 114.3 \text{ lb/ft}^3$$

Or

$$\rho_d = \left(\frac{2038 \text{ kg/m}^3}{\frac{11.3}{100} + 1} \right) = 1831 \text{ kg/m}^3 \quad \rho_d = \left(\frac{127.2 \text{ lb/ft}^3}{\frac{11.3}{100} + 1} \right) = 114.3 \text{ lb/ft}^3$$

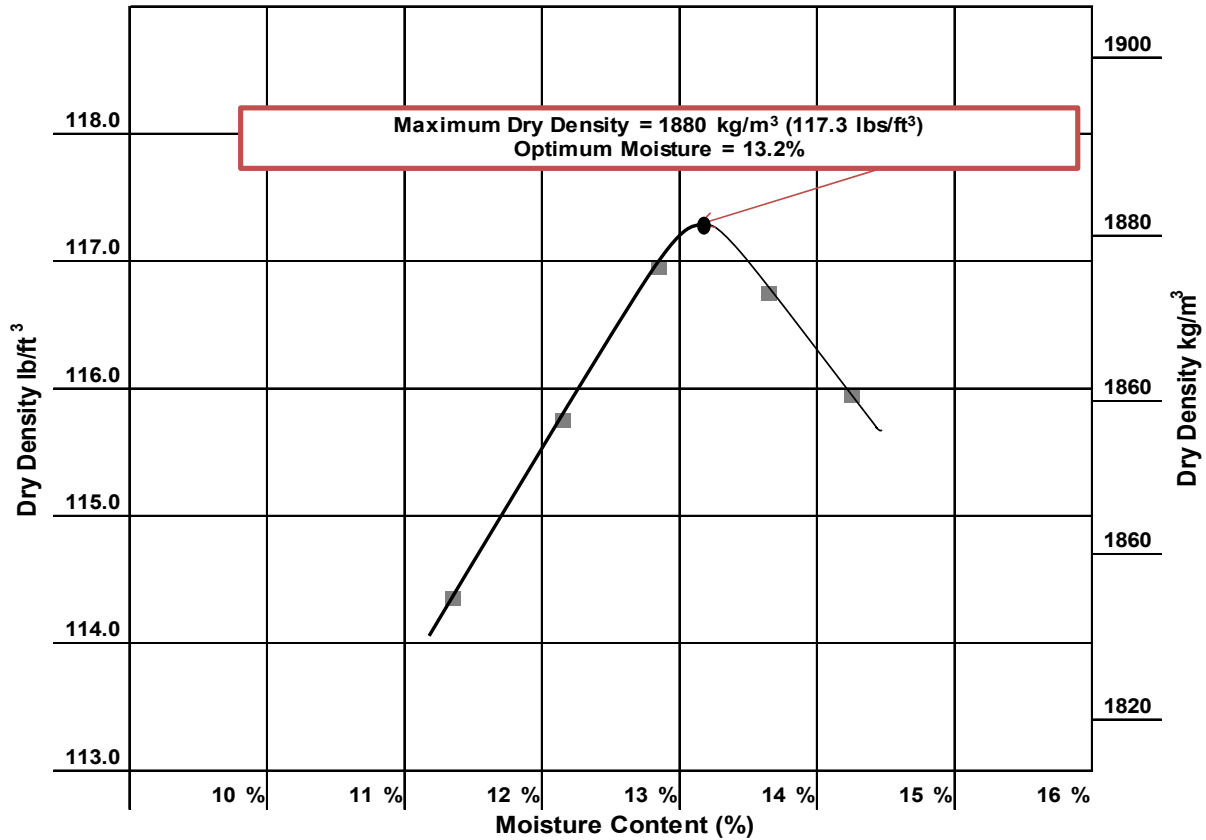
Moisture-Density Curve Development

When dry density is plotted on the vertical axis versus moisture content on the horizontal axis and the points are connected with a smooth line, a moisture-density curve is developed. The coordinates of the peak of the curve are the maximum dry density, or just “maximum density,” and the “optimum moisture content” of the soil.

Example

Given the following dry density and corresponding moisture content values develop a moisture-density relations curve and determine maximum dry density and optimum moisture content.

Dry Density		Moisture Content, %
kg/m ³	lb/ft ³	
1831	114.3	11.3
1853	115.7	12.1
1873	116.9	12.8
1869	116.7	13.6
1857	115.9	14.2



In this case, the curve has its peak at:

Maximum dry density = 1880 kg/m³ (117.3 lb/ft³)

Optimum moisture content = 13.2%

Note that both values are approximate since they are based on sketching the curve to fit the points.

Report

- Results on forms approved by the agency
- Sample ID
- Maximum dry density to the nearest 1 kg/m³ (0.1 lb/ft³)
- Optimum moisture content to the nearest 0.1 percent

ANNEX A

CORRECTION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE FOR OVERSIZED PARTICLES

(Mandatory Information)

This section corrects the maximum dry density and moisture content of the material retained on the 4.75 mm (No. 4) sieve, Methods A and B; or the material retained on the 19 mm (¾ in.) sieve, Methods C and D. The maximum dry density, corrected for oversized particles and total moisture content, are compared with the field-dry density and field moisture content.

This correction can be applied to the sample on which the maximum dry density is performed. A correction may not be practical for soils with only a small percentage of oversize material. The agency shall specify a minimum percentage below which the method is not needed. If not specified, this method applies when more than 5 percent by weight of oversize particles is present.

Bulk specific gravity (G_{sb}) of the oversized particles is required to determine the corrected maximum dry density. Use the bulk specific gravity as determined using the FOP for AASHTO T 85 in the calculations. For construction activities, an agency established value or specific gravity of 2.600 may be used.

This correction can also be applied to the sample obtained from the field while performing in-place density.

Procedure

1. Use the sample from this procedure or a sample obtained according to the FOP for AASHTO T 310.
2. Sieve the sample on the 4.75 mm (No. 4) sieve for Methods A and B or the 19 mm (¾ in.) sieve, Methods C and D.
3. Determine the dry mass of the oversized and fine fractions (M_{DC} and M_{DF}) by one of the following:
 - a. Dry the fractions, fine and oversized, in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F).
 - b. Calculate the dry masses using the moisture samples.

To determine the dry mass of the fractions using moisture samples.

1. Determine the moist mass of both fractions, fine (M_{Mf}) and oversized (M_{Mc}):
2. Obtain moisture samples from the fine and oversized material.
3. Determine the moisture content of the fine particles (MC_f) and oversized particles (MC_c) of the material by FOP for AASHTO T 255/T 265 or agency approved method.
4. Calculate the dry mass of the oversize and fine particles.

$$M_D = \frac{M_m}{1 + MC}$$

Where:

M_D = mass of dry material (fine or oversize particles)

M_m = mass of moist material (fine or oversize particles)

MC = moisture content of respective fine or oversized, expressed as a decimal

5. Calculate the percentage of the fine (P_f) and oversized (P_c) particles by dry weight of the total sample as follows: See Note 2.

$$P_f = \frac{100 \times M_{DF}}{M_{DF} + M_{DC}} \quad \frac{100 \times 15.4 \text{ lb}}{15.4 \text{ lbs} + 5.7 \text{ lb}} = 73\% \quad \frac{100 \times 6.985 \text{ kg}}{6.985 \text{ kg} + 2.585 \text{ kg}} = 73\%$$

And

$$P_c = \frac{100 \times M_{DC}}{M_{DF} + M_{DC}} \quad \frac{100 \times 5.7 \text{ lb}}{15.4 \text{ lbs} + 5.7 \text{ lb}} = 27\% \quad \frac{100 \times 2.585 \text{ kg}}{6.985 \text{ kg} + 2.585 \text{ kg}} = 27\%$$

Or for P_c :

$$P_c = 100 - P_f$$

Where:

P_f = percent of fine particles, of sieve used, by weight

P_c = percent of oversize particles, of sieve used, by weight

M_{DF} = mass of dry fine particles

M_{DC} = mass of dry oversize particles

Optimum Moisture Correction Equation

1. Calculate the corrected moisture content as follows:

$$MC_T = \frac{(MC_F \times P_f) + (MC_C \times P_C)}{100} = \frac{(13.2\% \times 73.0\%) + (2.1\% \times 27.0\%)}{100} = 10.2\%$$

MC_T = corrected moisture content of combined fines and oversized particles, expressed as a % moisture

MC_F = moisture content of fine particles, as a % moisture

MC_C = moisture content of oversized particles, as a % moisture

Note 1: Moisture content of oversize material can be assumed to be two (2) percent for most construction applications.

Note 2: In some field applications agencies will allow the percentages of oversize and fine materials to be determined with the materials in the wet state.

Density Correction Equation

2. Calculate the corrected dry density (ρ_d) of the total sample (combined fine and oversized particles) as follows:

$$\rho_d = \frac{100\%}{\left[\left(\frac{P_f}{\rho_f} \right) + \left(\frac{P_c}{k} \right) \right]}$$

Where:

ρ_d = corrected total dry density (combined fine and oversized particles)
kg/m³ (lb/ft³)

ρ_f = dry density of the fine particles kg/m³ (lb/ft³), determined in the lab

P_c = percent of dry oversize particles, of sieve used, by weight.

P_f = percent of dry fine particles, of sieve used, by weight.

k = Metric: 1,000 * Bulk Specific Gravity (G_{sb}) (oven dry basis)
of coarse particles (kg/m³).

k = English: 62.4 * Bulk Specific Gravity (G_{sb}) (oven dry basis)
of coarse particles (lb/ft³)

Note 3: If the specific gravity is known, then this value will be used in the calculation. For most construction activities the specific gravity for aggregate may be assumed to be 2.600.

Calculation

Example

- Metric:

Maximum laboratory dry density (ρ_p):	1880 kg/m ³
Percent coarse particles (P_c):	27%
Percent fine particles (P_f):	73%
Mass per volume coarse particles (k):	(2.697) (1000) = 2697 kg/m ³

$$\rho_d = \frac{100\%}{\left[\left(\frac{P_f}{\rho_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

$$\rho_d = \frac{100\%}{\left[\left(\frac{73\%}{1880 \text{ kg/m}^3}\right) + \left(\frac{27\%}{2697 \text{ kg/m}^3}\right)\right]}$$

$$\rho_d = \frac{100\%}{[0.03883 \text{ kg/m}^3 + 0.01001 \text{ kg/m}^3]}$$

$$\rho_d = 2047.5 \text{ kg/m}^3 \text{ report } 2048 \text{ kg/m}^3$$

English:

Maximum laboratory dry density (ρ_f): 117.3 lb/ft³

Percent coarse particles (P_c): 27%

Percent fine particles (P_f): 73%

Mass per volume of coarse particles (k): (2.697) (62.4) = 168.3 lb/ft³

$$\rho_d = \frac{100\%}{\left[\left(\frac{P_f}{\rho_f}\right) + \left(\frac{P_c}{k}\right)\right]}$$

$$\rho_d = \frac{100\%}{\left[\left(\frac{73\%}{117.3 \text{ lb/ft}^3}\right) + \left(\frac{27\%}{168.3 \text{ lb/ft}^3}\right)\right]}$$

$$\rho_d = \frac{100\%}{[0.6223 \text{ lb/ft}^3 + 0.1604 \text{ lb/ft}^3]}$$

$$\rho_d = \frac{100\%}{0.7827 \text{ lb/ft}^3}$$

$$\rho_d = 127.76 \text{ lb/ft}^3 \quad \text{Report } 127.8 \text{ lb/ft}^3$$

Report

- On forms approved by the agency
- Sample ID
- Corrected maximum dry density to the nearest 1 kg/m³ (0.1 lb/ft³)
- Corrected optimum moisture to the nearest 0.1 percent

ANNEX B

STANDARDIZATION OF THE MOLD

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedure as described herein will produce inaccurate or unreliable test results.

Apparatus

- Mold and base plate
- Balance or scale – Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Cover plate – A piece of plate glass, at least 6 mm (1/4 in.) thick and at least 25 mm (1 in.) larger than the diameter of the mold.
- Thermometers – Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

1. Create a watertight seal between the mold and base plate.
2. Determine and record the mass of the dry sealed mold, base plate, and cover plate.
3. Fill the mold with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the cover plate in such a way as to eliminate bubbles and excess water.
4. Wipe the outside of the mold, base plate, and cover plate dry, being careful not to lose any water from the mold.
5. Determine and record the mass of the filled mold, base plate, cover plate, and water.
6. Determine and record the mass of the water in the mold by subtracting the mass in Step 2 from the mass in Step 5.
7. Measure the temperature of the water and determine its density from Table B1, interpolating, as necessary.
8. Calculate the volume of the mold, V_m , by dividing the mass of the water in the mold by the density of the water at the measured temperature.

Calculations

$$V_m = \frac{M}{\rho_{water}}$$

Where:

V_m = volume of the mold

M = mass of water in the mold

ρ_{water} = density of water at the measured temperature

Example

Mass of water in mold = 0.94367 kg (2.0800 lb)

ρ_{water} at 23°C (73.4°F) = 997.54 kg/m³ (62.274 lb/ft³)

$$V_m = \frac{0.94367 \text{ kg}}{997.54 \text{ kg/m}^3} = 0.000946 \text{ m}^3 \quad V_m = \frac{2.0800 \text{ lb}}{62.274 \text{ lb/ft}^3} = 0.0334 \text{ ft}^3$$

Table B1
Unit Mass of Water
15°C to 30°C

°C	(°F)	kg/m ³	(lb/ft ³)	°C	(°F)	kg/m ³	(lb/ft ³)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

- Mold ID
- Date Standardized
- Temperature of the water
- Volume, V_m , of the mold to the nearest 0.000001 m^3 (0.0001 ft^3)

SLUMP OF HYDRAULIC CEMENT CONCRETE FOP FOR AASHTO T 119

Scope

This procedure provides instructions for determining the slump of hydraulic cement concrete in accordance with AASHTO T 119-18. It is not applicable to non-plastic and non-cohesive concrete.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Mold: conforming to AASHTO T 119
 - Metal: a metal frustum of a cone provided with foot pieces and handles. The mold must be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free from dents. A mold that clamps to a rigid nonabsorbent base plate is acceptable provided the clamping arrangement is such that it can be fully released without movement of the mold.
 - Non-metal: see AASHTO T 119, Section 5.1.2.
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means “half a sphere”; the tip is rounded like half of a ball.)
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Tape measure or ruler with at least 5 mm or 1/8 in. graduations
- Base: flat, rigid, non-absorbent moistened surface on which to set the slump mold

Procedure

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture contains aggregate retained on the 37.5mm (1½ in.) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

Begin testing within five minutes of obtaining the sample.

2. Dampen the inside of the mold and place it on a dampened, rigid, nonabsorbent surface that is level and firm.
3. Stand on both foot pieces to hold the mold firmly in place.
4. Use the scoop to fill the mold 1/3 full by volume, to a depth of approximately 67 mm (2 5/8 in.).

5. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete.
For this bottom layer, incline the rod slightly and make approximately half the strokes near the perimeter, and then progress with vertical strokes, spiraling toward the center.
 6. Use the scoop to fill the mold 2/3 full by volume, to a depth of approximately 155 mm (6 1/8 in.).
 7. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in.) into the bottom layer. Distribute the strokes evenly.
 8. Use the scoop to fill the mold to overflowing.
 9. Consolidate this layer with 25 strokes of the tamping rod, penetrate approximately 25 mm (1 in.) into the second layer. Distribute the strokes evenly. If the concrete falls below the top of the mold, stop, add more concrete, and continue rodding for a total of 25 strokes. Keep an excess amount of concrete above the top of the mold at all times. Distribute strokes evenly as before.
 10. Strike off the top surface of concrete with a screeding and rolling motion of the tamping rod.
 11. Clean overflow concrete away from the base of the mold.
 12. Remove the mold from the concrete by raising it carefully in a vertical direction. Raise the mold 300 mm (12 in.) in 5 ± 2 seconds by a steady upward lift with no lateral or torsional (twisting) motion being imparted to the concrete.
Complete the entire operation from the start of the filling through removal of the mold without interruption within an elapsed time of 2 1/2 minutes.
 13. Immediately measure the slump:
 - a. Invert the slump mold and set it next to the specimen.
 - b. Lay the tamping rod across the mold so that it is over the test specimen.
 - c. Measure the distance between the bottom of the rod and the displaced original center of the top of the specimen to the nearest 5 mm (1/4 in.).
- Note 1:* If a decided falling away or shearing off of concrete from one side or portion of the mass occurs, disregard the test and perform a new test on another portion of the sample. If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks the plasticity and cohesiveness necessary for the slump test to be applicable.
14. Discard the tested sample.

Report

- Results on forms approved by the agency
- Sample ID
- Slump to the nearest 5 mm (1/4 in.).



Oregon

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October 1, 2011

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 121**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Calculations Section;**
 - **Cement Content – Actual cement content includes all Cementitious Materials (cm), such as but not limited to; Portland Cement, Fly Ash, Silica Fume, Ground Granulated Blast Furnace Slag and Metakaolin.**
 - **Water Content – ODOT requires liquid additives to be included.**

DENSITY (UNIT WEIGHT), YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE FOP FOR AASHTO T 121

Scope

This method covers the determination of density, or unit weight, of freshly mixed concrete in accordance with AASHTO T 121-19. It also provides formulas for calculating the volume of concrete produced from a mixture of known quantities of component materials and provides a method for calculating cement content and cementitious material content – the mass of cement or cementitious material per unit volume of concrete. A procedure for calculating water/cement ratio is also covered.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Measure: May be the bowl portion of the air meter used for determining air content under the FOP for AASHTO T 152. Otherwise, it shall be a cylindrical metal container meeting the requirements of AASHTO T 121. The capacity and dimensions of the measure shall conform to those specified in Table 1.
- Balance or scale: Accurate to within 45 g (0.1 lb) or 0.3 percent of the test load, whichever is greater, at any point within the range of use.
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means “half a sphere”; the tip is rounded like half of a ball.)
- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) longer than the depth of the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).
- Mallet: With a rubber or rawhide head having a mass of 0.57 ± 0.23 kg (1.25 \pm 0.5 lb) for use with measures of 0.014 m³ (1/2 ft³) or less or having a mass of 1.02 ± 0.23 kg (2.25 \pm 0.5 lb) for use with measures of 0.028 m³ (1 ft³).

Table 1
Dimensions of Measures*

Capacity m ³ (ft ³)	Inside Diameter mm (in.)	Inside Height mm (in.)	Minimum Thicknesses mm (in.)		Nominal Maximum Size of Coarse Aggregate*** mm (in.)
			Bottom	Wall	
0.0071 (1/4)**	203 ±2.54 (8.0 ±0.1)	213 ±2.54 (8.4 ±0.1)	5.1 (0.20)	3.0 (0.12)	25 (1)
0.0142 (1/2)	254 ±2.54 (10.0 ±0.1)	279 ±2.54 (11.0 ±0.1)	5.1 (0.20)	3.0 (0.12)	50 (2)
0.0283 (1)	356 ±2.54 (14.0 ±0.1)	284 ±2.54 (11.2 ±0.1)	5.1 (0.20)	3.0 (0.12)	76 (3)

* **Note 1:** The indicated size of measure shall be for aggregates of nominal maximum size equal to or smaller than that listed.

** Measure may be the base of the air meter used in the FOP for AASHTO T 152.

*** Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure Selection

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in.), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in.), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency in order to obtain consistent, comparable results. For concrete with slump less than 25 mm (1 in.), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

When using measures greater than 0.0142 m³ (1/2 ft³) see AASHTO T 121.

Procedure

Sampling

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. Testing may be performed in conjunction with the FOP for AASHTO T 152. When doing so, this FOP should be performed before the FOP for AASHTO T 152.

Note 2: If the two tests are being performed using the same sample, this test shall begin within five minutes of obtaining the sample.

Rodding

1. Determine and record the mass of the empty measure.
2. Dampen the inside of the measure and empty excess water.

3. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.
5. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.
6. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
7. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
9. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
10. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
11. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
12. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
13. Continue with 'Strike-off and Determining Mass.'

Internal Vibration

1. Determine and record the mass of the empty measure.
2. Dampen the inside of the measure and empty excess water.
3. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
4. Insert the vibrator at three different points in each layer. Do not let the vibrator touch the bottom or side of the measure. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
5. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
6. Slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
7. Insert the vibrator at three different points, penetrating the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure.
8. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.

9. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
10. Continue with 'Strike-off and Determining Mass.'

Self-Consolidating Concrete

1. Determine and record the mass of the empty measure.
2. Dampen the inside of the measure and empty excess water.
3. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
5. Continue with 'Strike-off and Determining Mass.'

Strike-off and Determining Mass

1. Press the strike-off plate flat against the top surface, covering approximately 2/3 of the measure.
2. Withdraw the strike-off plate with a sawing motion to finish the 2/3 originally covered.
3. Cover the original 2/3 again with the plate; finishing the remaining 1/3 with a sawing motion (do not lift the plate; continue the sawing motion until the plate has cleared the surface of the measure).
4. Final finishing may be accomplished with several strokes with the inclined edge of the strike-off plate. The surface should be smooth and free of voids.
5. Clean off all excess concrete from the exterior of the measure including the rim.
6. Determine and record the mass of the measure and the concrete.
7. If the air content of the concrete is to be determined, ensure the rim (flange) is clean and proceed to 'Strike-off and Air Content' Step 3 of the FOP for AASHTO T 152.

Calculations

Mass of concrete in the measure

$$\text{concrete mass} = M_c - M_m$$

Where:

Concrete mass = mass of concrete in measure

M_c = mass of measure and concrete

M_m = mass of measure

Density

$$\rho = \frac{\text{concrete mass}}{V_m}$$

Where:

ρ = density of the concrete mix

V_m = volume of measure (Annex A)

Yield m^3

$$Y_{m^3} = \frac{W}{\rho}$$

Where:

Y_{m^3} = yield (m^3 of the batch of concrete)

W = total mass of the batch of concrete

Yield yd³

$$Y_{ft^3} = \frac{W}{\rho} \qquad Y_{yd^3} = \frac{Y_{ft^3}}{27ft^3/yd^3}$$

Where:

Y_{ft^3}	=	yield (ft ³ of the batch of concrete)
Y_{yd^3}	=	yield (yd ³ of the batch of concrete)
W	=	total mass of the batch of concrete
ρ	=	density of the concrete mix

Note 5: The total mass, W, includes the masses of the cement, water, and aggregates in the concrete.

Cement Content

$$N = \frac{N_t}{Y}$$

Where:

N	=	actual cementitious material content per Y_m^3 or Y_{yd^3}
N_t	=	mass of cementitious material in the batch
Y	=	Y_m^3 or Y_{yd^3}

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Water Content

The mass of water in a batch of concrete is the sum of:

- water added at batch plant
- water added in transit
- water added at jobsite
- free water on coarse aggregate*
- free water on fine aggregate*
- liquid admixtures (if required by the agency)

*Mass of free water on aggregate

This information is obtained from concrete batch tickets collected from the driver. Use the Table 2 to convert liquid measures.

Table 2
Liquid Conversion Factors

To Convert From	To	Multiply By
Liters, L	Kilograms, kg	1.0
Gallons, gal	Kilograms, kg	3.785
Gallons, gal	Pounds, lb	8.34
Milliliters, mL	Kilograms, kg	0.001
Ounces, oz	Milliliters, mL	28.4
Ounces, oz	Kilograms, kg	0.0284
Ounces, oz	Pounds, lb	0.0625
Pounds, lb	Kilograms, kg	0.4536

Mass of free water on aggregate

$$\text{Free Water Mass} = \text{CA or FC Aggregate} - \frac{\text{CA or FC Aggregate}}{1 + (\text{Free Water Percentage}/100)}$$

Where:

- Free Water Mass = on coarse or fine aggregate
 FC or CA Aggregate = mass of coarse or fine aggregate
 Free Water Percentage = percent of moisture of coarse or fine aggregate

Water/Cement Ratio

$$\frac{\text{Water Content}}{C}$$

Where:

- Water Content = total mass of water in the batch
 C = total mass of cementitious materials

Example

Mass of concrete in measure (M_m)	16.290 kg (36.06 lb)
Volume of measure (V_m)	0.007079 m ³ (0.2494 ft ³)

From batch ticket:

Yards batched	4 yd ³
Cement	950 kg (2094 lb)
Fly ash	180 kg (397 lb)
Coarse aggregate	3313 kg (7305 lb)
Fine aggregate	2339 kg (5156 lb)
Water added at plant	295 L (78 gal)

Other

Water added in transit	0
Water added at jobsite	38 L (10 gal)
Total mass of the batch of concrete (W)	7115 kg (15,686 lb)
Moisture content of coarse aggregate	1.7%
Moisture content of coarse aggregate	5.9%

Density

$$\rho = \frac{\text{concrete mass}}{V_m}$$

$$\rho = \frac{16.920 \text{ kg}}{0.007079 \text{ m}^3} = 2390 \text{ kg/m}^3 \quad \rho = \frac{36.06 \text{ lb}}{0.2494 \text{ ft}^3} = 144.6 \text{ lb/ft}^3$$

Given:

$$\text{concrete mass} = 16.920 \text{ kg (36.06 lb)}$$

$$V_m = 0.007079 \text{ m}^3 (0.2494 \text{ ft}^3) \text{ (Annex A)}$$

Yield m³

$$Y_{m^3} = \frac{W}{\rho}$$

$$Y_{m^3} = \frac{7115 \text{ kg}}{2390 \text{ kg/m}^3} = 2.98 \text{ m}^3$$

Given:

$$\text{Total mass of the batch of concrete (W), kg} = 7115 \text{ kg}$$

Yield yd^3

$$Y_{ft^3} = \frac{W}{\rho}$$

$$Y_{yd^3} = \frac{Y_{ft^3}}{27 ft^3/yd^3}$$

$$Y_{ft^3} = \frac{15,686 lb}{144.6 lb/ft^3} = 108.48 ft^3 \quad Y_{yd^3} = \frac{108.48 ft^3}{27 ft^3/yd^3} = 4.02 yd^3$$

Given:

Total mass of the batch of concrete (W), lb = 15,686 lb

Cement Content

$$N = \frac{N_t}{Y}$$

$$N = \frac{950 kg + 180 kg}{2.98 m^3} = 379 kg/m^3 \quad N = \frac{2094 lb + 397 lb}{4.02 yd^3} = 620 lb/yd^3$$

Given:

N_t (cement) = 950 kg (2094 lb)

N_t (flyash) = 180 kg (397 lb)

Y = Y_m^3 or Y_{yd^3}

Note 6: Specifications may require Portland Cement content and supplementary cementitious materials content.

Free water

$$\text{Free Water Mass} = \text{CA or FC Aggregate} - \frac{\text{CA or FC Aggregate}}{1 + (\text{Free Water Percentage}/100)}$$

$$\text{CA Free Water} = 3313 \text{ kg} - \frac{3313 \text{ kg}}{1 + (1.7/100)} = 55 \text{ kg}$$

$$\text{CA Free Water} = 7305 \text{ lb} - \frac{7305 \text{ lb}}{1 + (1.7/100)} = 122 \text{ lb}$$

$$\text{FA Free Water} = 2339 \text{ kg} - \frac{2339 \text{ kg}}{1 + (5.9/100)} = 130 \text{ kg}$$

$$\text{FA Free Water} = 5156 \text{ lb} - \frac{5156 \text{ lb}}{1 + (5.9/100)} = 287 \text{ lb}$$

Given:

CA aggregate = 3313 kg (7305 lb)

FC aggregate = 2339 kg (5156 lb)

CA moisture content = 1.7%

FC moisture content = 5.9%

Water Content

Total of all water in the mix.

$$\text{Water Content} = [(78 \text{ gal} + 10 \text{ gal}) * 3.785 \text{ kg/gal}] + 55 \text{ kg} + 130 \text{ kg} = 518 \text{ kg}$$

$$\text{Water Content} = [(78 \text{ gal} + 10 \text{ gal}) * 8.34 \text{ lb/gal}] + 122 \text{ lb} + 287 \text{ lb} = 1143 \text{ lb}$$

Given:

$$\text{Water added at plant} = 295 \text{ L (78 gal)}$$

$$\text{Water added at the jobsite} = 38 \text{ L (10 gal)}$$

Water/ Cement Ratio

$$W/C = \frac{518 \text{ kg}}{950 \text{ kg} + 180 \text{ kg}} = 0.458 \quad W/C = \frac{1143 \text{ lb}}{2094 \text{ lb} + 397 \text{ lb}} = 0.459$$

Report 0.46

Report

- Results on forms approved by the agency
- Sample ID
- Density (unit weight) to the nearest 1 kg/m³ (0.1 lb/ft³)
- Yield to the nearest 0.01 m³ (0.01 yd³)
- Cement content to the nearest 1 kg/m³ (1 lb/yd³)
- Cementitious material content to the nearest 1 kg/m³ (1 lb/yd³)
- Water/Cement ratio to the nearest 0.01

ANNEX A – STANDARDIZATION OF MEASURE

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described herein will produce inaccurate or unreliable test results.

Apparatus

- Listed in the FOP for AASHTO T 121
 - Measure
 - Balance or scale
 - Strike-off plate
- Thermometer: Standardized liquid-in-glass, or electronic digital total immersion type, accurate to 0.5°C (1°F)

Procedure

1. Determine the mass of the dry measure and strike-off plate.
2. Fill the measure with water at a temperature between 16°C and 29°C (60°F and 85°F) and cover with the strike-off plate in such a way as to eliminate bubbles and excess water.
3. Wipe the outside of the measure and cover plate dry, being careful not to lose any water from the measure.
4. Determine the mass of the measure, strike-off plate, and water in the measure.
5. Determine the mass of the water in the measure by subtracting the mass in Step 1 from the mass in Step 4.
6. Measure the temperature of the water and determine its density from Table A1, interpolating as necessary.
7. Calculate the volume of the measure, V_m , by dividing the mass of the water in the measure by the density of the water at the measured temperature.

Calculations

$$V_m = \frac{M}{\rho_w} \text{Where:}$$

V_m = volume of the mold

M = mass of water in the mold

ρ_w = density of water at the measured temperature

Example

Mass of water in Measure = 7.062 kg (15.53 lb)

Density of water at 23°C (73.4°F) (ρ_w) = 997.54 kg/m³ (62.274 lb/ft³)

$$V_m = \frac{7.062 \text{ kg}}{997.54 \text{ kg/m}^3} = 0.007079 \text{ m}^3 \quad V_m = \frac{15.53 \text{ lb}}{62.274 \text{ lb/ft}^3} = 0.2494 \text{ ft}^3$$

Table A1
Unit Mass of Water
15°C to 30°C

°C	(°F)	kg/m ³	(lb/ft ³)	°C	(°F)	kg/m ³	(lb/ft ³)
15	(59.0)	999.10	(62.372)	23	(73.4)	997.54	(62.274)
15.6	(60.0)	999.01	(62.366)	23.9	(75.0)	997.32	(62.261)
16	(60.8)	998.94	(62.361)	24	(75.2)	997.29	(62.259)
17	(62.6)	998.77	(62.350)	25	(77.0)	997.03	(62.243)
18	(64.4)	998.60	(62.340)	26	(78.8)	996.77	(62.227)
18.3	(65.0)	998.54	(62.336)	26.7	(80.0)	996.59	(62.216)
19	(66.2)	998.40	(62.328)	27	(80.6)	996.50	(62.209)
20	(68.0)	998.20	(62.315)	28	(82.4)	996.23	(62.192)
21	(69.8)	997.99	(62.302)	29	(84.2)	995.95	(62.175)
21.1	(70.0)	997.97	(62.301)	29.4	(85.0)	995.83	(62.166)
22	(71.6)	997.77	(62.288)	30	(86.0)	995.65	(62.156)

Report

- Measure ID
- Date Standardized
- Temperature of the water
- Volume, V_m , of the measure



Oregon

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October 31, 2020

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 152**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Annex A “Standardization of Air Meter Gauge”, delete the second paragraph and replace with the following: Standardization shall be performed at a minimum of once every three months or whenever test results are suspect. Record the date of the standardization, the standardization results, and the name of the technician performing the standardization in the log book kept with each air meter.**
- **Under Sampling, step 1, second sentence, delete 1 ½” and replace with 2”. Add the following sentence: If any aggregate is retained on the 2” sieve, wet sieve a sufficient amount of sample over the 1 ½” sieve according to the Wet Sieving portion of the FOP for WAQTC TM 2.**
- **An Aggregate Correction Factor is not required for Air Content Determination.**

AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD FOP FOR AASHTO T 152

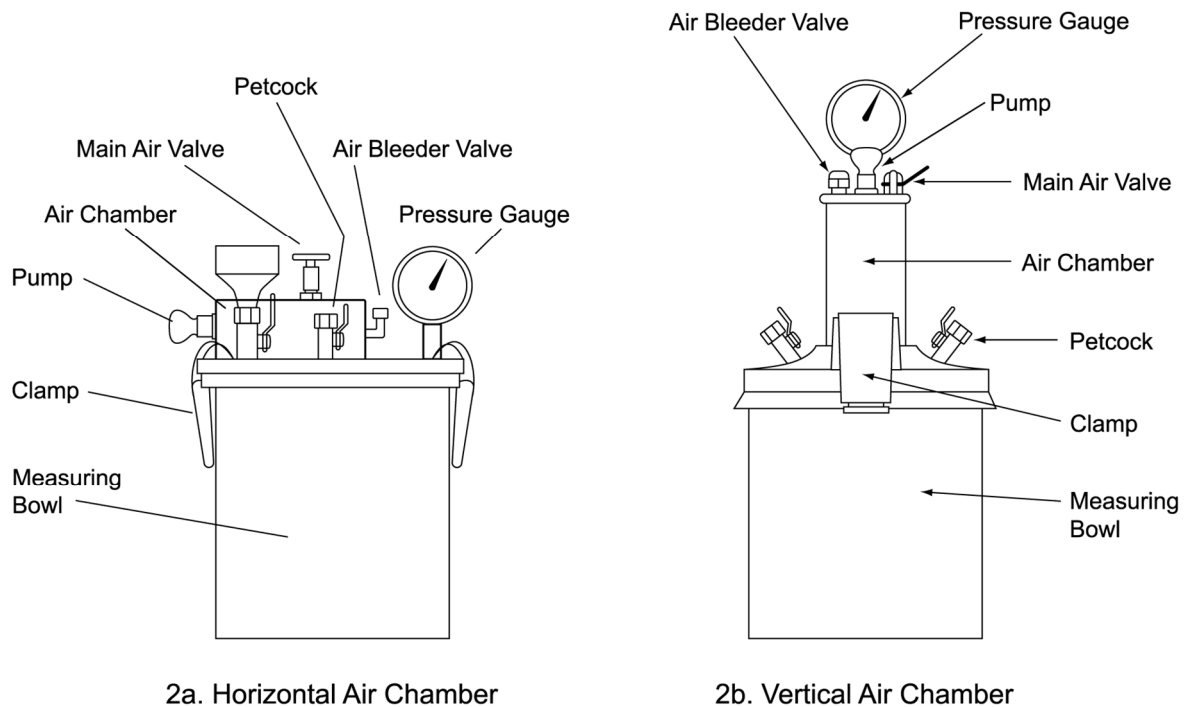
Scope

This procedure covers determination of the air content in freshly mixed Portland Cement Concrete containing dense aggregates in accordance with AASHTO T 152-19, Type B meter. It is not for use with lightweight or highly porous aggregates. This procedure includes standardization of the Type B air meter gauge, Annex A.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Air meter: Type B, as described in AASHTO T 152



Type B Meter

- Balance or scale: Accurate to 0.3 percent of the test load at any point within the range of use (for Method 1 standardization only)
- Tamping rod: 16 mm (5/8 in.) diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip the same diameter as the rod. (Hemispherical means “half a sphere”; the tip is rounded like half of a ball.)

- Vibrator: frequency at least 9000 vibrations per minute (150 Hz), at least 19 to 38 mm (3/4 to 1 1/2 in.) in diameter but not greater than 38 mm (1 1/2 in.), and the length of the shaft shall be at least 75 mm (3 in.) than the depth of the section being vibrated.
 - Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
 - Container for water: rubber syringe (may also be a squeeze bottle)
 - Strike-off bar: Approximately 300 mm x 22 mm x 3 mm (12 in. x 3/4 in. x 1/8 in.)
 - Strike-off plate: A flat rectangular metal plate at least 6 mm (1/4 in.) thick or a glass or acrylic plate at least 12 mm (1/2 in.) thick, with a length and width at least 50 mm (2 in.) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within tolerance of 1.5 mm (1/16 in.).
- Note 1:* Use either the strike-off bar or strike-off plate; both are not required.
- Mallet: With a rubber or rawhide head having a mass of 0.57 ± 0.23 kg (1.25 ± 0.5 lb)

Procedure Selection

There are two methods of consolidating the concrete – rodding and vibration. If the slump is greater than 75 mm (3 in.), consolidation is by rodding. When the slump is 25 to 75 mm (1 to 3 in.), internal vibration or rodding can be used to consolidate the sample, but the method used must be that required by the agency in order to obtain consistent, comparable results. For concrete with slumps less than 25 mm (1 in.), consolidate the sample by internal vibration. Do not consolidate self-consolidating concrete (SCC).

Procedure

Sampling

1. Obtain the sample in accordance with the FOP for WAQTC TM 2. If the concrete mixture contains aggregate retained on the 37.5mm (1½ in.) sieve, the aggregate must be removed in accordance with the Wet Sieving portion of the FOP for WAQTC TM 2.

Testing shall begin within five minutes of obtaining the sample.

Rodding

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/3 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Consolidate the layer with 25 strokes of the tamping rod, using the rounded end. Distribute the strokes evenly over the entire cross section of the concrete. Rod throughout its depth without hitting the bottom too hard.
4. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet to close voids and release trapped air.

5. Add the second layer, filling the measure about 2/3 full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the bottom layer.
7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Add the final layer, slightly overfilling the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
9. Consolidate this layer with 25 strokes of the tamping rod, penetrating about 25 mm (1 in.) into the second layer.
10. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
11. After consolidation, the measure should be slightly over full, about 3 mm (1/8 in.) above the rim. If there is a great excess of concrete, remove a portion with the trowel or scoop. If the measure is under full, add a small quantity. This adjustment may be done only after consolidating the final layer and before striking off the surface of the concrete.
12. Continue with 'Strike-off and Air Content.'

Internal Vibration

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to fill the measure approximately 1/2 full with concrete. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Insert the vibrator at three different points. Do not let the vibrator touch the bottom or side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
4. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
5. Use the scoop to fill the measure a bit over full. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
6. Insert the vibrator at three different points, penetrating the first layer approximately 25 mm (1 in.). Do not let the vibrator touch the side of the measure. Remove the vibrator slowly, so that no air pockets are left in the material. Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.
7. Tap around the perimeter of the measure smartly 10 to 15 times with the mallet.
8. Continue with 'Strike-off and Air Content.'

Self-Consolidating Concrete

1. Dampen the inside of the air meter measure and place on a firm level surface.
2. Use the scoop to slightly overfill the measure. Evenly distribute the concrete in a circular motion around the inner perimeter of the measure.
3. Continue with ‘Strike-off and Air Content.’

Strike-Off and Air Content

1. Strike off the surface of the concrete and finish it smoothly with a sawing action of the strike-off bar or plate, using great care to leave the measure just full. The surface should be smooth and free of voids.
2. Clean the top flange of the measure to ensure a proper seal.
3. Moisten the inside of the cover and check to see that both petcocks are open, and the main air valve is closed.
4. Clamp the cover on the measure.
5. Inject water through a petcock on the cover until water emerges from the petcock on the opposite side. Jar the meter gently until all air is expelled from this same petcock.
6. Verify that water is present in both petcocks.
7. Close the air bleeder valve and pump air into the air chamber until the needle goes past the initial pressure determined for the gauge. Allow a few seconds for the compressed air to cool.
8. Tap the gauge gently with one hand while slowly opening the air bleeder valve until the needle rests on the initial pressure. Close the air bleeder valve.
9. Close both petcocks.
10. Open the main air valve.
11. Tap the side of the measure smartly with the mallet.
12. With the main air valve open, lightly tap the gauge to settle the needle, and then read the air content to the nearest 0.1 percent.
13. Release or close the main air valve.
14. Open both petcocks to release pressure, remove the concrete, and thoroughly clean the cover and measure with clean water.
15. Open the main air valve to relieve the pressure in the air chamber.

Report

- On forms approved by the agency
- Sample ID
- Percent of air to the nearest 0.1 percent.
- Some agencies require an aggregate correction factor in order to determine total percent of entrained air.

Total % entrained air = Gauge reading – aggregate correction factor from mix design
(See AASHTO T 152 for more information.)

ANNEX A STANDARDIZATION OF AIR METER GAUGE

(Mandatory Information)

Standardization is a critical step to ensure accurate test results when using this apparatus. Failure to perform the standardization procedures as described below will produce inaccurate or unreliable test results.

Standardization shall be performed at a minimum of once every three months. Record the date of the standardization, the standardization results, and the name of the technician performing the standardization in the logbook kept with each air meter.

There are two methods for standardizing the air meter, mass or volume, both are covered below.

1. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the cover.
2. Determine and record the mass of the dry, empty air meter measure and cover assembly (mass method only).
3. Fill the measure nearly full with water.
4. Clamp the cover on the measure with the tube extending down into the water. Mark the petcock with the tube attached for future reference.
5. Add water through the petcock having the pipe extension below until all air is forced out the other petcock.
6. Wipe off the air meter measure and cover assembly; determine and record the mass of the filled unit (mass method only).
7. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
8. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 0 percent. If two or more tests show a consistent variation from 0 percent in the result, change the initial pressure line to compensate for the variation, and use the newly established initial pressure line for subsequent tests.
9. Determine which petcock has the straight tube attached to it. Attach the curved tube to external portion of the same petcock.
10. Pump air into the air chamber. Open the petcock with the curved tube attached to it. Open the main air valve for short periods of time until 5 percent of water by mass or volume has been removed from the air meter. Remember to open both petcocks to release the pressure in the measure and drain the water in the curved tube back into the measure. To determine the mass of the water to be removed, subtract the mass found in Step 2 from the mass found in Step 6. Multiply this value by 0.05. This is the mass of the water that must be removed. To remove 5 percent by volume, remove water until the external standardization vessel is level full.

Note A1: Many air meters are supplied with a standardization vessel(s) of known volume that are used for this purpose. Standardization vessel must be protected from crushing or denting. If an external standardization vessel is used, confirm what percentage volume it represents for the air meter being used. Vessels commonly represent 5 percent volume, but they are for specific size meters. This should be confirmed by mass.

11. Remove the curved tube. Pump up the air pressure to a little beyond the predetermined initial pressure indicated on the gauge. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
12. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle is stabilized. The gauge should now read 5.0 ± 0.1 percent. If the gauge is outside that range, the meter needs adjustment. The adjustment could involve adjusting the starting point so that the gauge reads 5.0 ± 0.1 percent when this standardization is run or could involve moving the gauge needle to read 5.0 percent. Any adjustment should comply with the manufacturer's recommendations.
13. When the gauge hand reads correctly at 5.0 percent, additional water may be withdrawn in the same manner to check the results at other values such as 10 percent or 15 percent.
14. If an internal standardization vessel is used, follow Steps 1 through 8 to set initial reading.
15. Release pressure from the measure and remove cover. Place the internal standardization vessel into the measure. This will displace 5 percent of the water in the measure. (See AASHTO T 152 for more information on internal standardization vessels.)
16. Place the cover back on the measure and add water through the petcock until all the air has been expelled.
17. Pump up the air pressure chamber to the initial pressure. Wait a few seconds for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure by pumping up or relieving pressure, as needed.
18. Close both petcocks and immediately open the main air valve exhausting air into the measure. Wait a few seconds until the meter needle stabilizes. The gauge should now read 5 percent.
19. Remove the extension tubing from threaded petcock hole in the underside of the cover before starting the test procedure.

Report

- Air meter ID
- Date standardized
- Initial pressure (IP)



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October 31, 2022

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 166**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Absorption Calculations are not required.**
- **When performing the Bulk Specific Gravity determination for the Core Correlation process (ODOT TM-327), use Method A. Method C is required for dry mass determination.**
- **Under Procedure – Method C (Rapid Test for Method A or B), delete step 4 and replace with the following: Place in an oven at a minimum of 105°C (221°F). Do not exceed the Job Mix Formula mixing temperature.**
- **When performing the Bulk Specific Gravity determination for Lab Fabricated Gyrotory Specimens, use Method A. The Method C option is not allowed.**
- **When performing the Bulk Specific Gravity determination for Cores removed for “density acceptance” purposes, see TM 327, “Procedure Density Cores”, section 4.4.**

BULK SPECIFIC GRAVITY (G_{mb}) OF COMPACTED ASPHALT MIXTURES USING SATURATED SURFACE-DRY SPECIMENS FOP FOR AASHTO T 166

Scope

This procedure covers the determination of bulk specific gravity (G_{mb}) of compacted asphalt mixtures using three methods – A, B, and C – in accordance with AASHTO T 166-22. This FOP is for use on specimens not having open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both. When specimens have open or interconnecting voids or absorbing more than 2.00 percent water by volume, or both, AASHTO T 275 or AASHTO T 331 should be performed.

Overview

- Method A: Suspension
- Method B: Volumeter
- Method C: Rapid test for A or B

Test Specimens

Test specimens may be either laboratory-molded or sampled from asphalt mixture pavement. For specimens it is recommended that the diameter be equal to four times the maximum size of the aggregate and the thickness be at least one and one half times the maximum size.

Terminology

Constant Mass: The state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus – Method A (Suspension)

- Balance or scale: 5 kg capacity, readable to 0.1 g, and fitted with a suitable suspension apparatus and holder to permit weighing the specimen while suspended in water, conforming to AASHTO M 231.
- Suspension apparatus: Wire of the smallest practical size and constructed to permit the container to be fully immersed.
- Water bath: For immersing the specimen in water while suspended under the balance or scale and equipped with an overflow outlet for maintaining a constant water level.
- Towel: Damp cloth towel used for surface drying specimens.
- Oven: Capable of maintaining a temperature of $52 \pm 3^{\circ}\text{C}$ ($126 \pm 5^{\circ}\text{F}$) for drying the specimens to a constant mass.

- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Thermometer: Having a range of 15 to 45°C (59 to 113°F) and, graduated in 0.1°C (0.2°F) subdivisions.
- Vacuum device: refer to the FOP for AASHTO R 79 (optional)

Procedure – Method A (Suspension)

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
 - a. Oven method
 - i. Initially dry overnight at $52 \pm 3^{\circ}\text{C}$ ($125 \pm 5^{\circ}\text{F}$).
 - ii. Determine and record the mass of the specimen. Designate this mass as M_p .
 - iii. Return the specimen to the oven for at least 2 hours.
 - iv. Determine and record the mass of the specimen. Designate this mass as M_n .
 - v. Determine percent change by subtracting the new mass determination, M_n , from the previous mass determination, M_p , divide by the previous mass determination M_p , and multiply by 100.
 - vi. Continue drying until there is no more than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
 - vii. Constant mass has been achieved; sample is defined as dry.
 - b. Vacuum dry method according to the FOP for AASHTO R 79.
2. Cool the specimen in air to $25 \pm 5^{\circ}\text{C}$ ($77 \pm 9^{\circ}\text{F}$), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as A.
3. Fill the water bath to overflow level with water at $25 \pm 1^{\circ}\text{C}$ ($77 \pm 2^{\circ}\text{F}$) and allow the water to stabilize.
4. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.
5. Immerse the specimen shaking to remove the air bubbles. Place the specimen on its side in the suspension apparatus. Leave it immersed for 4 ± 1 minutes.
6. Determine and record the submerged weight to the nearest 0.1 g. Designate this submerged weight as C.
7. Remove the sample from the water and quickly surface dry with a damp cloth towel within 5 seconds.

Note 1: To expedite the procedure, steps 1 and 2 may be performed last. To further expedite the process, see Method C.

8. Zero or tare the balance.
9. Immediately determine and record the mass of the saturated surface-dry (SSD) specimen to nearest 0.1 g. Designate this mass as B. Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen. Do not exceed 15 seconds performing Steps 7 through 9.

Calculations – Method A (Suspension)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g

M_n = new mass measurement, g

Bulk specific gravity (G_{mb}) and percent water absorbed:

$$G_{mb} = \frac{A}{B - C}$$

$$Percent\ Water\ Absorbed\ (by\ volume) = \frac{B - A}{B - C} \times 100$$

Where:

- G_{mb} = Bulk specific gravity
- A = Mass of dry specimen in air, g
- B = Mass of SSD specimen in air, g
- C = Weight of specimen in water at $25 \pm 1^\circ C$ ($77 \pm 2^\circ F$), g

Example:

$$G_{mb} = \frac{4833.6 \text{ g}}{4842.4 \text{ g} - 2881.3 \text{ g}} = 2.465$$

$$\% \text{ Water Absorbed (by volume)} = \frac{4842.4 \text{ g} - 4833.6 \text{ g}}{4842.4 \text{ g} - 2881.3 \text{ g}} \times 100 = 0.45\%$$

Given:

A	=	4833.6 g
B	=	4842.4 g
C	=	2881.3 g

Apparatus – Method B (Volumeter)

- Balance or scale: 5 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Water bath: For immersing the specimen in water, capable of maintaining a uniform temperature at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$).
- Thermometer: Range of 15 to 45°C (59 to 113°F) and graduated in 0.1°C (0.2°F) subdivisions.
- Volumeter: Calibrated to 1200 mL or appropriate capacity for test sample and having a tapered lid with a capillary bore.
- Oven: Capable of maintaining a temperature of $52 \pm 3^\circ\text{C}$ ($126 \pm 5^\circ\text{F}$). for drying the specimens to a constant mass.
- Pan: Pan or other suitable container of known mass, large enough to hold a sample for drying in oven.
- Towel: Damp cloth towel used for surface drying specimens.
- Vacuum device: refer to the FOP for AASHTO R 79 (optional)

Procedure – Method B (Volumeter)

Recently molded laboratory samples that have not been exposed to moisture do not need drying.

1. Dry the specimen to constant mass, if required.
 - a. Oven method:
 - i. Initially dry overnight at $52 \pm 3^{\circ}\text{C}$ ($125 \pm 5^{\circ}\text{F}$).
 - ii. Determine and record the mass of the specimen. Designate this mass as M_p .
 - iii. Return the specimen to the oven for at least 2 hours.
 - iv. Determine and record the mass of the specimen. Designate this mass as M_n .
 - v. Determine percent change by subtracting the new mass determination, M_n , from the previous mass determination, M_p , divide by the previous mass determination, M_p , and multiply by 100.
 - vi. Continue drying until there is no more than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
 - vii. Constant mass has been achieved; sample is defined as dry.
 - b. Vacuum dry method according to the FOP for AASHTO R 79.
2. Cool the specimen in air to $25 \pm 5^{\circ}\text{C}$ ($77 \pm 9^{\circ}\text{F}$), and determine and record the dry mass to the nearest 0.1 g. Designate this mass as A.
3. Immerse the specimen in the temperature-controlled water bath at $25 \pm 1^{\circ}\text{C}$ ($77 \pm 2^{\circ}\text{F}$) for at least 10 minutes.
4. At the end of the ten-minute period, fill the volumeter with distilled water at $25 \pm 1^{\circ}\text{C}$ ($77 \pm 2^{\circ}\text{F}$) making sure some water escapes through the capillary bore of the tapered lid.
5. Wipe the volumeter dry. Determine the mass of the volumeter and water to the nearest 0.1 g. Designate this mass as D.
6. Remove the specimen from the water bath and quickly surface dry with a damp cloth towel within 5 seconds.
7. Immediately determine and record the mass of the SSD specimen to the nearest 0.1 g. Designate this mass as B. Any water that seeps from the specimen during the mass determination is considered part of the saturated specimen.
8. Place the specimen in the volumeter and let stand 60 seconds.
9. Bring the temperature of the water to $25 \pm 1^{\circ}\text{C}$ ($77 \pm 2^{\circ}\text{F}$) and cover the volumeter, making sure some water escapes through the capillary bore of the tapered lid.
10. Wipe the volumeter dry.
11. Determine and record the mass of the volumeter, water, and specimen to the nearest 0.1 g. Designate this mass as E.

Note 2: Method B is not acceptable for use with specimens that have more than 6 percent air voids.

Calculations – Method B (Volumeter)

Constant Mass:

Calculate constant mass using the following formula:

$$\%Change = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement, g

M_n = new mass measurement, g

Bulk specific gravity (G_{mb}) and percent water absorbed:

$$G_{mb} = \frac{A}{B + D - E}$$

$$\text{Percent Water Absorbed (by volume)} = \frac{B - A}{B + D - E} \times 100$$

Where:

G_{mb} = Bulk specific gravity

A = Mass of dry specimen in air, g

B = Mass of SSD specimen in air, g

D = Mass of volumeter filled with water at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$), g

E = Mass of volumeter filled with specimen and water, g

Example:

$$G_{mb} = \frac{4833.6 \text{ g}}{4842.4 \text{ g} + 2924.4 \text{ g} - 5806.0 \text{ g}} = 2.465$$

$$\% \text{ Water Absorbed (by volume)} = \frac{4842.4 \text{ g} - 4833.6 \text{ g}}{4842.4 \text{ g} + 2924.4 \text{ g} - 5806.0 \text{ g}} \times 100 = 0.45\%$$

Given:

A	=	4833.6 g
B	=	4842.4 g
D	=	2924.4 g
E	=	5806.0 g

Apparatus – Method C (Rapid Test for Method A or B)

- Oven: Capable of maintaining a temperature of $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$) for drying the specimens to a constant mass.

See Methods A or B.

Note 3: This procedure can be used for specimens that are not required to be saved and contain substantial amounts of moisture. Cores can be tested the same day as obtained by this method.

Procedure – Method C (Rapid Test for Method A or B)

1. Start on Step 3 of Method A or B, and complete that procedure, then determine dry mass, A, as follows.
2. Determine and record mass of a large, flat-bottom container.
3. Place the specimen in the container.
4. Place in an oven at $110 \pm 5 \text{ C}$ ($230 \pm 9 \text{ F}$).
5. Dry until the specimen can be easily separated into fine aggregate particles that are not larger than 6.3 mm ($\frac{1}{4}$ in.).
6. Determine and record the mass of the specimen. Designate this mass as M_p .
7. Return the specimen to the oven for at least 2 hours.
8. Determine and record the mass of the specimen. Designate this mass as M_n .

9. Determine percent change by subtracting the new mass determination, M_n , from the previous mass determination, M_p , divide by the previous mass determination, M_p , and multiply by 100.
10. Continue drying until there is no more than 0.05 percent change in specimen mass after 2-hour drying intervals (constant mass).
11. Constant mass has been achieved; sample is defined as dry.
12. Cool in air to $25 \pm 5^\circ\text{C}$ ($77 \pm 9^\circ\text{F}$).
13. Determine and record the mass of the container and dry specimen to the nearest 0.1 g.
14. Determine and record the mass of the dry specimen to the nearest 0.1 g by subtracting the mass of the container from the mass determined in Step 13. Designate this mass as A.

Calculations – Method C (Rapid Test for Method A or B)

Complete the calculations as outlined in Methods A or B, as appropriate.

Report

- On forms approved by the agency
- Sample ID
- G_{mb} to the nearest 0.001
- Absorption to the nearest 0.01 percent
- Method performed.



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October 31, 2022

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 176**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Materials, 2nd bullet, the use of potable water for the working solution is allowed, but the Agency may require distilled or demineralized water, if test results are in question or potable water is found detrimental to the test.**
- **Under Procedure, Delete Step 10f.**
- **Run a minimum of Two Sand Equivalent samples. If these results do not meet the requirements of "Procedure, Step 10e." run an additional three samples discarding the high and low results and average the remaining three samples.**

PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY THE USE OF THE SAND EQUIVALENT TEST FOP FOR AASHTO T 176

Scope

This procedure covers the determination of plastic fines in accordance with AASHTO T 176-22. It serves as a rapid test to show the relative proportion of fine dust or clay-like materials in fine aggregates (FA) and soils.

Apparatus

See AASHTO T 176 for a detailed listing of sand equivalent apparatus. Note that the siphon tube and blow tube may be glass or stainless steel as well as copper.

- Graduated plastic cylinder.
- Rubber stopper.
- Irrigator tube.
- Weighted foot assembly: Having a mass of 1000 ± 5 g. There are two models of the weighted foot assembly. The older model has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder. It is read using a slot in the centering screws. The newer model has a sand-reading indicator 254 mm (10 in.) above this point and is preferred for testing clay-like materials.
- Bottle: clean, glass or plastic, of sufficient size to hold working solution
- Siphon assembly: The siphon assembly will be fitted to a 4 L (1 gal.) bottle of working calcium chloride solution placed on a shelf 915 ± 25 mm (36 ± 1 in.) above the work surface.
- Measuring can: With a capacity of 85 ± 5 mL (3 oz.).
- Balance or scale: Capacity sufficient for sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g and meeting the requirements of AASHTO M 231.
- Funnel: With a wide mouth for transferring sample into the graduated cylinder.
- Quartering cloth: 600 mm (2 ft.) square nonabsorbent cloth, such as plastic or oilcloth.
- Mechanical splitter: See the FOP for AASHTO R 76.
- Strike-off bar: A straightedge or spatula.
- Clock or watch reading in minutes and seconds.
- Manual shaker: A manually operated sand equivalent shaker capable of producing an oscillating motion at a rate of 100 complete cycles in 45 ± 5 seconds, with a hand assisted half stroke length of 127 ± 5 mm (5 ± 0.2 in.). It may be held stable by hand during the shaking operation. It is recommended that this shaker be fastened securely to a firm and level mount, by bolts or clamps, if many determinations are to be made.

- Mechanical shaker: See AASHTO T 176 for equipment and procedure.
- Oven: Capable of maintaining a temperature of $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$).
- Thermometer: Calibrated liquid-in-glass or electronic digital type designed for total immersion and accurate to 0.1°C (0.2°F).
- Sieve: 4.75-mm (No. 4) sieve meeting the requirements of the FOP for AASHTO T 27/T 11

Materials

- Stock calcium chloride solution: Obtain commercially prepared calcium chloride stock solution meeting AASHTO requirements.
- Working calcium chloride solution: Make 3.8 L (1 gal) of working solution. Fill the bottle with 2 L (1/2 gal) of distilled or demineralized water, add one 3 oz. measuring can (85 ± 5 mL) of stock calcium chloride solution. Agitate vigorously for 1 to 2 minutes. Add the remainder of the water, approximately 2 L (1/2 gal.) for a total of 3.8 L (1 gal) of working solution. Repeat the agitation process. Tap water may be used if it is proven to be non-detrimental to the test and if it is allowed by the agency. The shelf life of the working solution is approximately 30 days. Label working solution with the date mixed. Discard working solutions more than 30 days old.

Note 1: The graduated cylinder filled to 4.4 in. contains 88 mL and may be used to measure the stock solution.

Control

The temperature of the working solution should be maintained at $22 \pm 3^{\circ}\text{C}$ ($72 \pm 5^{\circ}\text{F}$) during the performance of the test. If field conditions preclude the maintenance of the temperature range, reference samples should be submitted to the Central/Regional Laboratory, as required by the agency, where proper temperature control is possible. Samples that meet the minimum sand equivalent requirement at a working solution temperature outside of the temperature range need not be subject to reference testing.

Sample Preparation

1. Obtain the sample in accordance with the FOP for AASHTO R 90 and reduce in accordance with the FOP for AASHTO R 76.
2. Sieve the sample over the 4.75 mm (No. 4) sieve. If the material is in clods, break it up and re-screen it over a 4.75 mm (No. 4) sieve. Clean all fines from particles retained on the 4.75 mm (No. 4) sieve and include with the material passing that sieve.
3. Split or quarter 1000 to 1500 g of material from the portion passing the 4.75 mm (No. 4) sieve. Use extreme care to obtain a truly representative portion of the original sample.

Note 2: Experiments show that, as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is reduced. It is imperative that the sample be split or quartered carefully. When it appears necessary, dampen the material before splitting or quartering to avoid segregation or loss of fines.

Note 3: All tests, including reference tests, will be performed using Alternative Method No. 2 as described in AASHTO T 176, unless otherwise specified.

4. The sample must have the proper moisture content to achieve reliable results. This condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture content has been obtained.

Note 4: Clean sands having little 75 μm (No. 200), such as sand for Portland Cement Concrete (PCC), may not form a cast.

If the material is too dry, the cast will crumble, and it will be necessary to add water and remix and retest until the material forms a cast. When the moisture content is altered to provide the required cast, the altered sample should be placed in a pan, covered with a lid or with a damp cloth that does not touch the material, and allowed to stand for a minimum of 15 minutes. Samples that have been sieved without being air-dried and still retain enough natural moisture are exempted from this requirement.

If the material shows any free water, it is too wet to test and must be drained and air dried. Mix frequently to ensure uniformity. This drying process should continue until squeezing provides the required cast.

5. Place the sample on the quartering cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, being careful to keep the top of the cloth parallel to the bottom, thus causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.
6. Fill the measuring can by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measuring can. As the can is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and placing the maximum amount in the can. Strike off the can level with the straightedge or spatula.
7. When required, repeat steps 5 and 6 to obtain additional samples.

Procedure

1. Start the siphon by forcing air into the top of the solution bottle through the tube while the pinch clamp is open. Siphon 101.6 \pm 2.5 mm (4 \pm 0.1 in.) of working calcium chloride solution into the plastic cylinder.
2. Pour the prepared test sample from the measuring can into the plastic cylinder, using the funnel to avoid spilling.
3. Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.
4. Allow the wetted sample to stand undisturbed for 10 \pm 1 minutes.
5. At the end of the 10-minute period, stopper the cylinder and loosen the material from the bottom by simultaneously partially inverting and shaking the cylinder.

6. After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:
 - a. Mechanical Method – Place the stoppered cylinder in the mechanical shaker, set the timer, and allow the machine to shake the cylinder and contents for 45 ± 1 seconds.

Caution: Agencies may require additional operator qualifications for the next two methods.

- b. Manual Method – Secure the stoppered cylinder in the three spring clamps on the carriage of the manually-operated sand equivalent shaker and set the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right hand spring strap.

Remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right-hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation.

Proper shaking action is accomplished when the tip of the pointer reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue shaking for 100 strokes.

- c. Hand Method – Hold the cylinder in a horizontal position and shake it vigorously in a horizontal linear motion from end to end. Shake the cylinder 90 cycles in approximately 30 seconds using a throw of $229 \text{ mm} \pm 25 \text{ mm}$ ($9 \pm 1 \text{ in.}$). A cycle is defined as a complete back and forth motion. To properly shake the cylinder at this speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.
7. Set the cylinder upright on the worktable and remove the stopper.
8. Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action while the working solution flows from the irrigator tip. Work the irrigator tube to the bottom of the cylinder as quickly as possible as it becomes more difficult to do this as the washing proceeds. This flushes the fine material into suspension above the coarser sand particles.

Continue to apply a stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 381 mm (15 in.) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at about 381 mm (15 in.) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 381 mm (15 in.).

Note 5: Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening. Also, keep the tip sharp as an aid to penetrating the sample.

9. Allow the cylinder and contents to stand undisturbed for 20 minutes \pm 15 seconds. Start timing immediately after withdrawing the irrigator tube.

Note 6: Any vibration or movement of the cylinder during this time will interfere with the normal settling rate of the suspended clay and will cause an erroneous result.

10. Clay and sand readings:

- a. At the end of the 20-minute sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the clay reading.
- b. If no clear line of demarcation has formed at the end of the 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual samples of the same material. Read and record the clay column height of the sample requiring the shortest sedimentation period only. Once a sedimentation time has been established, subsequent tests will be run using that time. The time will be recorded along with the test results on all reports.
- c. After the clay reading has been taken, place the weighted foot assembly over the cylinder and gently lower the assembly until it comes to rest on the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. Subtract 254 mm (10 in.) from the level indicated by the extreme top edge of the indicator and record this value as the sand reading.
- d. If clay or sand readings fall between 2.5 mm (0.1 in.) graduations, record the level of the higher graduation as the reading. For example, a clay reading that appears to be 7.95 would be recorded as 8.0; a sand reading that appears to be 3.22 would be recorded as 3.3.
- e. If two Sand Equivalent (SE) samples are run on the same material and the second varies by more than \pm 4, based on the first cylinder result, additional tests shall be run.
- f. If three or more Sand Equivalent (SE) samples are run on the same material, average the results. If an individual result varies by more than \pm 4, based on the average result, additional tests shall be run.

Calculations

Calculate the SE to the nearest 0.1 using the following formula:

$$SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} \times 100$$

Example

$$SE = \frac{3.3}{8.0} \times 100 = 41.25 \text{ or } 41.3 \quad \text{Report 42}$$

Given:

Sand Reading = 3.3

Clay Reading = 8.0

Note 7: This example reflects the use of equipment made with English units. At this time, equipment made with metric units is not available.

Report the SE as the next higher whole number. In the example above, the 41.3 would be reported as 42. An SE of 41.0 would be reported as 41.

When averaging two or more samples, raise each calculated SE value to the next higher whole number (reported value) before averaging.

Example:

calculated value 1 = 41.3

calculated value 2 = 42.8

These values are reported as 42 and 43, respectively.

Average the two reported values:

$$\text{Average SE} = \frac{42 + 43}{2} = 42.5 \quad \text{Report 43}$$

If the average value is not a whole number, raise it to the next higher whole number.

Report

- On forms approved by the agency
- Sample ID
- Results to the next higher whole number
- Sedimentation time if over 20 minutes

**Air Content of Freshly Mixed Concrete
by the Volumetric Method**

AASHTO Designation: T 196-22

ASTM Designation: C 173-10

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Test Procedure AASHTO T 209 Continued

- Under Section “Mixtures Containing Uncoated Porous Aggregates” or “Dryback” procedure observe the following:
 - a) Perform the “Dryback” procedure at the beginning of ACP production and after any JMF target adjustment.
 - b) The “Dryback Trigger” is based on a 2 test average. By computing the percent difference between, Mass of Sample in air (A) to Mass of saturated surface-dry sample in air (A_{ssd}) according to the following formula:

$$\frac{A_{ssd} - A}{A_{ssd}} \times 100 = \% \text{ Diff. (Compute to nearest 0.01\%)}$$

- c) If the calculated difference of startup results or the average of the 2 results after a JMF target adjustment exceeds 0.17%, then the “Dryback” procedure will be required for subsequent testing. Use the results of the “Dryback” procedure on all MDV and MAMD calculations.
- d) If the calculated results are 0.17% or less, then subsequent testing may be performed without the “Dryback” procedure.

Procedure – Mixtures Containing Uncoated Porous Aggregate

Delete steps 1 thru 3 and replace with the following

1. Within 5 minutes of completing ‘Procedure – General’, carefully drain water from the sample over a #40 or smaller opening sieve to prevent loss of material.
 2. Dry the sample by spreading it out in a container that has sides high enough to prevent material loss when stirred and is large enough to allow the sample to be in a layer no thicker than $\frac{3}{4}$ inch. Direct an electric fan so that it is blowing directly on the sample.
 3. After a minimum of 1 hour of continuous exposure to the fan, determine the mass of the sample. Stir the sample and spread out as in step 2. Continue to step 4.
- Under the calculation section, Theoretical Maximum Density, Delete the second sentence and replace with the following: The density of water at (77°F) is 62.4.



Oregon

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November 30, 2020

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 209**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under apparatus delete Bleeder valve and replace with, inline bleeder valve capable of regulating the vacuum between 25 & 30mm of mercury.**
- **Under the Standardization Section, delete the second sentence and add the following: The container shall be standardized annually and when the calibration value is in question.**
- **Use the flask method.**
- **Under Test Sample Preparation Section add the following: The test sample will be cured for a minimum of 1 hr. and a maximum of 3 hrs. according to the placement temperature range shown on the Mix Design. If the total time of storage and haul is less than 1 hour as determined by the Region QAC, Contractor CAT II and Project Manager then the test sample shall not be cured.**
- **Under the Procedure- (Pycnometer or Volumetric Flask) Delete step 12B, 13B and Note 2 and replace with the following: Fill the flask with (77.0°F +- 2°F) water and allow to stand for 10 ±1 minutes.**
- **Under Procedure – (Pycnometer or Volumetric Flask) Delete step 14B and replace with the following: The water temperature upon finishing filling the flask shall be at (77.0°F +- 2°F). Place the cover or a glass plate on the flask, and eliminate all air from the flask.**

(See Next Page)

THEORETICAL MAXIMUM SPECIFIC GRAVITY (G_{mm}) AND DENSITY OF ASPHALT MIXTURES FOP FOR AASHTO T 209

Scope

This procedure covers the determination of the maximum specific gravity (G_{mm}) of uncompacted asphalt mixtures in accordance with AASHTO T 209-22. Two methods using different containers – bowl and pycnometer / volumetric flask– are covered.

Specimens prepared in the laboratory shall be cured according to agency standards.

Apparatus

- Balance or scale: 10,000 g capacity, readable to 0.1 g, meeting AASHTO M 231, Class G2
- Container: A glass, metal, or plastic bowl, pycnometer or volumetric flask between 2000 and 10,000 mL as required by the minimum sample size requirements in Table 1 sample and capable of withstanding full vacuum applied
- Pycnometer / volumetric flask cover: A glass plate or a metal or plastic cover with a vented opening
- Vacuum lid: A transparent lid with a suitable vacuum connection, with a vacuum opening to be covered with a fine wire mesh
- Vacuum pump or water aspirator: Capable of evacuating air from the container to a residual pressure of 3.4 kPa (25 mm Hg)
- Vacuum measurement device: Residual pressure manometer or vacuum gauge, capable of measuring residual pressure down to 3.4 kPa (25 mm Hg) or less and accurate to 0.1 kPa (1 mm Hg)
- 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 for Pycnometer or Volumetric Flask Method)
- Thermometers: Thermometric devices accurate to 0.25°C (0.5°F) and with a temperature range of at least 20 to 45°C (68 to 113°F).
- Bleeder valve to adjust vacuum
- Automatic vacuum control unit (optional)
- Timer
- Towel

Standardization

Use a container that has been standardized according to Annex A. The container shall be standardized periodically in conformance with procedures established by the agency.

Test Sample Preparation

1. Obtain samples in accordance with the FOP for AASHTO R 97 and reduce according to the FOP for AASHTO R 47.
2. Test sample size shall conform to the requirements of Table 1. Samples larger than the capacity of the container may be tested in two or more increments. Results will be combined by calculating the weighted average ($G_{mm (avg)}$). If the increments have a specific gravity difference greater than 0.013, the test must be re-run.
3. Plant-produced samples may be short-term conditioned according to AASHTO R 30 as specified by the agency.

Note 1: Short-term conditioning at the specified temperature is especially important when absorptive aggregates are used. This short-term conditioning will ensure the computation of realistic values for the amount of asphalt absorbed by the aggregate and void properties of the mix. Plant-produced asphalt mixtures should be evaluated to make sure short-term conditioning has taken place during production and delivery.

Table 1
Test Sample Size for G_{mm}

Nominal Maximum* Aggregate Size mm (in.)	Minimum Mass g
37.5 or greater (1½)	4000
19 to 25 (¾ to 1)	2500
12.5 or smaller (½)	1500

*Nominal maximum size: One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained.

Procedure – General

Two procedures – bowl and pycnometer / volumetric flask – are covered. The first 11 steps are the same for both.

1. Separate the particles of the sample, taking care not to fracture the mineral particles, so that the particles of the fine aggregate portion are not larger than 6.3 mm (¼ in.). If the mixture is not sufficiently soft to be separated manually, place it in a large flat pan and warm in an oven only until it is pliable enough for separation.
2. Cool the sample to room temperature.
3. Determine and record the mass of the dry container to the nearest 0.1 g.
4. Place the sample in the container.
5. Determine and record the mass of the dry container and sample to the nearest 0.1 g.

6. Determine and record the mass of the sample by subtracting the mass determined in Step 3 from the mass determined in Step 5. Designate this mass as “A.”
 7. Add sufficient water at approximately 25° C (77° F) to cover the sample by about 25 mm (1 in.).
- Note 1:* The release of entrapped air may be facilitated by the addition of a wetting agent. Check with the agency to see if this is permitted and, if it is, for a recommended agent.
8. Place the lid on the container and attach the vacuum line. To ensure a proper seal between the container and the lid, wet the O-ring or use a petroleum gel.
 9. Remove entrapped air by subjecting the sample to a partial vacuum of 3.7 ± 0.3 kPa (27.5 ± 2.5 mm Hg) residual pressure for 15 ± 1 minutes.
 10. Agitate the container and sample, either continuously by mechanical device or manually by vigorous shaking at 2-minute intervals. This agitation facilitates the removal of air.
 11. Release the vacuum. Increase the pressure to atmospheric pressure in 10 to 15 seconds if the vacuum release is not automated. Turn off the vacuum pump and remove the lid. When performing the pycnometer / volumetric flask method, complete steps 12B through 16B within 10 ± 1 minute.

Procedure – Bowl

- 12A. Fill the water bath to overflow level with water at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$) and allow the water to stabilize.
- 13A. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.
- 14A. Suspend and immerse the bowl and sample in water at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$) for 10 ± 1 minute. The holder shall be immersed sufficiently to cover both it and the bowl.
- 15A. Determine and record the submerged weight of the bowl and sample to the nearest 0.1 g. Designate as “C.”

Procedure – Pycnometer or Volumetric Flask

- 12B. Immediately fill the pycnometer / volumetric flask with water without reintroducing air.
- 13B. Stabilize the temperature of the pycnometer / volumetric flask and sample so that the final temperature is within $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$).
- 14B. Finish filling the pycnometer / volumetric flask with water that is $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$), place the cover or a glass plate on the pycnometer / volumetric flask, and eliminate all air.

Note 2: 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.

- 15B. Towel dry the outside of the pycnometer / volumetric flask and cover.

16B. Determine and record the mass of the pycnometer / volumetric flask, cover, de-aired water, and sample to the nearest 0.1 g. within 10 ±1 minute of completion of Step 11. Designate this mass as “E.”

Procedure – Mixtures Containing Uncoated Porous Aggregate

If the pores of the aggregates are not thoroughly sealed by a bituminous film, they may become saturated with water during the vacuuming procedure, resulting in an error in maximum density. To determine if this has occurred, complete the general procedure and then:

1. Carefully drain water from sample through a towel held over the top of the container to prevent loss of material.
2. Spread sample in a flat shallow pan and place before an electric fan to remove surface moisture.
3. Determine the mass of the sample when the surface moisture appears to be gone.
4. Continue drying and determine the mass of the sample at 15-minute intervals until less than a 0.5 g loss is found between determinations.
5. Record the mass as the saturated surface dry mass to the nearest 0.1 g. Designate this mass as “A_{SSD}.”
6. Calculate, as indicated below, G_{mm} using “A” and “A_{SSD},” and compare the two values.

Calculation

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

Bowl Procedure

$$G_{mm} = \frac{A}{A + B - C} \quad \text{or} \quad G_{mm} = \frac{A}{A_{SSD} + B - C}$$

(for mixes containing uncoated aggregate materials)

Where:

- A = mass of dry sample in air, g
- A_{SSD} = mass of saturated surface dry sample in air, g
- B = standardized submerged weight of the bowl, g (see Annex A)
- C = submerged weight of sample and bowl, g

Example:

$$G_{mm} = \frac{1432.7 \text{ g}}{1432.7 \text{ g} + 286.3 \text{ g} - 1134.9 \text{ g}} = 2.453 \quad \text{or}$$

$$G_{mm} = \frac{1432.7 \text{ g}}{1434.2 \text{ g} + 286.3 \text{ g} - 1134.9 \text{ g}} = 2.447$$

Given:

A = 1432.7 g

A_{SSD} = 1434.2 g

B = 286.3 g

C = 1134.9 g

Pycnometer / Volumetric Flask Procedure

$$G_{mm} = \frac{A}{A + D - E} \quad \text{or} \quad G_{mm} = \frac{A}{A_{SSD} + D - E}$$

(for mixtures containing uncoated materials)

Where:

A = mass of dry sample in air, g

A_{SSD} = mass of saturated surface-dry sample in air, g

D = standardized mass of pycnometer / volumetric flask filled with water at 25°C (77°F), g, (See Annex A)

E = mass of pycnometer / volumetric flask filled with water and the test sample at test temperature, g

Example (two increments of a large sample):

$$G_{mm_1} = \frac{2200.3 \text{ g}}{2200.3 \text{ g} + 7502.5 \text{ g} - 8812.0 \text{ g}} = 2.470$$

$$G_{mm_2} = \frac{1960.2 \text{ g}}{1960.2 \text{ g} + 7525.5 \text{ g} - 8690.8 \text{ g}} = 2.466$$

Given:

Increment 1	Increment 2
A ₁ = 2200.3 g	A ₂ = 1960.2 g
D ₁ = 7502.5 g	D ₂ = 7525.5 g
E ₁ = 8812.0 g	E ₂ = 8690.8 g

$$\text{Variation} = 2.470 - 2.466 = 0.004, \text{ which is } < 0.013$$

Allowable variation is: 0.013. The values may be used.

Weighted average

For large samples tested a portion at a time, calculate the $G_{mm(avg)}$ by multiplying the dry mass of each increment by its G_{mm} , add the results together (Σ) and divide by the sum (Σ) of the dry masses.

$$G_{mm(avg)} = \frac{\Sigma(A_x \times G_{mm_x})}{\Sigma A_x}$$

or

$$G_{mm(avg)} = \frac{(A_1 \times G_{mm_1}) + (A_2 \times G_{mm_2})}{A_1 + A_2} \text{ etc.}$$

Where:

- A_x = mass of dry sample increment in air, g
- G_{mmx} = theoretical maximum specific gravity of the increment

Example:

$$G_{mm(avg)} = \frac{(2200.3 \text{ g} \times 2.470) + (1960.2 \text{ g} \times 2.466)}{2200.3 \text{ g} + 1960.2 \text{ g}} = \frac{10,268.6}{4160.5 \text{ g}} = 2.468$$

Theoretical Maximum Density

To calculate the theoretical maximum density at 25°C (77°F) use one of the following formulas. The density of water at 25°C (77°F) is 997.1 kg/ m³ in Metric units or 62.245 lb/ft³ in English units.

$$\text{Theoretical maximum density kg/m}^3 = G_{mm} \times 997.1 \text{ kg/ m}^3$$

$$2.468 \times 997.1 \text{ kg/ m}^3 = 2461 \text{ kg/ m}^3$$

or

$$\text{Theoretical maximum density lb/ft}^3 = G_{mm} \times 62.245 \text{ lb/ft}^3$$

$$2.468 \times 62.245 \text{ lb/ft}^3 = 153.6 \text{ lb/ft}^3$$

Report

- On forms approved by the agency
- Sample ID
- G_{mm} to the nearest 0.001
- Theoretical maximum density to the nearest 1 kg/m³ (0.1 lb/ft³)

ANNEX A – STANDARDIZATION OF BOWL AND PYCNOMETER OR VOLUMETRIC FLASK

(Mandatory Information)

Bowl – Standardization

1. Fill the water bath to overflow level with $25 \pm 1^{\circ}\text{C}$ ($77 \pm 2^{\circ}\text{F}$) water and allow the water to stabilize.
2. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.
3. Suspend and completely immerse the bowl for 10 ± 1 minute.
4. Determine and record the submerged weight of the bowl to the nearest 0.1 g.
5. Refill the water bath to overflow level.
6. Perform Steps 2 through 5 two more times for a total of three determinations.
7. If the range of the three determinations is less than or equal to 0.3 g., average the determinations. Designate as “B.”
8. If the range of the three determinations is greater than 0.3 g., take corrective action and perform the standardization procedure again.

Bowl – Check

1. Fill the water bath to overflow level $25 \pm 1^{\circ}\text{C}$ ($77 \pm 2^{\circ}\text{F}$) water and allow the water to stabilize.
2. Zero or tare the balance with the immersion apparatus attached, ensuring that the device is not touching the sides or the bottom of the water bath.
3. Suspend and completely immerse the bowl for 10 ± 1 minute.
4. Determine and record the submerged weight of the bowl to the nearest 0.1 g.
5. If this determination is within 0.3 g of the standardized value, use the standardized value for “B.”
6. If it is not within 0.3 g, take corrective action and perform the standardization procedure again.
7. For labs that check the bowl standardization frequently (such as daily), calculate the moving average and range of the last three mass determinations. Designate the average of the last three masses as “B.”
8. If the moving range exceeds 0.3 g at any time, take corrective action and perform the standardization procedure again.

Pycnometer or Volumetric Flask – Standardization

1. Fill the pycnometer / volumetric flask with water at approximately 25°C (77°F).
2. Place the metal or plastic cover, or a glass plate on the pycnometer / volumetric flask and eliminate all air. (See Note 2.)
3. Stabilize the pycnometer / volumetric flask at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$) for 10 ± 1 min.
4. Towel dry the outside of the pycnometer / volumetric flask and cover.
5. Determine and record the mass of the pycnometer / volumetric flask, water, and lid to the nearest 0.1 g.
6. Perform Steps 2 through 5 two more times for a total of three determinations.
7. If the range of the three determinations is less than or equal to 0.3 g, average the three determinations. Designate as “D.”
8. If the range of the determinations is greater than 0.3 g., take corrective action and perform the “Pycnometer or Volumetric Flask – Standardization” again.

Pycnometer or Volumetric Flask – Check

1. Fill the pycnometer / volumetric flask with water at approximately 25°C (77°F).
2. Place the metal or plastic cover or a glass plate on the pycnometer / volumetric flask and eliminate all air. (See Note 2.)
3. Stabilize the pycnometer / volumetric flask at $25 \pm 1^\circ\text{C}$ ($77 \pm 2^\circ\text{F}$) for 10 ± 1 min.
4. Towel dry the outside of the pycnometer / volumetric flask and cover.
5. Determine and record the mass of the pycnometer / volumetric flask, water, and lid.
6. If this determination is within 0.3 g of the standardized value, use the standardized value for “D.”
7. If it is not within 0.3 g, perform the standardization procedure again.



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October 1, 2022

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 217**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Procedure- Delete step 7 and replace with the following: Rotate the vessel for 30 seconds, rest for 30 seconds and repeat until gauge dial reflects no further increase. A minimum of 3 rotations (3 minutes) is required. Allow time for the dissipation of heat generated by the chemical reaction, before taking the final reading.**
- **Moisture Determination - Addendum to step 1, Use the following equation in lieu of the conversion curve to calculate the moisture content based on the dry weight of material.**

$$\% \text{ Moisture based on Dry} = \frac{\% \text{ Moisture Gauge Reading}}{100 - \% \text{ Moisture Gauge Reading}} \times 100$$

DETERMINATION OF MOISTURE IN SOILS BY MEANS OF CALCIUM CARBIDE GAS PRESSURE MOISTURE TESTER FOP FOR AASHTO T 217

Scope

This procedure uses a calcium carbide gas pressure moisture tester to determine the moisture content of materials passing the No. 4 sieve in accordance with AASHTO T 217. This FOP does not apply to the Super 200 D tester (see AASHTO 217).

CAUTION: This procedure involves a potentially dangerous chemical reaction. When calcium carbide reacts with water, acetylene gas is produced. Breathing the acetylene gas and running the test where the potential for sparks or other ignition may cause a fire must be avoided.

Apparatus

- Calcium carbide gas pressure moisture tester.
- Balance or scale, conforming to the requirements for AASHTO M 231 and having a capacity of 2 kg and sensitive to 0.1 g. Most testers include a balance built into the transportation container.
- Cleaning brush and cloth.
- Scoop (or cap built into unit) for putting the soil sample into the pressure chamber. Some testers include a cap built into the unit.
- Steel balls, 31.75 mm (1.25 inch)

Material

- Calcium carbide reagent meeting the requirements of AASHTO T 217.

Note 1: Check the manufacturer's recommendations for storage requirements and the maximum shelf life for the calcium carbide reagent.

Procedure

1. Place three scoops, approximately 24 g, of calcium carbide, into the body of the moisture tester.
2. To prevent damage to the pressure gauge, place the moisture tester in a horizontal position before inserting the two steel balls into the vessel.
3. Obtain a representative wet mass sample of soil specified by the manufacturer, using the built-in balance or external scale. Transfer the soil mass to the moisture tester cap or scoop without loss of material.

Note 2: This method shall not be used on granular material retained on the No. 4 sieve where larger particles may affect the accuracy of the test.

Note 3: If the anticipated moisture content of the wet mass exceeds the capacity of the instrument being used, then one-half of the specified soil mass should be placed into the unit, and the resulting gauge reading multiplied by two.

4. With the instrument still in a horizontal position, so that calcium carbide does not come into contact with the soil, seat the cap on the body and tighten down on the clamp, thereby sealing the tester.
5. Carefully raise the unit to a vertical orientation and gently tap the cap to allow the soil to fall into the pressure vessel, taking care to prevent the steel balls from striking the bottom of the pressure vessel.
6. After the soil mass is introduced to the calcium carbide, return the vessel to a horizontal position. With a circular rotating motion vigorously roll the steel balls around the interior perimeter of the vessel to break up lumps of soil. Do not allow the steel balls to hit the cap or the bottom of the pressure vessel.
7. Continue this motion for 60 seconds. Allow time for the dissipation of the heat generated by the chemical reaction. Repeat motion and resting cycles until no further reaction occurs.
8. When the gauge needle stops moving, take a reading while holding the unit in a horizontal position at eye level.
9. Record the sample mass and the gauge reading. If the initial soil mass was reduced in half, multiply gauge reading by two.
10. Position the unit so that the cap is away from the user and slowly loosen the clamp to release the gas from the pressure chamber. Inspect the sample inside the pressure chamber. If it is not completely pulverized, a new sample must be obtained and tested after the instrument has been thoroughly cleaned.

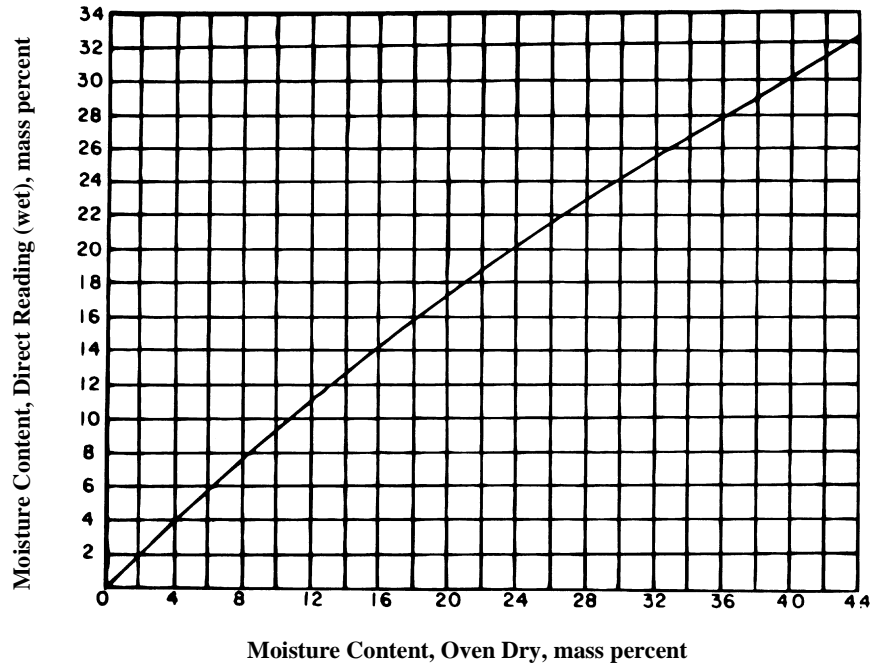
Moisture Determination

1. The tester determines moisture content based on the wet mass of the soil. Moisture content based on the dry mass of soil is obtained from a conversion chart or curve supplied with each tester. See Figure 1 for curve from AASHTO T 217.

Note 4: Check the accuracy of the gauge and the conversion chart or curve periodically, in accordance with agency requirements, by testing samples of known moisture content. Develop correction factors, if necessary.

Figure 1

Conversion Curve for Moisture Tester Reading



Example:

Gauge reading: 18.5
 Conversion from chart: 22.1
 Recorded % moisture: 22%

Report

Results shall be reported on standard forms approved by the agency. Report the moisture content to the nearest 0.1 percent.

Capping Cylindrical Concrete Specimens

AASHTO Designation: T 231-17

ASTM Designation: C 617-15

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**TOTAL EVAPORABLE MOISTURE CONTENT OF AGGREGATE BY DRYING
FOP FOR AASHTO T 255
LABORATORY DETERMINATION OF MOISTURE CONTENT OF SOILS
FOP FOR AASHTO T 265**

Scope

This procedure covers the determination of moisture content of aggregate and soil in accordance with AASHTO T 255-22 and AASHTO T 265-22. It may also be used for other construction materials.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: capacity sufficient for the principal sample mass, accurate to 0.1 percent of sample mass or readable to 0.1 g, and meeting the requirements of AASHTO M 231
- Containers, clean, dry, and capable of being sealed
- Suitable drying containers
- Microwave safe container with ventilated lid
- Heat source, thermostatically controlled, capable of maintaining $110 \pm 5^{\circ}\text{C}$ ($230 \pm 9^{\circ}\text{F}$).
 - Forced draft oven (preferred)
 - Ventilated oven
 - Convection oven
- Heat source, uncontrolled, for use when allowed by the agency, will not alter the material being dried, and close control of the temperature is not required:
 - Infrared heater/heat lamp, hot plate, fry pan, or any other device/method allowed by the agency .
 - Microwave oven (900 watts minimum)
- Utensils such as spoons
- Hot pads or gloves

Sample Preparation

Obtain a representative sample according to the FOP for AASHTO R 90 in its existing condition. If necessary, reduce the sample to moisture content sample size according to the FOP for AASHTO R 76.

For aggregate, the moisture content sample size is based on Table 1 or other information that may be specified by the agency.

TABLE 1
Sample Sizes for Moisture Content of Aggregate

Nominal Maximum Size* mm (in.)	Minimum Sample Mass g (lb)
150 (6)	50,000 (110)
100 (4)	25,000 (55)
90 (3 1/2)	16,000 (35)
75 (3)	13,000 (29)
63 (2 1/2)	10,000 (22)
50 (2)	8000 (18)
37.5 (1 1/2)	6000 (13)
25.0 (1)	4000 (9)
19.0 (3/4)	3000 (7)
12.5 (1/2)	2000 (4)
9.5 (3/8)	1500 (3.3)
4.75 (No. 4)	500 (1.1)

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum.

For soils the moisture content sample size is based on Table 2 or other information that may be specified by the agency.

TABLE 2
Sample Sizes for Moisture Content of Soil

Maximum Particle Size mm (in.)	Minimum Sample Mass g
50 (2)	1000
25.0 (1)	500
12.5 (1/2)	300
4.75 (No. 4)	100
0.425 (No. 40)	10

Immediately seal or cover moisture content samples to prevent any change in moisture content or follow the steps in “Procedure.”

Procedure

Determine and record the sample mass as follows:

- For aggregate, determine and record all masses to the nearest 0.1 percent of the sample mass or to the nearest 0.1 g.
- For soil, determine and record all masses to the nearest 0.1 g.

When determining the mass of hot samples or containers or both, place and tare a buffer between the sample container and the balance. This will eliminate damage to or interference with the operation of the balance or scale.

1. Determine and record the mass of the container (and lid for microwave drying).
2. Place the wet sample in the container.
3. Determine and record the total mass of the container and wet sample.
 - a. For oven(s), hot plates, infrared heaters, etc.: Spread the sample in the container.
 - b. For microwave oven: Heap sample in the container; cover with ventilated lid.
4. Determine and record the wet mass of the sample (M_w) by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 3.
5. Place the sample in one of the following drying apparatuses:
 - a. For aggregate –
 - i. Controlled heat source (oven): at $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$).
 - ii. Uncontrolled heat source (Hot plate, infrared heater, or other heat source as allowed by the agency): Stir frequently to avoid localized overheating.
 - b. For soil – controlled heat source (oven): at $110 \pm 5^\circ\text{C}$ ($230 \pm 9^\circ\text{F}$).

Note 1: Soils containing gypsum or significant amounts of organic material require special drying. For reliable moisture contents dry these soils at 60°C (140°F). For more information see AASHTO T 265, Note 2.

6. Dry until sample appears moisture free.
7. Determine mass of sample and container.
8. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 7.
9. Return sample and container to the heat source for additional drying.
 - a. For aggregate –
 - i. Controlled heat source (oven): 30 minutes
 - ii. Uncontrolled heat source (Hot plate, infrared heater, or other heat source as allowed by the agency): 10 minutes
 - iii. Uncontrolled heat source (Microwave oven): 2 minutes

Caution: Some minerals in the sample may cause the aggregate to overheat, crack, and explode; altering the aggregate gradation.

- b. For soil – controlled heat source (oven): 1 hour
10. Determine mass of sample and container.
11. Determine and record the mass of the sample by subtracting the container mass determined in Step 1 from the mass of the container and sample determined in Step 10.
12. Determine percent change by subtracting the new mass determination (M_n) from the previous mass determination (M_p) divide by the previous mass determination (M_p) multiply by 100.
13. Continue drying, performing steps 9 through 12, until there is less than a 0.10 percent change after additional drying time.
14. Constant mass has been achieved; sample is defined as dry.
15. Allow the sample to cool. Immediately determine and record the total mass of the container and dry sample.
16. Determine and record the dry mass of the sample (M_D) by subtracting the mass of the container determined in Step 1 from the mass of the container and sample determined in Step 15.
17. Determine and record percent moisture (w) by subtracting the final dry mass determination (M_D) from the initial wet mass determination (M_w) divide by the final dry mass determination (M_D) multiply by 100.

Table 3
Methods of Drying

Aggregate		
Heat Source	Specific Instructions	Drying intervals to achieve constant mass (minutes)
Controlled:		
Forced draft (preferred), ventilated, or convection oven	110 ±5°C (230 ±9°F)	30
Uncontrolled:		
Hot plate, infrared heater, or any other device/method allowed by the agency	Stir frequently	10
Microwave	Heap sample and cover with ventilated lid	2
Soil		
Heat Source	Specific Instructions	Drying increments (minutes)
Controlled:		
Forced draft (preferred), ventilated, or convection oven	110 ±5°C (230 ±9°F)	1 hour

Calculation

Constant Mass

Calculate constant mass using the following formula:

$$\% \text{ Change} = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement

M_n = new mass measurement

Example:

Mass of container: 1232.1 g

Mass of container and sample after first drying cycle: 2637.2 g

Mass, M_p , of possibly dry sample: $2637.2 \text{ g} - 1232.1 \text{ g} = 1405.1 \text{ g}$

Mass of container and sample after second drying cycle: 2634.1 g

Mass, M_n , of sample: $2634.1 \text{ g} - 1232.1 \text{ g} = 1402.0 \text{ g}$

$$\% \text{ Change} = \frac{1405.1 \text{ g} - 1402.0 \text{ g}}{1405.1 \text{ g}} \times 100 = 0.22\%$$

0.22 percent is not less than 0.10 percent, so continue drying.

Mass of container and sample after third drying cycle: 2633.0 g

Mass, M_n , of sample: $2633.0 \text{ g} - 1232.1 \text{ g} = 1400.9 \text{ g}$

$$\% \text{ Change} = \frac{1402.0 \text{ g} - 1400.9 \text{ g}}{1402.0 \text{ g}} \times 100 = 0.08\%$$

0.08 percent is less than 0.10 percent, so constant mass has been reached.

Moisture Content:

Calculate the moisture content, as a percent, using the following formula:

$$w = \frac{M_W - M_D}{M_D} \times 100$$

where:

w = moisture content, percent

M_w = wet mass

M_D = dry mass

Example:

Mass of container: 1232.1 g

Mass of container and wet sample: 2764.7 g

Mass, M_w, of wet sample: 2764.7 g - 1232.1 g = 1532.6 g

Mass of container and dry sample (COOLED): 2633.5 g

Mass, M_D, of dry sample: 2633.5 g - 1232.1 g = 1401.4 g

$$w = \frac{1532.6 \text{ g} - 1401.4 \text{ g}}{1401.4 \text{ g}} \times 100 = \frac{131.2 \text{ g}}{1401.4 \text{ g}} \times 100 = 9.36\% \text{ report } 9.4\%$$

Report

- On forms approved by the agency
- Sample ID
- M_w, wet mass
- M_D, dry mass
- w, moisture content to the nearest 0.1 percent

EMBANKMENT AND BASE
IN-PLACE DENSITY

WAQTC

FOP AASHTO T 255 / T 265 (22)



Oregon

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October 31, 2022

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 272**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **AASHTO T 99 (Methods B & C) are not allowed on ODOT contracts.**
- **Use AASHTO T 99 (Methods A or D) based on the following criteria:**
- **The moisture content of the one point may be determined according to AASHTO T 217.**
- **The moisture content of the one point must be determined according to AASHTO T 255/265 for Method D applications.**
- **Under the calculations section, add the following: Wet density may be determined according to T 99 - Yellow Sheet, using a "Mold Factor".**
- **Delete Section "Maximum Dry Density and Optimum Moisture Content Determination Using an Individual Moisture / Density Curve".**
- **Under Section Maximum Dry Density and Optimum Moisture Content Determination Using a Family of Curves, if the one-point plot doesn't meet the requirements of this section (steps 2, 3, & 5), then a full curve must be developed or the guidelines for Selecting a Single Curve (Appendix A) located at the end of AASHTO T 272.**
- **Delete the Individual Moisture / Density Curve figure and example on page E&B/ID 15-5.**

ONE-POINT METHOD FOR DETERMINING MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE FOP FOR AASHTO T 272

Scope

This procedure provides for a rapid determination of the maximum dry density and optimum moisture content of a soil sample, using a one-point determination in accordance with AASHTO T 272-18. This procedure is related to the FOPs for AASHTO T 99/T 180 and R 75.

One-point determinations are made by compacting the soil in a mold of a given size with a specified rammer dropped from a specified height and then compared to an individual moisture/density curve (FOP for AASHTO T 99 or T 180) or a family of curves (FOP for AASHTO R 75). Four alternate methods – A, B, C, and D – are used and correspond to the methods described in the FOP for AASHTO T 99/T 180. The method used in AASHTO T 272 must match the method used for the reference curve or to establish the family of curves. For example, when moisture-density relationships as determined by T 99 - Method C are used to form the family of curves or an individual moisture density curve, then T 99 - Method C must be used to for the one-point determination.

Apparatus

See the FOP for AASHTO T 99/T 180.

Sample

Sample size determined according to the FOP for AASHTO T 310. In cases where the existing individual curve or family cannot be used a completely new curve will need to be developed and the sample size will be determined by the FOP for AASHTO T 99/T 180.

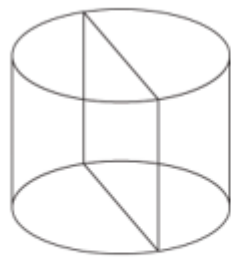
1. If the sample is damp, dry it until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus maintained at a temperature not exceeding 60°C (140°F).
2. Thoroughly break up aggregations in a manner that avoids reducing the natural size of individual particles.
3. Pass the material through the appropriate sieve.

Procedure

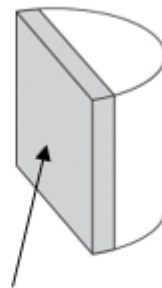
Use the method matching the individual curve or Family of Curves. Refer to Table 1 of the FOP for AASHTO T 99 / T 180 for corresponding mold size, number of layers, number of blows, sieve size, and rammer specification for the various test methods.

1. Determine the mass of the clean, dry mold. Include the base plate but exclude the extension collar. Record the mass to the nearest 1 g (0.005 lb).
2. Thoroughly mix the sample with sufficient water to adjust moisture content to 80 to 100 percent of the anticipated optimum moisture.

3. Form a specimen by compacting the prepared soil in the mold (with collar attached) in approximately equal layers. For each layer:
 - a. Spread the loose material uniformly in the mold.
- Note 1:* It is recommended to cover the remaining material with a non-absorbent sheet or damp cloth to minimize loss of moisture.
- b. Lightly tamp the loose material with the manual rammer or other similar device, this establishes a firm surface.
 - c. Compact each layer with uniformly distributed blows from the rammer.
 - d. Trim down material that has not been compacted and remains adjacent to the walls of the mold and extends above the compacted surface.
 4. Remove the extension collar. Avoid shearing off the sample below the top of the mold. The material compacted in the mold should not be over 6 mm (¼ in.) above the top of the mold once the collar has been removed.
 5. Trim the compacted soil even with the top of the mold with the beveled side of the straightedge.
 6. Clean soil from exterior of the mold and base plate.
 7. Determine the mass of the mold and wet soil to the nearest 1 g (0.005 lb).
 8. Determine the wet mass of the sample by subtracting the mass in Step 1 from the mass in Step 7.
 9. Calculate the wet density (ρ_w) as indicated below under “Calculations.”
 10. Extrude the material from the mold. For soils and soil-aggregate mixtures, slice vertically through the center and remove one of the cut faces for a representative moisture content sample. For granular materials, a vertical face will not exist. Take a representative sample ensuring that all layers are represented. This sample must meet the sample size requirements of the test method used to determine moisture content.



Extruded material



**Representative moisture
content sample**

11. Determine the moisture content (w) of the sample in accordance with the FOP for AASHTO T 255 / T 265.

Calculations

1. Calculate the wet density, in kg/m^3 (lb/ft^3), by dividing the wet mass by the measured volume of the mold (T 19).

Example – Methods A or C mold:

Wet mass = 2.0055 kg (4.42 lb)

Measured volume of the mold = 0.0009469 m^3 (0.0334 ft^3)

$$\rho_w = \frac{2.0055 \text{ kg}}{0.0009469 \text{ m}^3} = 2118 \text{ kg/m}^3$$

$$\rho_w = \frac{4.42 \text{ lb}}{0.0334 \text{ ft}^3} = 132.2 \text{ lb/ft}^3$$

Where:

$$\rho_w = \text{Wet density, kg/m}^3 \text{ (lb/ft}^3\text{)}$$

2. Calculate the dry density as follows.

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

Where:

$$\rho_d = \text{Dry density, kg/m}^3 \text{ (lb/ft}^3\text{)}$$

w = Moisture content, as a percentage

Example:

$$\rho_w = 2118 \text{ kg/m}^3 \text{ (132.2 lb/ft}^3\text{)}$$

$$w = 13.5\%$$

$$\rho_d = \left(\frac{2118 \text{ kg/m}^3}{13.5 + 100} \right) \times 100 = 1866 \text{ kg/m}^3 \quad \rho_d = \left(\frac{132.2 \text{ lb/ft}^3}{13.5 + 100} \right) \times 100 = 116.5 \text{ lb/ft}^3$$

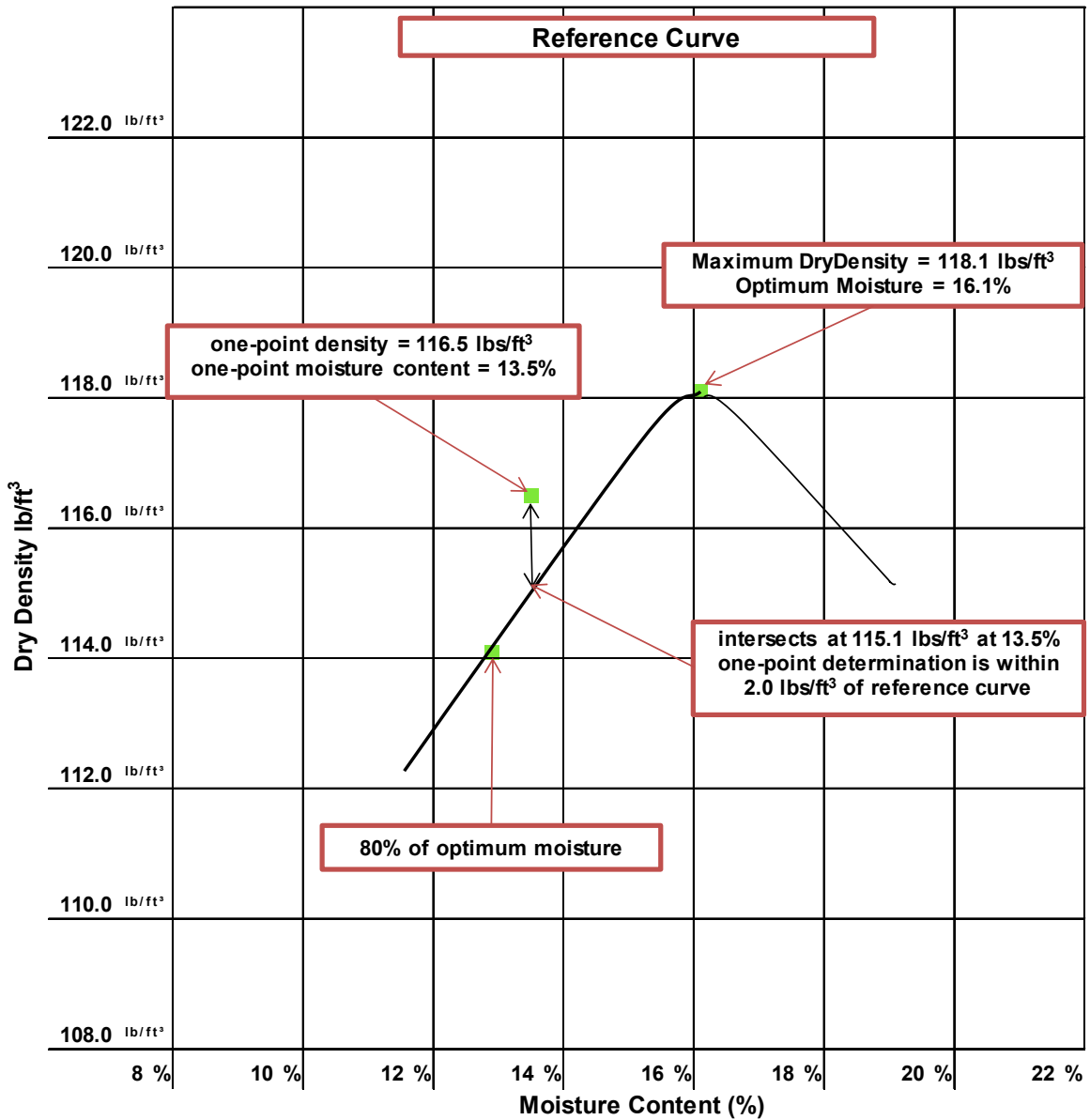
or

$$\rho_d = \left(\frac{2118 \text{ kg/m}^3}{\frac{13.5}{100} + 1} \right) = 1866 \text{ kg/m}^3 \quad \rho_d = \left(\frac{132.2 \text{ lb/ft}^3}{\frac{13.5}{100} + 1} \right) = 116.5 \text{ lb/ft}^3$$

Maximum Dry Density and Optimum Moisture Content Determination Using an Individual Moisture / Density Curve

1. The moisture content must be within 80 to 100 percent of optimum moisture of the reference curve. Compact another specimen, using the same material, at an adjusted moisture content if the one-point does not fall in the 80 to 100 percent of optimum moisture range.
2. Plot the one-point, dry density on the vertical axis and moisture content on the horizontal axis, on the reference curve graph.
3. If the one-point falls on the reference curve or within ± 2.0 lbs/ft³, use the maximum dry density and optimum moisture content determined by the curve.
4. Use the FOP for AASHTO T 99/T 180 Annex A to determine corrected maximum dry density and optimum moisture content if oversize particles have been removed.
5. Perform a full moisture-density relationship if the one-point does not fall on or within ± 2.0 lbs/ft³ of the reference curve at 80 to 100 percent optimum moisture.

Example



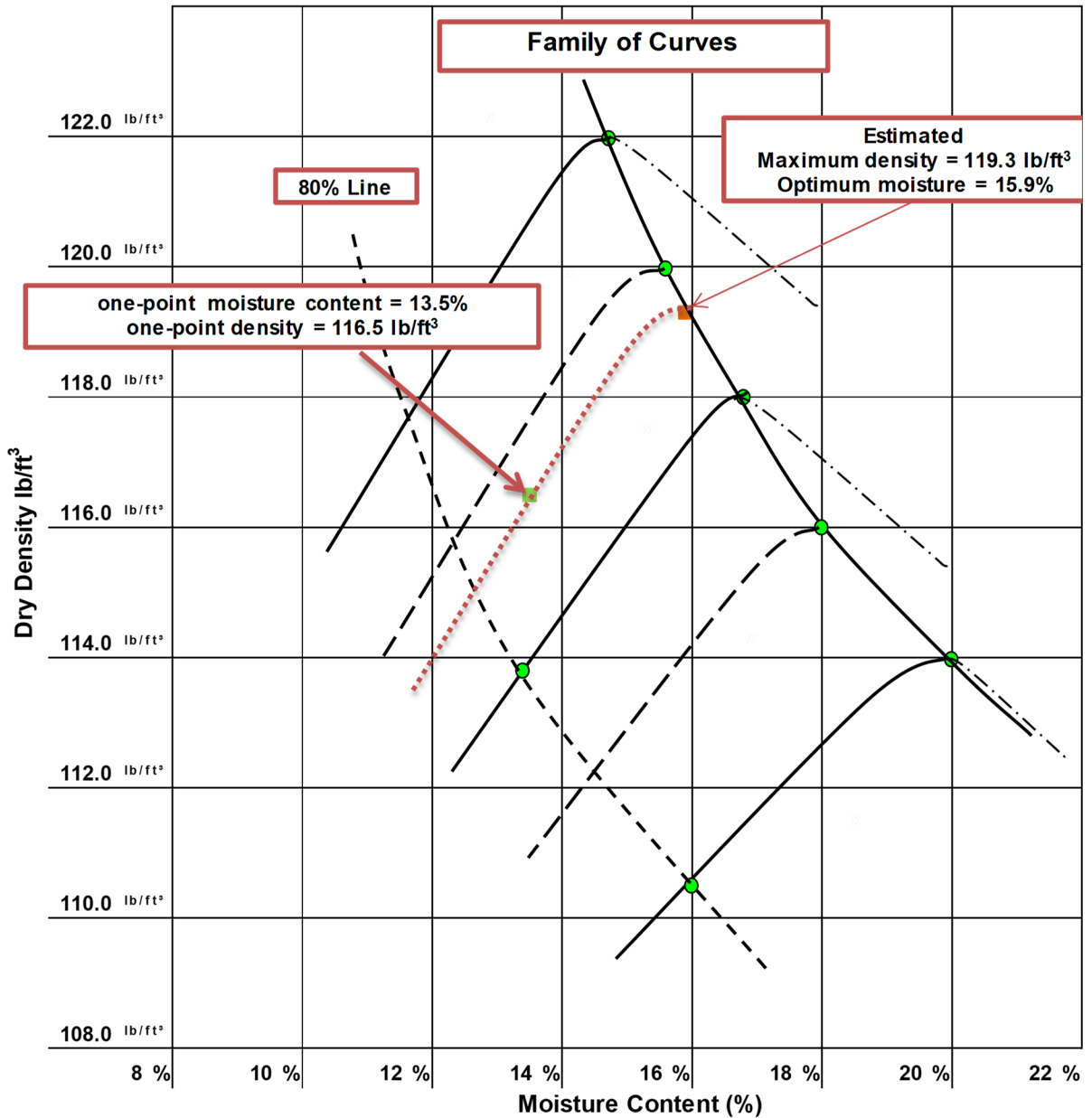
The results of a one-point determination were 116.5 lb/ft³ at 13.5 percent moisture. The point was plotted on the reference curve graph. The one-point determination is within 2.0 lb/ft³ of the point on the curve that corresponds with the moisture content.

Maximum Dry Density and Optimum Moisture Content Determination Using a Family of Curves

1. Plot the one-point, dry density on the vertical axis and moisture content on the horizontal axis, on the reference family of curves graph.
2. If the moisture-density one-point falls on one of the curves in the family of curves, use the maximum dry density and optimum moisture content defined by that curve.
3. If the moisture-density one-point falls within the family of curves but not on an existing curve, draw a new curve through the plotted single point, parallel and in character with the nearest existing curve in the family of curves. Use the maximum dry density and optimum moisture content as defined by the new curve.
 - a. The one-point must fall either between or on the highest or lowest curves in the family. If it does not, then a full curve must be developed.
 - b. If the one-point plotted within or on the family of curves does not fall in the 80 to 100 percent of optimum moisture content, compact another specimen, using the same material, at an adjusted moisture content that will place the one point within this range.
4. Use the FOP for AASHTO T 99/T 180 Annex A to determine corrected maximum dry density and optimum moisture content if oversize particles have been removed.
5. If the new curve through a one-point is not well defined or is in any way questionable, perform a full moisture-density relationship to correctly define the new curve and verify the applicability of the family of curves.

Note 2: New curves drawn through plotted single point determinations shall not become a permanent part of the family of curves until verified by a full moisture-density procedure following the FOP for AASHTO T 99/T 180.

Example



The results of a one-point determination were 116.5 lb/ft³ at 13.5 percent moisture. The point was plotted on the reference curve graph. The point was plotted on the appropriate family between two previously developed curves near and intermediate curve.

The “dotted” curve through the moisture-density one-point was sketched between the existing curves. A maximum dry density of 119.3 lb/ft³ and a corresponding optimum moisture content of 15.9 percent were estimated.

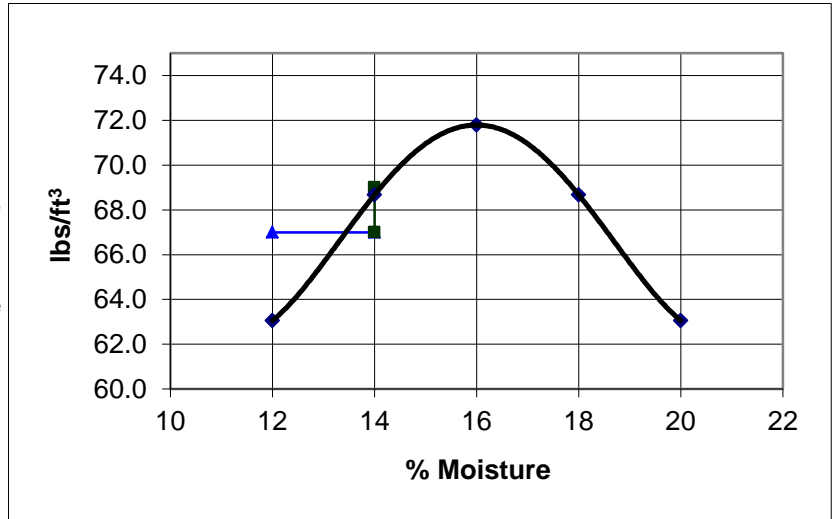
Report

- On forms approved by the agency
- Sample ID
- Maximum dry density to the nearest 1 kg/m^3 (0.1 lb/ft^3)
- Corrected maximum dry density (if applicable)
- Optimum moisture content to the nearest 0.1 percent
- Corrected optimum moisture content (if applicable)
- Reference curve or Family of Curves used

Appendix "A" Guidelines for Selecting a Single Curve

- 1) Select all curves where the One Point plots within 2 lbs/ft³ and 2.0% of the curve.
 - a) Plot the One Point on the curve.
 - b) Extend a line vertically 2 lbs/ft³ in length from the One Point towards the curve.
 - c) Extend a line Horizontally 2.0% in length from the One Point towards the curve.

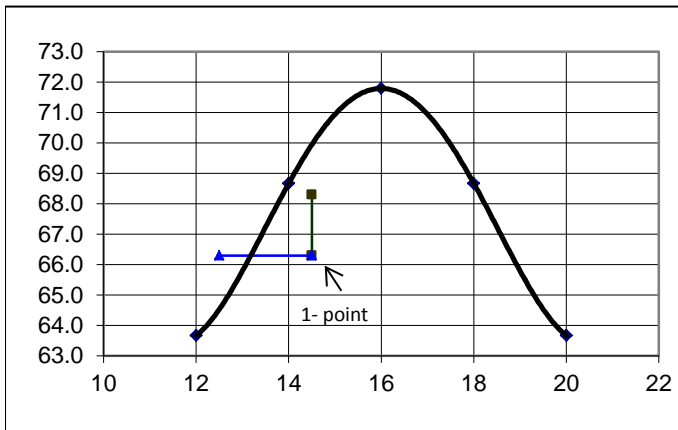
Example Shown: The One Point is 67 lbs/ft³ @ 14% moisture. Therefore the horizontal extension is 12% (-2%) and the vertical extension is to 69 lbs/ft³ (+2lbs/ft³).



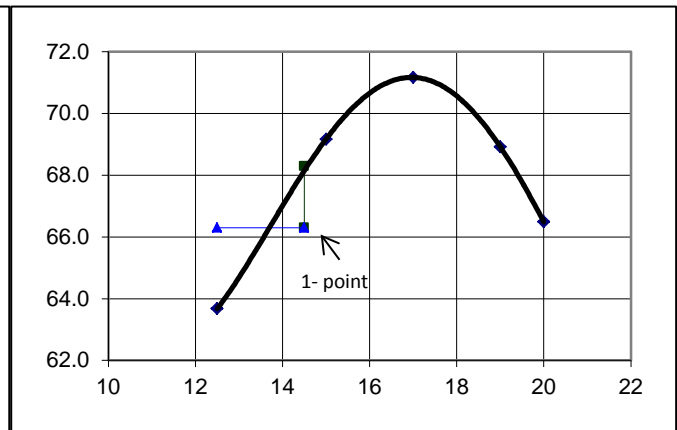
- 2) Retain only those curves where the One Point has a lower moisture content than the Optimum Moisture of the curve being used for comparison.
- 3) Review the remaining curves and select the curve which, best fits in order of the following parameters:
 - a) One Point closest to the "dry" curve line
 - b) Highest Maximum Density
 - c) Lowest Optimum Moisture

EXAMPLE

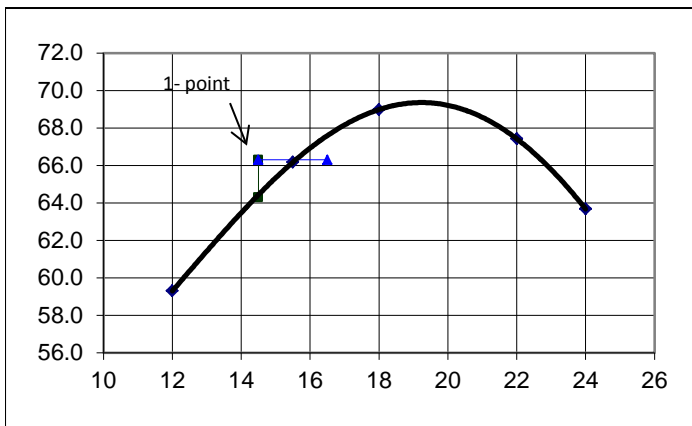
Curve #1



Curve #2



Curve #3



One Point = 66.3 lbs/ft³ @ 14.5% moisture

- 1) Only two curves meet requirement 1, (2 & 3).
- 2) Both curves 2 & 3 have higher Optimum moistures than the One Point Plot. Meeting requirement 2.
- 3) Therefore use requirement 3:
 - a) Curve 2 & 3 appear to be equal distant from the two curves
 - b) Curve 2 has the higher Maximum Density.

Therefore, use Curve # 2

Test Procedure AASHTO T 283 Continued

- **Test Sample with 8 Specimens:**
 1. **Of the initial 8 specimens; select the specimen with highest air voids and the specimen with the lowest air voids and designate them “Wet”.**
 2. **Of the remaining 6 specimens; select the specimen with highest air voids and the specimen with the lowest air voids and designate them “Dry”.**
 3. **Of the remaining 4 specimens; select the specimen with highest air voids and the specimen with the lowest air voids and designate them “Wet”.**
 4. **The remaining 2 specimens are designated “Dry”**

All Specimens

- **Section 10.4.9, Delete this section. Freeze-thaw conditioning is not required.**



Oregon

Kate Brown, Governor

Department of Transportation

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December 1, 2021

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 283**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

Preparation of Lab-Mixed, Lab Compacted Specimens

- **Section 6.3, only 6” specimens are allowed for this step.**
- **Section 6.5, Do not perform the 2-hr cooling and 16-hr loose mix curing required by this section.**
- **Section 6.7, Compact each specimen to the required air void range.**

Preparation of Field-Mixed, Lab compacted Specimens

- **Section 7.4, only 6” specimens are allowed for this step.**

Grouping of test Specimens for Conditioning

- **Test Sample with 6 Specimens:**
 1. **Of the initial 6 specimens; select the specimen with highest air voids and the specimen with the lowest air voids and designate them “Wet”.**
 2. **Of the remaining 4 specimens; select the specimen with highest air voids and the specimen with the lowest air voids and designate them “Dry”.**
 3. **Of the remaining 2 specimens; select the specimen with the lowest air voids and designate it “Wet”. The remaining specimen is designated “Dry”.**

(See Next Page)

Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage

AASHTO Designation: T 283-22

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<https://www.oregon.gov/ODOT/Forms/2ODOT/7345110.pdf>

To order AASHTO's *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, visit the [AASHTO Store website](#).

Test Procedure AASHTO T 308 Continued

- When a separate sample is tested for moisture, then the following equations shall apply:

$$M_{id} = \left\{ \frac{M_i}{1 + \left(\frac{\% M}{100} \right)} \right\}$$

Where: M_i = Initial mass of sample prior to ignition, including moisture.
 $\%M$ = Moisture content of sample based on final dry weight per AASHTO T 329.

$$P_b = \left(\frac{M_{id} - M_f}{M_{id}} \right) \times 100 - C_f$$

Where: M_f = Final mass of aggregate remaining after ignition.
 M_{id} = Initial "Dry" mass of mixture prior to ignition.
 C_f = Correction Factor

- When the sample is oven dried to a constant mass, then the following equation shall apply:

$$P_b = \left(\frac{M_i - M_f}{M_i} \right) \times 100 - C_f$$

Where: M_i = Initial Oven "Dried" mass of mixture prior to ignition.
 M_f = Final mass of aggregate remaining after ignition.
 C_f = Correction Factor

- Delete Annex - Correction Factors. Perform calibration of Ignition Furnace according to ODOT TM 323.



Oregon

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October 31, 2018

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 308**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Test Procedures, Method A and Method B steps 1, when a furnace using Infra-Red elements is used, turn on and warm up the furnace as recommended by the manufacturer before performing a test.**
- **All other requirements of the test procedure apply to the Infra-Red furnace.**
- **For Test Procedure Method A and Method B, external scale measurements taken at approximately the same temperature (+- 10C (25F)) are required for the initial and final mass determinations. Loss from the printed tickets shall not be used.**
- **For Test Procedure Method B, replace step 7, 45 min burn time with 60 minute burn time. Delete steps 10 thru 14.**
- **Compute the percent binder based on the following calculations and conditions:**

(See Next Page)

DETERMINING THE ASPHALT BINDER CONTENT OF ASPHALT MIXTURES BY THE IGNITION METHOD FOP FOR AASHTO T 308

Scope

This procedure covers the determination of asphalt binder content of asphalt mixtures by ignition of the binder in accordance with AASHTO T 308-22.

Overview

The sample is heated in a furnace at 538°C (1000°F) or less; samples may be heated by convection or direct infrared irradiation (IR). The aggregate remaining after burning can be used for sieve analysis using the FOP for AASHTO T 30.

Some agencies allow the use of recycled asphalt mixtures. When using recycled asphalt mixtures, check with the agency for specific correction procedures.

Asphalt binder in the asphalt mixture is ignited in a furnace. Asphalt binder content is calculated as the percentage difference between the initial mass of the asphalt mixture and the mass of the residual aggregate, with the asphalt binder correction factor, and moisture content subtracted. The asphalt binder content is expressed as percent of moisture-free mix mass.

Two methods, A and B, are presented.

Apparatus

Note 1: The apparatus must be calibrated for the specific mix design. See “Correction Factors” at the end of this FOP.

The apparatus for the Methods A and B is the same except that the furnace for Method A requires an internal balance.

- **Ignition Furnace:** A forced-air ignition furnace that heats the specimens by either the convection or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature between at least 530 and 545°C (986 and 1013°F) and have a temperature control accurate within $\pm 5^{\circ}\text{C}$ ($\pm 9^{\circ}\text{F}$).

For Method A, the furnace will be equipped with an internal scale thermally isolated from the furnace chamber and accurate to 0.1 g. The scale shall be capable of determining the mass of a 3500 g sample in addition to the sample baskets. A data collection system will be included so that mass can be automatically determined and displayed during the test. The furnace shall have a built-in computer program to calculate the change in mass of the sample and provide for the input of a correction factor for aggregate loss. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss, temperature compensation, correction factor, corrected asphalt binder content, test time, and test temperature. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes. Perform lift test according to manufacturer’s instructions weekly during use, if applicable. The furnace shall be

designed to permit the operator to change the ending mass loss percentage from both 0.01 percent to 0.02 percent.

For both Method A and Method B, the furnace chamber dimensions shall be adequate to accommodate a 3500 g sample. The furnace door shall be equipped so that it cannot be opened during the ignition test. A method for reducing furnace emissions shall be provided and the furnace shall be vented so that no emissions escape into the laboratory. The furnace shall have a fan to pull air through the furnace to expedite the test and to eliminate the escape of smoke into the laboratory.

- Sample Basket Assembly: consisting of sample basket(s), catch pan, and basket guards. Sample basket(s) will be of appropriate size allowing samples to be thinly spread and allowing air to flow through and around the sample particles. Sets of two or more baskets shall be nested. A catch pan: of sufficient size to hold the sample basket(s) so that aggregate particles and melting asphalt binder falling through the screen mesh are caught. Basket guards will completely enclose the basket and be made of screen mesh, perforated stainless steel plate, or other suitable material.
- Thermometer, or other temperature measuring device, with a temperature range of 10 - 260°C (50-500°F).
- Oven capable of maintaining 110 ±5°C (230 ±9°F).
- Balance or scale: Capacity sufficient for the sample mass and conforming to the requirements of M 231, Class G2.
- **Safety equipment:** Safety glasses or face shield, high temperature gloves, long sleeved jacket, a heat resistant surface capable of withstanding 650°C (1202°F), a protective cage capable of surrounding the sample baskets during the cooling period, and a particle mask for use during removal of the sample from the basket assembly.
- Miscellaneous equipment: A container larger than the sample basket(s) for transferring sample after ignition, large flat pan, spatulas, bowls, and wire brushes.

Sampling

1. Obtain samples of asphalt mixture in accordance with the FOP for AASHTO R 97.
2. Reduce asphalt mixture samples in accordance with the FOP for AASHTO R 47.
3. If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan in an oven at 110 ±5°C (230 ±9°F) until soft enough.
4. Test sample size shall conform to the mass requirement shown in Table 1.

Note 2: When the mass of the test specimen exceeds the capacity of the equipment used or for large samples of fine mixes, the test specimen may be divided into suitable increments, tested, and the results appropriately combined through a weighted average for calculation of the asphalt binder content.

Table 1

Nominal Maximum Aggregate Size* mm (in.)	Minimum Mass Specimen g	Maximum Mass Specimen g
37.5 (1 ½)	4000	4500
25.0 (1)	3000	3500
19.0 (¾)	2000	2500
12.5 (½)	1500	2000
9.5 (3/8)	1200	1700
4.75 (No. 4)	1200	1700

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

Procedure – Method A (Internal Balance)

1. For the convection-type furnace, preheat the ignition furnace to $538 \pm 5^{\circ}\text{C}$ ($1000 \pm 9^{\circ}\text{F}$) or to the temperature determined in the Correction Factors Annex of this method. Manually record the furnace temperature (set point) before the initiation of the test if the furnace does not record automatically. For the direct IR irradiation-type furnace, use the same burn profile as used during the correction factor determination.
2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.
3. Determine and record the mass of the sample basket assembly to the nearest 0.1 g.
4. Evenly distribute the sample in the sample basket assembly, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.
5. Determine and record the total mass of the sample and sample basket assembly at room temperature to the nearest 0.1 g.
6. Calculate the initial mass of the sample by subtracting the mass of the sample basket from the mass of the sample and sample basket assembly and record to the nearest 0.1 g. Designate this mass as (M_i).
7. Record the correction factor or input into the furnace controller for the specific asphalt mixture.
8. Input the initial mass of the sample (M_i) into the ignition furnace controller. Verify that the correct mass has been entered.
9. Verify the furnace scale is reading zero, if not, reset to zero.

CAUTION: Operator should wear safety equipment – high temperature gloves, face shield, fire-retardant shop coat – when opening the door to load or unload the sample.

10. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Close the chamber door and verify that the sample mass displayed on the furnace scale equals the total mass of the sample and sample basket assembly recorded in Step 5 within ± 5 g.

Note 3: Differences greater than 5 g or failure of the furnace scale to stabilize may indicate that the specimen basket assembly is contacting the furnace wall.

Note 4: Furnace temperature will drop below the set point when the door is opened but will recover when the door is closed, and ignition begins. Sample ignition typically increases the temperature well above the set point – relative to sample size and asphalt binder content.

11. Initiate the test by pressing the start button. This will lock the sample chamber and start the combustion blower.

Safety note: Do not attempt to open the furnace door until the asphalt binder has been completely burned off.

12. Allow the test to continue until the stable light and audible stable indicator indicate that the change in mass does not exceed 0.01 percent for three consecutive minutes. Press the stop button. This will unlock the sample chamber and cause the printer to print out the test results.

Note 5: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.

13. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 minutes).
14. Determine and record the mass of the sample and sample basket assembly after ignition to the nearest 0.1 g.
15. Calculate the mass of the sample by subtracting the mass of the sample basket assembly from the mass of the sample and sample basket assembly and record to the nearest 0.1 g. Designate this mass as M_f .
16. Use the asphalt binder content percentage from the printed ticket. Subtract the moisture content and the correction factor if not entered into the furnace controller from the printed ticket asphalt binder content and report the difference as the corrected asphalt binder content.

Asphalt binder content percentage can also be calculated using the formula from “Method B” Step 16.

Calculation

Corrected asphalt binder content:

$$P_b = BC - MC - C_f^*$$

*If correction factor is not entered into the furnace controller

where:

P_b = the corrected asphalt binder content as a percent by mass of the asphalt mixture

BC = asphalt binder content shown on printed ticket

MC = moisture content of the companion asphalt mixture sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried before initiating the procedure, $MC=0$)

C_f = correction factor as a percent by mass of the asphalt mixture sample

Procedure – Method B (External Balance)

1. Preheat the ignition furnace to $538 \pm 5^\circ\text{C}$ ($1000 \pm 9^\circ\text{F}$) or to the temperature determined in the Correction Factor Annex of this method. Manually record the furnace temperature (set point) before the initiation of the test if the furnace does not record automatically.
2. Dry the sample to constant mass, according to the FOP for AASHTO T 329; or determine the moisture content of a companion sample in accordance with the FOP for AASHTO T 329.
3. Determine and record the mass of the sample basket assembly to the nearest 0.1 g.
4. Place the sample basket(s) in the catch pan. Evenly distribute the sample in the sample basket(s), taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the sample.
5. Determine and record the mass of the sample and sample basket assembly at room temperature to the nearest 0.1 g.
6. Calculate the initial mass of the sample by subtracting the mass of the sample basket from the mass of the sample and sample basket assembly and record to the nearest 0.1 g. Designate this mass as (M_i).
7. Record the correction factor for the specific asphalt mixture.
8. Open the chamber door and gently set the sample basket assembly in the furnace. Carefully position the sample basket assembly so it is not in contact with the furnace wall. Burn the asphalt mixture sample in the furnace for 45 minutes or the length of time determined in the “Correction Factors” section.

9. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample and allow it to cool to room temperature (approximately 30 min).
10. Determine and record the mass of the sample and sample basket assembly to the nearest 0.1 g.
11. Calculate the sample mass by subtracting the mass of the sample basket assembly from the mass of the sample and sample basket assembly and record to the nearest 0.1 g.
12. Place the sample basket assembly back into the furnace.
13. Burn the sample for at least 15 minutes after the furnace reaches the set temperature.
14. Open the chamber door, remove the sample basket assembly, and place on the cooling plate or block. Place the protective cage over the sample basket assembly and allow it to cool to room temperature (approximately 30 min.).
15. Determine and record the mass of the sample and sample basket assembly to the nearest 0.1 g.
16. Calculate the mass of the sample by subtracting the mass of the sample basket assembly from the mass of the sample and sample basket assembly and record to the nearest 0.1 g.
17. Repeat Steps 10 through 13 until the change in measured mass of the sample after ignition does not exceed 0.01 percent of the previous sample mass.
Note 5: An ending mass loss percentage of 0.02 may be used, if allowed by the agency, when aggregate that exhibits an excessive amount of loss during ignition testing is used.
18. Determine and record the mass of the sample and sample basket assembly to the nearest 0.1 g.
19. Calculate the final sample mass by subtracting the mass of the sample basket assembly and sample and sample basket assembly and record to the nearest 0.1 g. Designate this mass as M_f .
20. Calculate the asphalt binder content of the sample.

Calculations

Calculate the asphalt binder content of the sample as follows:

$$P_b = \frac{M_i - M_f}{M_i} \times 100 - MC - C_f$$

where:

P_b = the corrected asphalt binder content as a percent by mass of the asphalt mixture sample

M_f = the final sample mass after ignition, g

M_i = the initial mass of the asphalt mixture sample before ignition, g

MC = moisture content of the companion asphalt mixture sample, percent, as determined by the FOP for AASHTO T 329 (if the specimen was oven-dried before initiating the procedure, MC = 0).

C_f = correction factor as a percent by mass of the asphalt mixture sample

Example

Correction Factor	= 0.42%
Moisture Content	= 0.04%
Initial Mass of Sample and Basket	= 5292.7 g
Mass of Basket Assembly	= 2931.5 g
M_i	= 2361.2 g
Total Mass after First ignition + basket	= 5154.4 g
Sample Mass after First ignition	= 2222.9 g
Sample Mass after additional 15 min ignition	= 2222.7 g

$$\%change = \frac{2222.9 \text{ g} - 2222.7 \text{ g}}{2222.9 \text{ g}} \times 100 = 0.009\%$$

%change is not greater than 0.01 percent, so $M_f = 2222.7 \text{ g}$

$$P_b = \frac{2361.2 \text{ g} - 2222.7 \text{ g}}{2361.2 \text{ g}} \times 100 - 0.42\% - 0.04\% = 5.41\%$$

$P_b = 5.41\%$

Gradation

1. Empty contents of the basket(s) into a container, being careful to capture all material. Use a small wire brush to ensure all residual fines are removed from the baskets.

Note 7: Particle masks are a recommended safety precaution.

2. Perform the gradation analysis in accordance with the FOP for AASHTO T 30.

Report

- On forms approved by the agency
- Sample ID
- Method of test (A or B)
- Corrected asphalt binder content, P_b , to the nearest 0.01 percent or per agency standard
- Correction factor, C_f , to the nearest 0.01 percent
- Temperature compensation factor (Method A only)
- Total percent loss
- Sample mass
- Moisture content to the nearest 0.01%
- Test temperature

Attach the original printed ticket with all intermediate values (continuous tape) to the report for furnaces with internal balances.

ANNEX – CORRECTION FACTORS

ASPHALT BINDER AND AGGREGATE

(Mandatory Information)

Asphalt binder content results may be affected by the type of aggregate in the mixture and by the ignition furnace. Asphalt binder and aggregate correction factors must, therefore, be established by testing a set of correction specimens for each Job Mix Formula (JMF) mix design. Each ignition furnace will have its own unique correction factor determined in the location where testing will be performed.

This procedure must be performed before any acceptance testing is completed, and repeated each time there is a change in the mix ingredients or design. Any changes greater than 5 percent in stockpiled aggregate proportions should require a new correction factor.

All correction samples will be prepared by a central / regional laboratory unless otherwise directed.

Asphalt binder correction factor: A correction factor must be established by testing a set of correction specimens for each Job Mix Formula (JMF). Certain aggregate types may result in unusually high correction factors (> 1.00 percent). Such mixes should be corrected and tested at a lower temperature as described below.

Aggregate correction factor: Due to potential aggregate breakdown during the ignition process, a correction factor will need to be determined for the following conditions:

- a. Aggregates that have a proven history of excessive breakdown
- b. Aggregate from an unknown source.

This correction factor will be used to adjust the acceptance gradation test results obtained according to the FOP for AASHTO T 30.

Procedure

1. Obtain samples of aggregate in accordance with the FOP for AASHTO R 90.
2. Obtain samples of asphalt binder in accordance with the FOP for AASHTO R 66.
Note 8: Include other additives that may be required by the JMF.
3. Prepare an initial, or “butter,” mix at the design asphalt binder content. Mix and discard the butter mix before mixing any of the correction specimens to ensure accurate asphalt content.
4. Prepare two correction specimens at the JMF design asphalt binder content. Aggregate used for correction specimens shall be sampled from material designated for use on the project. An agency approved method will be used to combine aggregate. An additional “blank” specimen shall be batched and tested for aggregate gradation in accordance with the FOP for AASHTO T 30. The gradation from the “blank” shall fall within the agency specified mix design tolerances.
5. Place the freshly mixed specimens directly into the sample basket assembly. If mixed specimens are allowed to cool before placement in the sample basket assembly, the

specimens must be dried to constant mass according to the FOP for AASHTO T 329. Do not preheat the sample basket assembly.

6. Test the specimens in accordance with Method A or Method B of the procedure.
7. Once both correction specimens have been burned, determine the asphalt binder content for each specimen by calculation or from the printed ignition furnace tickets, if available.
8. If the difference between the asphalt binder contents of the two specimens exceeds 0.15 percent, repeat with two more specimens and, from the four results, discard the high and low result. Determine the correction factor from the two original or remaining results, as appropriate. Calculate the difference between the actual and measured asphalt binder contents for each specimen to 0.01 percent. The asphalt binder correction factor, C_f , is the average of the differences expressed as a percent by mass of asphalt mixture.
9. If the asphalt binder correction factor exceeds 1.00 percent, the test temperature must be lowered to $482 \pm 5^\circ\text{C}$ ($900 \pm 9^\circ\text{F}$) and new samples must be burned. If the correction factor is the same or higher at the lower temperature, it is permissible to use the higher temperature. The temperature for determining the asphalt binder content of asphalt mixture samples by this procedure shall be the same temperature determined for the correction samples.
10. For the direct IR irradiation-type burn furnaces, the **default** burn profile should be used for most materials. The operator may select burn-profile Option 1 or Option 2 to optimize the burn cycle. The burn profile for testing asphalt mixture samples shall be the same burn profile selected for correction samples.
 - Option 1** is designed for aggregate that requires a large asphalt binder correction factor (greater than 1.00 percent) – typically very soft aggregate (such as dolomite).
 - Option 2** is designed for samples that may not burn completely using the **default** burn profile.
11. Perform a gradation analysis on the residual aggregate in accordance with the FOP for AASHTO T 30, if required. The results will be utilized in developing an “Aggregate Correction Factor” and should be calculated and reported to 0.1 percent.
12. From the gradation results subtract the percent passing for each sieve, for each sample, from the percent passing each sieve of the “Blank” specimen gradation results from Step 4.
13. Determine the average difference of the two values. If the difference for any single sieve exceeds the allowable difference of that sieve as listed in Table 2, then aggregate gradation correction factors (equal to the resultant average differences) for all sieves shall be applied to all acceptance gradation test results determined by the FOP for AASHTO T 30. If the 75 μm (No. 200) is the only sieve outside the limits in Table 2, apply the aggregate correction factor to only the 75 μm (No. 200) sieve.

**Table 2
Permitted Sieving Difference**

Sieve	Allowable Difference
Sizes larger than or equal to 2.36 mm (No.8)	± 5.0%
Sizes larger than to 75 µm (No.200) and smaller than 2.36 mm (No.8)	± 3.0%
Sizes 75 µm (No.200) and smaller	± 0.5%

Examples:

Sieve Size mm (in.)	Correction Factor Blank Sample % Passing	Correction Factor Sample #1 % Passing	Correction Factor Sample #2 % Passing	Difference 1 / 2	Avg. Diff.	Sieves to adjust
19.0 (3/4)	100	100	100	0/0	0.0	
12.5 (1/2)	86.3	87.4	86.4	-1.1/-0.1	-0.6	
9.5 (3/8)	77.4	76.5	78.8	+0.9/-1.4	-0.3	
4.75 (No. 4)	51.5	53.6	55.9	-2.1/-4.4	-3.3	
2.36 (No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	
01.18 (No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	
0.600 (No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.3	
0.300 (No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	
0.150 (No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	
75 µm (No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	- 0.6

In this example, all gradation test results performed on the residual aggregate (FOP for AASHTO T 30) would have an aggregate correction factor applied to the percent passing the 75 µm (No. 200) sieve. The correction factor must be applied because the average difference on the 75 µm (No. 200) sieve is outside the tolerance from Table 2.

In the following example, aggregate correction factors would be applied to each sieve because the average difference on the 4.75 mm (No. 4) is outside the tolerance from Table 2.

Sieve Size mm (in.)	Correction Factor Blank Sample % Passing	Correction Factor Sample #1 % Passing	Correction Factor Sample #2 % Passing	Difference 1 / 2	Avg. Diff.	Sieves to adjust
19.0 (3/4)	100	100	100	0/0	0.0	0.0
12.5 (1/2)	86.3	87.4	86.4	-1.1/-0.1	-0.6	-0.6
9.5 (3/8)	77.4	76.5	78.8	+0.9/-1.4	-0.3	-0.3
4.75 (No. 4)	51.5	55.6	57.9	-4.1/-6.4	-5.3	-5.3
2.36 (No. 8)	34.7	36.1	37.2	-1.4/-2.5	-2.0	-2.0
01.18 (No. 16)	23.3	25.0	23.9	-1.7/-0.6	-1.2	-1.2
0.600 (No. 30)	16.4	19.2	18.1	-2.8/-1.7	-2.3	-2.3
0.300 (No. 50)	12.0	11.1	12.7	+0.9/-0.7	+0.1	+0.1
0.150 (No. 100)	8.1	9.9	6.3	-1.8/+1.8	0.0	0.0
75 μm (No. 200)	5.5	5.9	6.2	-0.4/-0.7	-0.6	-0.6



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DATE: October 15, 2004

TO: All Holders of the Manual of Field Test Procedures

File Code:

SECTION: **Test Procedure AASHTO T 309**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Apparatus, Temperature Measuring Device, Metal Immersion Types of Thermometers, meeting the apparatus requirements are acceptable.**

TEMPERATURE OF FRESHLY MIXED PORTLAND CEMENT CONCRETE FOP FOR AASHTO T 309

Scope

This procedure covers the determination of the temperature of freshly mixed Portland Cement Concrete in accordance with AASHTO T 309-22.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Container: Made of non-absorptive material and large enough to cover the sensor with concrete at least 75 mm (3 in.) in all directions; concrete cover must also be a least three times the nominal maximum size of the coarse aggregate.
- Thermometer: Capable of measuring the temperature of the concrete throughout the temperature range likely to be encountered, at least -18 to 50°C (0 to 120°F), and readable to $\pm 0.5^{\circ}\text{C}$ ($\pm 1^{\circ}\text{F}$) or smaller.

Note 1: Thermometer types suitable for use include ASTM E1 mercury thermometer or ASTM E2251 Low Hazard Precision Liquid-in-glass thermometer; ASTM E2877 digital metal stem thermometer; or thermocouple thermometer ASTM E230, Type T Special or IEC 60584 Type T, Class 1.

Standardization of Thermometer

Each thermometer shall be verified for accuracy annually and whenever there is a question of accuracy. Standardization shall be performed by comparing readings on the thermometer with another calibrated thermometer at two temperatures at least 15°C or 27°F apart.

Sample Locations and Times

The temperature of freshly mixed concrete may be measured in the transporting equipment, in forms, or in sample containers, provided the sensor of the thermometer has at least 75 mm (3 in.) of concrete cover in all direction around it.

Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.

Procedure

1. Dampen the sample container.
2. Obtain the sample in accordance with the FOP for WAQTC TM 2.
3. Place sensor of the thermometer in the freshly mixed concrete so that it has at least 75 mm (3 in.) of concrete cover in all directions around it.
4. Gently press the concrete in around the sensor of the thermometer at the surface of the concrete so that air cannot reach the sensor.
5. Leave the sensor of the thermometer in the freshly mixed concrete for a minimum of two minutes, or until the temperature reading stabilizes.
6. Complete the temperature measurement of the freshly mixed concrete within 5 minutes of obtaining the sample.
7. Read and record the temperature to the nearest 0.5°C (1°F).

Report

- Results on forms approved by the agency
- Sample ID
- Measured temperature of the freshly mixed concrete to the nearest 0.5°C (1°F)



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October 31, 2013

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 310**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **ODOT TM-158 shall be satisfied prior to performing AASHTO T 310.**
- **Document results of ODOT TM 158.**
- **Under Calibration add; Comply with ODOT TM 304.**
- **Under Procedure, use Method A.**
- **The backscatter/air-gap ratio method is not allowed on ODOT contracts.**

Earthwork:

- **Steps 11, 12, and 13 are required**
- **Step 12, moisture content other method allowed is AASHTO T 217**

Crushed Processed Aggregate:

- **AASHTO T 272 is not required**
- **Steps 11, 12 & 13 are not required.**

IN-PLACE DENSITY AND MOISTURE CONTENT OF SOIL AND SOIL- AGGREGATE BY NUCLEAR METHODS (SHALLOW DEPTH) FOP FOR AASHTO T 310

Scope

This procedure covers the determination of density, moisture content, and relative compaction of soil, aggregate, and soil-aggregate mixes in accordance with AASHTO T 310-22. This procedure provides a rapid, nondestructive technique for determining the in-place wet density and moisture content of soil, aggregate, and soil-aggregate mixes. This field operating procedure is derived from AASHTO T 310. The nuclear moisture-density gauge is used in the direct transmission mode.

Apparatus

- Nuclear density gauge with the factory matched standard reference block.
- Drive pin, guide/scrapper plate, and hammer for testing in direct transmission mode.
- Transport case for properly shipping and housing the gauge and tools.
- Instruction manual for the specific make and model of gauge.
- Radioactive materials information and calibration packet containing:
 - Daily Standard Count Log.
 - Factory and Laboratory Calibration Data Sheet.
 - Leak Test Certificate.
 - Shippers Declaration for Dangerous Goods.
 - Procedure Memo for Storing, Transporting and Handling Nuclear Testing Equipment.
 - Other radioactive materials documentation as required by local regulatory requirements.
- Sealable containers and utensils for moisture content determinations.

Radiation Safety

This method does not purport to address all of the safety problems associated with its use. This test method involves potentially hazardous materials. The gauge utilizes radioactive materials that may be hazardous to the health of the user unless proper precautions are taken. Users of this gauge must become familiar with the applicable safety procedures and governmental regulations. All operators will be trained in radiation safety prior to operating nuclear density gauges. Some agencies require the use of personal monitoring devices such as a thermoluminescent dosimeter or film badge. Effective instructions together with routine safety procedures such as source leak tests, recording and evaluation of personal monitoring device data, etc., are a recommended part of the operation and storage of this gauge.

Calibration

Calibrate the nuclear gauge as required by the agency. This calibration may be performed by the agency using manufacturer's recommended procedures or by other facilities approved by the agency. Verify or re-establish calibration curves, tables, or equivalent coefficients every 12 months.

Standardization

1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) prior to standardization. Leave the power on during the day's testing.
2. Standardize the nuclear gauge at the construction site at the start of each day's work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired and/or recalibrated.
3. Record the standard count for both density and moisture in the Daily Standard Count Log. The exact procedure for standard count is listed in the manufacturer's Operator's Manual.

Note 1: New standard counts may be necessary more than once a day. See agency requirements.

Overview

There are two methods for determining in-place density of soil / soil aggregate mixtures. See agency requirements for method selection.

- Method A Single Direction
- Method B Two Direction

Procedure

1. Select a test location(s) randomly and in accordance with agency requirements. Test sites should be relatively smooth and flat and meet the following conditions:
 - a. At least 10 m (30 ft) away from other sources of radioactivity
 - b. At least 3 m (10 ft) away from large objects
 - c. The test site should be at least 150 mm (6 in.) away from any vertical projection.
 - d. Correct for trench wall effect according to manufacturer's correction procedures if the test site is closer than 600 mm (24 in.) to vertical projection. See Note 2.

Note 2: To perform moisture and density tests in a trench or against a large solid object, it is necessary to perform a trench offset correction to adjust the gauge, or it may read a falsely high moisture content. Moisture present in the walls can thermalize neutrons which return to the gauge and are read as moisture by the detector in the gauge.

2. Remove all loose and disturbed material and remove additional material as necessary to expose the top of the material to be tested.
3. Prepare a flat area sufficient in size to accommodate the gauge. Plane the area to a smooth condition so as to obtain maximum contact between the gauge and the

material being tested. For Method B, the flat area must be sufficient to permit rotating the gauge 90 or 180 degrees about the source rod.

4. Fill in surface voids beneath the gauge with fines of the material being tested passing the 4.75 mm (No. 4) sieve or finer. Smooth the surface with the guide plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm (1/8 in.).
5. Make a hole perpendicular to the prepared surface using the guide plate and drive pin. The hole shall be at least 50 mm (2 in.) deeper than the desired source rod depth and shall be aligned such that insertion of the source rod will not cause the gauge to tilt from the plane of the prepared area. Remove the drive pin by pulling straight up and twisting the extraction tool.
6. Place the gauge on the prepared surface so the source rod can enter the hole without disturbing loose material.
7. Lower the source rod into the hole to the desired test depth using the handle and trigger mechanism.
8. Seat the gauge firmly by partially rotating it back and forth about the source rod. Ensure the gauge is seated flush against the surface by pressing down on the gauge corners and making sure that the gauge does not rock.
9. Pull gently on the gauge to bring the side of the source rod nearest to the scaler / detector firmly against the side of the hole.
10. Perform one of the following methods, per agency requirements:
 - a. Method A Single Direction: Take a test consisting of the average of two, one-minute readings, and record both density and moisture data. The two wet density readings should be within 32 kg/m^3 (2.0 lb/ft^3) of each other. The average of the two wet densities and moisture contents will be used to compute dry density.
 - b. Method B Two Direction: Take a one-minute reading and record both density and moisture data. Rotate the gauge 90 or 180 degrees, pivoting it around the source rod. Reseat the gauge by pulling gently on the gauge to bring the side of the source rod nearest to the scaler/detector firmly against the side of the hole and take a one-minute reading. (In trench locations, rotate the gauge 180 degrees for the second test.) Some agencies require multiple one-minute readings in both directions. Analyze the density and moisture data. A valid test consists of wet density readings in both gauge positions that are within 50 kg/m^3 (3.0 lb/ft^3). If the tests do not agree within this limit, move to a new location. The average of the wet density and moisture contents will be used to compute dry density.
11. If required by the agency, obtain a representative sample of the material, 4 kg (9 lb) minimum, from directly beneath the gauge full depth of material tested. This sample will be used to verify moisture content and / or identify the correct density standard. Immediately seal the material to prevent loss of moisture.

The material tested by direct transmission can be approximated by a cylinder of soil approximately 300 mm (12 in.) in diameter directly beneath the centerline of the

radioactive source and detector. The height of the cylinder will be approximately the depth of measurement. When organic material or large aggregate is removed during this operation, disregard the test information, and move to a new test site.

12. To verify the moisture content from the nuclear gauge, determine the moisture content with a representative portion of the material using the FOP for AASHTO T 255/T 265 or other agency approved methods. If the moisture content from the nuclear gauge is within ± 1 percent, the nuclear gauge readings can be accepted. Moisture content verification is gauge and material specific. Retain the remainder of the sample at its original moisture content for a one-point compaction test under the FOP for AASHTO T 272, or for gradation, if required.

Note 2: Example: A gauge reading of 16.8 percent moisture and an oven dry of 17.7 percent are within the ± 1 percent requirement. Moisture correlation curves will be developed according to agency guidelines. These curves should be reviewed and possibly redeveloped every 90 days.

13. Determine the dry density by one of the following.
 - a. From nuclear gauge readings, compute by subtracting the mass (weight) of the water (kg/m^3 or lb/ft^3) from the wet density (kg/m^3 or lb/ft^3) or compute using the percent moisture by dividing wet density from the nuclear gauge by 1 plus the moisture content expressed as a decimal.
 - b. When verification is required and the nuclear gauge readings cannot be accepted, the moisture content is determined by the FOP for AASHTO T 255/T 265 or other agency approved methods. Compute dry density by dividing wet density from the nuclear gauge by 1 plus the moisture content expressed as a decimal.

Percent Compaction

- Percent compaction is determined by comparing the in-place dry density as determined by this procedure to the appropriate agency density standard. For soil or soil-aggregate mixes, these are moisture-density curves developed using the FOP for AASHTO T 99/T 180. When using maximum dry densities from the FOP for AASHTO T 99/T 180 or FOP for AASHTO T 272, it may be necessary to use the Annex in the FOP for T 99/T 180 to determine corrected maximum dry density and optimum moisture content.

For coarse granular materials, the density standard may be density-gradation curves developed using a vibratory method such as AKDOT&PF's ATM 212, ITD's T 74, WAQTC TM 15, or WFLHD's Humphres.

See appropriate agency policies for use of density standards.

Calculation

Calculate the dry density as follows:

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

Where:

ρ_d = Dry density, kg/m³ (lb/ft³)

ρ_w = Wet density, kg/m³ (lb/ft³)

w = Moisture content from the FOP's for AASHTO T 255 / T 265, as a percentage

Calculate percent compaction as follows:

$$\% \text{ Compaction} = \frac{\rho_d}{\text{Agency density standard}} \times 100$$

Where:

ρ_d = Dry density, kg/m³ (lb/ft³)

Agency density standard = Corrected maximum dry density
from the FOP from T 99/T 180 Annex

Example:

Wet density readings from gauge: 1948 kg/m³ (121.6 lb/ft³)

1977 kg/m³ (123.4 lb/ft³)

Avg: 1963 kg/m³ (122.5 lb/ft³)

Moisture readings from gauge: 14.2% and 15.4% = Avg 14.8%

Moisture content from the FOP's for AASHTO T 255/ T 265: 15.9%

Moisture content is greater than 1 percent different so the gauge moisture cannot be used.

Calculate the dry density as follows:

$$\rho_d = \left(\frac{1963 \text{ kg/m}^3 \text{ or } 122.5 \text{ lb/ft}^3}{15.9 + 100} \right) \times 100 \text{ or } \rho_d = \frac{1963 \text{ kg/m}^3 \text{ or } 122.5 \text{ lb/ft}^3}{\frac{15.9}{100} + 1}$$
$$= 1694 \text{ kg/m}^3 \text{ or } 105.7 \text{ lb/ft}^3$$

Given:

$$\rho_w = 1963 \text{ kg/m}^3 \text{ or } 122.5 \text{ lb/ft}^3$$

$$w = 15.9\%$$

Calculate percent compaction as follows:

$$\% \text{ Compaction} = \frac{105.7 \text{ lb/ft}^3}{111.3 \text{ lb/ft}^3} \times 100 = 95\%$$

Given:

$$\text{Agency density standard} = 111.3 \text{ lb/ft}^3$$

Report

- On forms approved by the agency
- Sample ID
- Location of test, elevation of surface, and thickness of layer tested
- Visual description of material tested
- Make, model and serial number of the nuclear moisture-density gauge
- Wet density to the nearest 0.1 lb/ft³
- Moisture content as a percent, by mass, of dry soil mass to the nearest 0.1 percent
- Dry density to the nearest 0.1 lb/ft³
- Density standard to the nearest 0.1 lb/ft³
- Percent compaction the nearest 1 percent
- Name and signature of operator

Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures

AASHTO Designation: T 324-22

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November 30, 2012

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 329**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under test procedure, step 8, delete the $\pm 9^{\circ}\text{C}$ (15°F) reference and replace with $\pm 10^{\circ}\text{C}$ (25°F).**
- **RAP and RAS moisture content shall be determined by this test method.**
- **Report RAP and RAS moisture content to the nearest 0.1%.**

MOISTURE CONTENT OF ASPHALT MIXTURES BY OVEN METHOD FOP FOR AASHTO T 329

Scope

This procedure covers the determination of moisture content of asphalt mixtures in accordance with AASHTO T 329-22.

Overview

Moisture content is determined by comparing the wet mass of a sample and the mass of the sample after drying to constant mass. The term constant mass is used to define when a sample is dry.

Constant mass – the state at which a mass does not change more than a given percent, after additional drying for a defined time interval, at a required temperature.

Apparatus

- Balance or scale: 2 kg capacity, readable to 0.1 g and conforming to AASHTO M 231.
- Forced draft, ventilated, or convection oven: Capable of maintaining the temperature surrounding the sample at $163 \pm 14^{\circ}\text{C}$ ($325 \pm 25^{\circ}\text{F}$).
- Sample Container: Clean, dry, not affected by heat and of sufficient size to contain a test sample without danger of spilling.
- Thermometer or other suitable device with a temperature range of 50 to 200°C (122 to 392°F) and readable to the nearest 2°C (4°F).

Sample

The test sample shall be obtained in accordance with the FOP for AASHTO R 97 and reduced in accordance with the FOP for AASHTO R 47. The size of the test sample shall be a minimum of 1000 g.

Procedure

1. Preheat the oven to the Job Mix Formula (JMF) mixing temperature range. If the mixing temperature is not supplied, a temperature of $163 \pm 14^{\circ}\text{C}$ ($325 \pm 25^{\circ}\text{F}$) is to be used.
2. Determine and record the mass of the sample container, including release media, to the nearest 0.1 g.
Note 1: When using paper or other absorptive material to line the sample container ensure it is dry before determining initial mass of sample container.
3. Place the test sample in the sample container.
4. Determine and record the temperature of the test sample.
5. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.

6. Calculate the initial, moist mass (M_i) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 5.
7. The test sample shall be initially dried for 90 ± 5 minutes, and its mass determined. Then it shall be dried at 30 ± 5 minute intervals until further drying does not alter the mass by more than 0.05 percent.
8. Cool the sample container and test sample to $\pm 9^\circ\text{C}$ ($\pm 15^\circ\text{F}$) of the temperature determined in Step 4.
9. Determine and record the total mass of the sample container and test sample to the nearest 0.1 g.
10. Calculate the final, dry mass (M_f) of the test sample by subtracting the mass of the sample container as determined in Step 2 from the total mass of the sample container and the test sample as determined in Step 9.

Note 2: Moisture content and the number of samples in the oven will affect the rate of drying at any given time. Placing wet samples in the oven with nearly dry samples could affect the drying process.

Calculations

Constant Mass:

Calculate constant mass using the following formula:

$$\% \text{ Change} = \frac{M_p - M_n}{M_p} \times 100$$

Where:

M_p = previous mass measurement

M_n = new mass measurement

Example:

Mass of container:	232.6 g
Mass of container and sample after first drying cycle:	1361.8 g
Mass, M_p , of possibly dry sample:	$1361.8 \text{ g} - 232.6 \text{ g} = 1129.2 \text{ g}$
Mass of container and possibly dry sample after second drying cycle:	1360.4 g
Mass, M_n , of possibly dry sample:	$1360.4 \text{ g} - 232.6 \text{ g} = 1127.8 \text{ g}$

$$\% \text{ Change} = \frac{1129.2 \text{ g} - 1127.8 \text{ g}}{1129.2 \text{ g}} \times 100 = 0.12\%$$

0.12 percent is not less than 0.05 percent, so continue drying the sample.

Mass of container and possibly dry sample after third drying cycle:	1359.9 g
Mass, M_n , of dry sample:	$1359.9 \text{ g} - 232.6 \text{ g} = 1127.3 \text{ g}$

$$\% \text{ Change} = \frac{1127.8 \text{ g} - 1127.3 \text{ g}}{1127.8 \text{ g}} \times 100 = 0.04\%$$

0.04 percent is less than 0.05 percent, so constant mass has been reached.

Moisture Content:

Calculate the moisture content, as a percent, using the following formula.

$$\text{Moisture Content} = \frac{M_i - M_f}{M_f} \times 100$$

Where:

M_i = initial, moist mass

M_f = final, dry mass

Example:

$$M_i = 1134.9 \text{ g}$$

$$M_f = 1127.3 \text{ g}$$

$$\text{Moisture Content} = \frac{1134.9 \text{ g} - 1127.3 \text{ g}}{1127.3 \text{ g}} \times 100 = 0.674, \text{ say } 0.67\%$$

Report

- On forms approved by the agency
- Sample ID
- Moisture content to the nearest 0.01 percent

DETERMINING THE PERCENTAGE OF FRACTURE IN COARSE AGGREGATE FOP FOR AASHTO T 335

Scope

This procedure covers the determination of the percentage, by mass, of a coarse aggregate (CA) sample that consists of fractured particles meeting specified requirements in accordance with AASHTO T 335-09.

In this FOP, a sample of aggregate is screened on the sieve separating CA and fine aggregate (FA). This sieve will be identified in the agency's specifications but might be the 4.75 mm (No. 4) sieve. CA particles are visually evaluated to determine conformance to the specified fractured criteria. The percentage of conforming particles, by mass, is calculated for comparison to the specifications.

Apparatus

- Balance or scale: Capacity sufficient for the principal sample mass, accurate to 0.1 percent of the sample mass or readable to 0.1 g and meeting the requirements of AASHTO M 231.
- Sieves: Meeting requirements of the FOP for AASHTO T 27/T 11.
- Splitter: Meeting the requirements of FOP for AASHTO R 76.

Terminology

1. Fractured criteria: Determined by the agency to define a fractured particle.
2. Fractured face: An angular, rough, or broken surface of an aggregate particle created by crushing or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well-defined edges. This excludes small nicks.
3. Fractured particle: A particle of aggregate having at least the minimum number of fractured faces specified. (This is usually one or two.)

Sampling and Sample Preparation

1. Sample and reduce the aggregate in accordance with the FOPs for AASHTO R 90 and R 76.
2. When the specifications list only a total fracture percentage, the sample shall be prepared in accordance with Method 1. When the specifications require that the fracture be counted and reported on each sieve, the sample shall be prepared in accordance with Method 2.
3. Method 1 - Combined Fracture Determination
 - a. Dry the sample sufficiently to obtain a clean separation of FA and CA material in the sieving operation.

- b. Sieve the sample in accordance with the FOP for AASHTO T 27/ T 11 over the 4.75 mm (No. 4) sieve, or the appropriate sieve listed in the agency’s specifications for this material.

Note 1: Where necessary, wash the sample over the sieve designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with the FOP for AASHTO T 255.

- c. Reduce the sample using Method A – Mechanical Splitter, in accordance with the FOP for AASHTO R 76, to the appropriate test size. This test size should be slightly larger than shown in Table 1, to account for loss of fines through washing if necessary.

TABLE 1
Sample Size
Method 1 (Combined Sieve Fracture)

Nominal Maximum Size* mm (in.)	Minimum Cumulative Sample Mass Retained on 4.75 mm (No. 4) Sieve g (lb)
37.5 (1 1/2)	2500 (6)
25.0 (1)	1500 (3.5)
19.0 (3/4)	1000 (2.5)
12.5 (1/2)	700 (1.5)
9.5 (3/8)	400 (0.9)
4.75 (No. 4)	200 (0.4)

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.

4. Method 2 – Individual Sieve Fracture Determination

- a. Dry the sample sufficiently to obtain a clean separation of FA and CA material in the sieving operation. A washed sample from the gradation determination (the FOP for T 27/T 11) may be used.
- b. If not, sieve the sample in accordance with the FOP for AASHTO T 27 over the sieves listed in the specifications for this material.

Note 2: If overload (buffer) sieves are used the material from that sieve must be added to the next specification sieve.

- c. The size of test sample for each sieve shall meet the minimum size shown in Table 2. Utilize the total retained sieve mass or select a representative portion from each sieve mass by splitting or quartering in accordance with the FOP for AASHTO R 76.

Note 3: Where necessary, wash the sample over the sieves designated for the determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with the FOP for AASHTO T 255.

TABLE 2
Sample Size
Method 2 (Individual Sieve Fracture)

Sieve Size mm (in.)	Minimum Sample Mass g (lb)
31.5 (1 1/4)	1500 (3.5)
25.0 (1)	1000 (2.2)
19.0 (3/4)	700 (1.5)
16.0 (5/8)	500 (1.0)
12.5 (1/2)	300 (0.7)
9.5 (3/8)	200 (0.5)
6.3 (1/4)	100 (0.2)
4.75 (No. 4)	100 (0.2)
2.36 (No. 8)	25 (0.1)
2.00 (No. 10)	25 (0.1)

Note 4: If fracture is determined on a sample obtained for gradation, use the mass retained on the individual sieves, even if it is less than the minimum listed in Table 2. If less than 5 percent of the total mass is retained on a single specification sieve, include that material on the next smaller specification sieve. If a smaller specification sieve does not exist, this material shall not be included in the fracture determination.

Procedure

1. After cooling, spread the dried sample on a clean, flat surface.
2. Examine each particle face and determine if the particle meets the fractured criteria.
3. Separate the sample into three categories:
 - Fractured particles meeting the criteria
 - Particles not meeting the criteria
 - Questionable or borderline particles
4. Determine the dry mass of particles in each category to the nearest 0.1 g.
5. Calculate the percent questionable particles to the nearest 1 percent.
6. Re-sort the questionable particles when more than 15 percent is present. Continue sorting until there is no more than 15 percent in the questionable category.
7. Calculate the percent fractured particles meeting criteria to nearest 0.1 percent. Report to 1 percent.

Calculation

Calculate the percent questionable particles to the nearest 1 percent using the following formula:

$$\%Q = \frac{Q}{F + Q + N} \times 100$$

Where:

- %Q = Percent of questionable particles
- F = Mass of fractured particles
- Q = Mass of questionable or borderline particles
- N = Mass of unfractured particles

Example:

$$\%Q = \frac{97.6 \text{ g}}{632.6 \text{ g} + 97.6 \text{ g} + 352.6 \text{ g}} \times 100 = 9\%$$

Given:

- F = 632.6 g
- Q = 97.6 g
- N = 352.6 g

Calculate the percent fractured particles to the nearest 0.1 percent using the following formula:

$$P = \frac{\frac{Q}{2} + F}{F + Q + N} \times 100$$

Where:

- P = Percent of fractured particles
- F = Mass of fractured particles
- Q = Mass of questionable particles
- N = Mass of unfractured particles

Example:

$$P = \frac{\frac{97.6 \text{ g}}{2} + 632.6 \text{ g}}{632.6 \text{ g} + 97.6 \text{ g} + 352.6 \text{ g}} \times 100 = 62.9\% \quad \text{Report 63\%}$$

Given:

$$F = 632.6 \text{ g}$$

$$Q = 97.6 \text{ g}$$

$$N = 352.6 \text{ g}$$

Report

- On forms approved by the agency
- Sample ID
- Fractured particles to the nearest 1 percent.



Oregon

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October 31, 2018

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO T 355**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Calibration: ODOT requires calibration verified according to TM 304.**
- **Under Procedure, Step 2, a filler material is defined as material passing the No. 8 or finer sieve and from the aggregate source used to produce the Job Mix Formula.**
- **Under Procedure, use Method A for density determinations. Method B is not allowed.**
- **Delete Appendix – Correlation with Cores**
- **For Core Correlation use ODOT TM-327 and utilize form 734-2327 for reporting.**

Density testing of ACP shall conform to the following:

- **Select 5 longitudinal test locations in a stratified random pattern in accordance with ODOT TM 400.**

IN-PLACE DENSITY OF ASPHALT MIXTURES BY NUCLEAR METHODS FOP FOR AASHTO T 355

Scope

This test method describes a procedure for determining the density of asphalt mixtures by means of a nuclear gauge using the backscatter method in accordance with AASHTO T 355-18. Correlation with densities determined under the FOP for AASHTO T 166 is required by some agencies.

Apparatus

- Nuclear density gauge with the factory-matched standard reference block.
- Transport case for properly shipping and housing the gauge and tools.
- Instruction manual for the specific make and model of gauge.
- Radioactive materials information and calibration packet containing:
 - Daily standard count log
 - Factory and laboratory calibration data sheet
 - Leak test certificate
 - Shippers' declaration for dangerous goods
 - Procedure memo for storing, transporting, and handling nuclear testing equipment
 - Other radioactive materials documentation as required by local regulatory requirements

Material

- Filler material: Fine-graded sand from the source used to produce the asphalt pavement or other agency approved materials.

Radiation Safety

This method does not purport to address all of the safety problems associated with its use. This test method involves potentially hazardous materials. The gauge utilizes radioactive materials that may be hazardous to the health of the user unless proper precautions are taken. Users of this gauge must become familiar with the applicable safety procedures and governmental regulations. All operators will be trained in radiation safety before operating nuclear density gauges. Some agencies require the use of personal monitoring devices such as a thermoluminescent dosimeter or film badge. Effective instructions, together with routine safety procedures such as source leak tests, recording and evaluation of personal monitoring device data, etc., are a recommended part of the operation and storage of this gauge.

Calibration

Calibrate the nuclear gauge as required by the agency. This calibration may be performed by the agency using the manufacturer's recommended procedures or by other facilities approved by the agency. Verify or re-establish calibration curves, tables, or equivalent coefficients every 12 months.

Standardization

1. Turn the gauge on and allow it to stabilize (approximately 10 to 20 minutes) before standardization. Leave the power on during the day's testing.
2. Standardize the nuclear gauge at the construction site at the start of each day's work and as often as deemed necessary by the operator or agency. Daily variations in standard count shall not exceed the daily variations established by the manufacturer of the gauge. If the daily variations are exceeded after repeating the standardization procedure, the gauge should be repaired, recalibrated, or both.
3. Record the standard count for both density and moisture in the daily standard count log. The exact procedure for standard count is listed in the manufacturer's Operator's Manual.

Note 1: New standard counts may be necessary more than once a day. See agency requirements.

Test Site Location

1. Select a test location(s) randomly and in accordance with agency requirements. Test sites should be relatively smooth and flat and meet the following conditions:
 - a. At least 10 m (30 ft.) away from other sources of radioactivity.
 - b. At least 3 m (10 ft.) away from large objects.
 - c. If the gauge will be closer than 600 mm (24 in.) to any vertical mass, or less than 300 mm (12 in.) from a vertical pavement edge, use the gauge manufacturer's correction procedure.

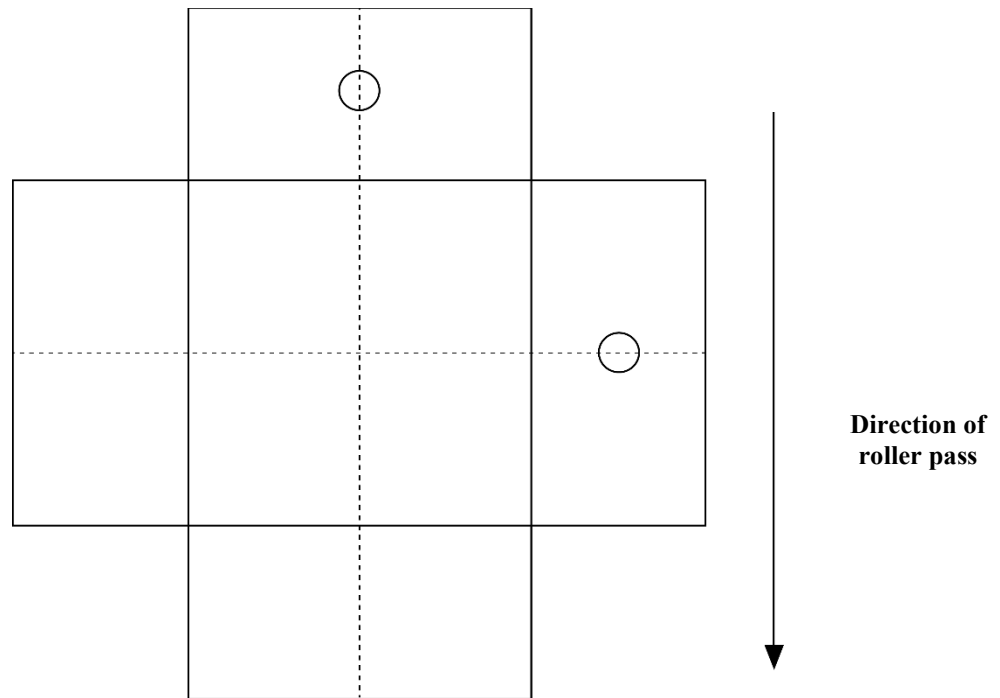
Procedure

1. Maintain maximum contact between the base of the gauge and the surface of the material under test.
2. Use filler material to fill surface voids.
3. Spread a small amount of filler material over the test site surface and distribute it evenly. Strike off the surface with a straightedge (such as a lathe or flat-bar steel) to remove excess material.
4. If using thin-layer mode, enter the anticipated overlay thickness into the gauge.

Note 2: If core correlation is required, entered thickness, anticipated thickness, and nominal core thickness may be required to match.

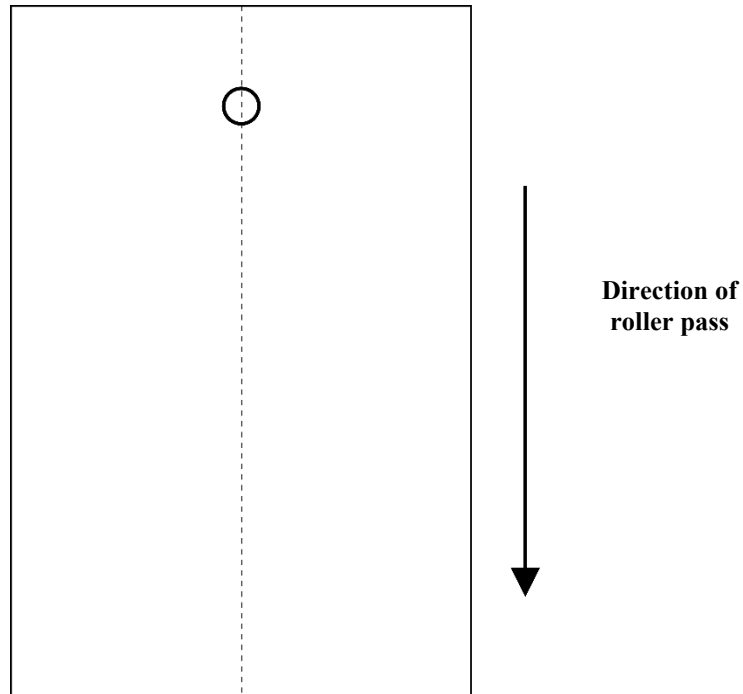
Method A – Average of two one-minute tests

1. Place the gauge on the test site, perpendicular to the roller passes.
2. Using a crayon (not spray paint), mark the outline or footprint of the gauge.
3. Extend the source rod to the backscatter position.
4. Take a one-minute test and record the wet density reading.
5. Rotate the gauge 90 degrees centered over the original footprint. Mark the outline or footprint of the gauge.
6. Take another one-minute test and record the wet density reading.
7. If the difference between the two one-minute tests is greater than 40 kg/m^3 (2.5 lb/ft^3), retest in both directions. If the difference of the retests is still greater than 40 kg/m^3 (2.5 lb/ft^3) test at 180 and 270 degrees.
8. The density reported for each test site shall be the average of the two individual one-minute wet density readings.



Method B – One four-minute test

1. Place the gauge on the test site, parallel to the roller passes.
2. Using a crayon (not spray paint), mark the outline or footprint of the gauge.
3. Extend the source rod to the backscatter position.
4. Take one 4-minute test and record the wet density reading.



Method B
Footprint of the gauge test site

Calculation of Results

Percent (%) compaction is determined by comparing the in-place wet density as determined by this method to the appropriate agency density standard. See appropriate agency policy for use of density standards.

$$\% \text{ Compaction} = \frac{\text{Corrected Reading}}{\text{Maximum Density}} \times 100$$

Method A Example:

Reading #1: 141.5 lb/ft³

Reading #2: 140.1 lb/ft³ Are the two readings within the tolerance? (YES)

Reading average: 140.8 lb/ft³

Core correction: +2.1 lb/ft³

Corrected reading: 142.9 lb/ft³

Method B Example:

Reading: 140.8 lb/ft³

Core correction: +2.1 lb/ft³

Corrected reading 142.9 lb/ft³

Example percent (%) compaction:

From the FOP for AASHTO T 209:

$$G_{mm} = 2.466$$

$$\text{Theoretical Maximum Density} = 2.466 \times 62.245 \text{ lb/ft}^3 = 153.5 \text{ lb/ft}^3$$

$$\% \text{ Compaction} = \frac{142.9 \text{ lb/ft}^3}{153.5 \text{ lb/ft}^3} \times 100 = 93.1\%$$

Report

- On forms approved by the agency
- Test ID
- Location of test and thickness of layer tested
- Mixture type
- Make, model and serial number of the nuclear moisture-density gauge
- Calculated wet density of each measurement and any adjustment data
- Density standard
- Compaction to the nearest 0.1 percent
- Name and signature of operator

APPENDIX – CORRELATION WITH CORES

(Nonmandatory Information)

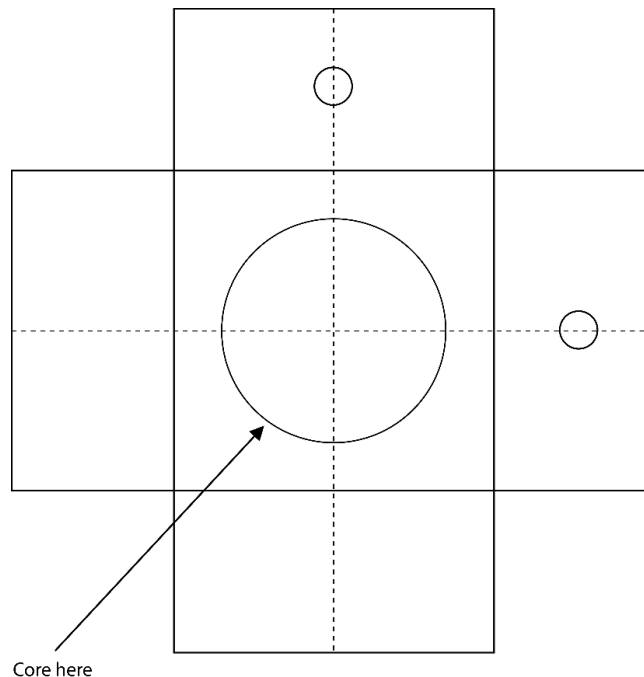
The bulk specific gravity (G_{mb}) of the core is a physical measurement of the in-place asphalt mixture and can be compared with the nuclear density gauge readings. Comparing the core value to the corresponding gauge values, a correlation can be established.

The correlation can then be used to adjust the gauge readings to the in-place density of the cores. The core correlation is gauge specific and must be determined without traffic allowed on the pavement between nuclear density gauge readings and obtaining the core. When using multiple nuclear density gauges each gauge should be correlated to the core locations before removal of the core.

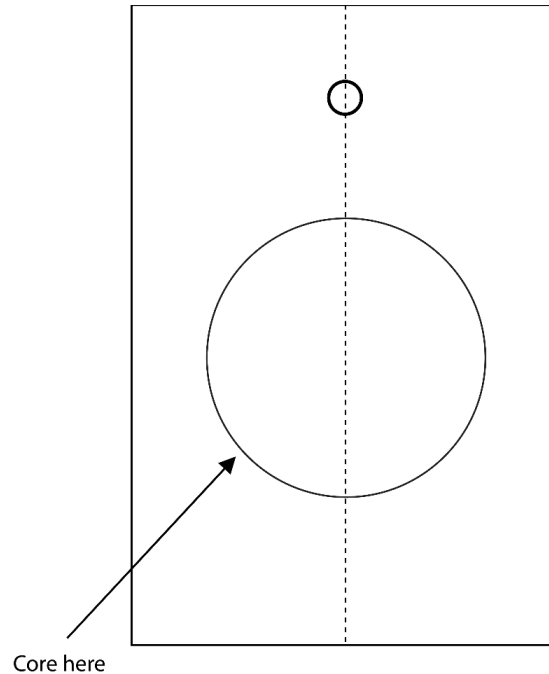
When density correlation with the FOP for AASHTO T 166 is required, correlation of the nuclear gauge with pavement cores shall be made on the first day's paving (within 24 hours) or from a test strip constructed before the start of paving. Cores must be taken before traffic is allowed on the pavement.

Correlation with Cores

1. Determine the number of cores required for correlation from the agency's specifications. Cores shall be located on the first day's paving or on the test strip. Locate the test sites in accordance with the agency's specifications. Follow the "Procedure" section above to establish test sites and obtain densities using the nuclear gauge.
2. Obtain a pavement core from each of the test sites according to AASHTO R 67. The core should be taken from the center of the nuclear gauge footprint.



Method A – Footprint of the gauge test site. Core location in the center of the footprint.



Method B - Footprint of the gauge test site.

4. Calculate a correlation factor for the nuclear gauge reading as follows:
 - a. Calculate the difference between the core density and the average nuclear gauge density at each test site to the nearest 1 kg/m^3 (0.1 lb/ft^3). Calculate the average difference and standard deviation of the differences for the entire data set to the nearest 1 kg/m^3 (0.1 lb/ft^3).
 - b. If the standard deviation of the differences is equal to or less than 40 kg/m^3 (2.5 lb/ft^3), the correlation factor applied to the average nuclear gauge density shall be the average difference calculated above in 4.a.
 - c. If the standard deviation of the differences is greater than 40 kg/m^3 (2.5 lb/ft^3), the test site with the greatest variation from the average difference shall be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b.
 - d. If the standard deviation of the modified data set still exceeds the maximum specified in 4.b, additional test sites will be eliminated from the data set and the data set properties and correlation factor recalculated following 4.a and 4.b. If the data set consists of less than five test sites, additional test sites shall be established.

Note A1: The exact method used in calculating the nuclear gauge correlation factor shall be defined by agency policy.

Note A2: The above correlation procedure must be repeated if there is a new job mix formula. Adjustments to the job mix formula beyond tolerances established in the contract documents will constitute a new

job mix formula. A correlation factor established using this procedure is only valid for the particular gauge used in the correlation procedure. If another gauge is brought onto the project, it shall be correlated using the same procedure. Multiple gauges may be correlated from the same series of cores if done at the same time.

Note A3: For the purpose of this procedure, a job mix formula is defined as the percent and grade of paving asphalt used with a specified gradation of aggregate from a designated aggregate source. A new job mix formula may be required whenever compaction of the wearing surface exceeds the agency's specified maximum density or minimum air voids.

Calculations

Correlation Factor

$$\sqrt{\frac{\sum x^2}{n-1}}$$

Where:

\sum = Sum

x = Difference from the average Difference

n-1 = number of data sets minus 1

Example

Core #	Core results from T 166:	Average Gauge reading	Difference:	x	x ²
1	144.9 lb/ft ³	142.1 lb/ft ³	2.8 lb/ft ³	-0.7	0.49
2	142.8 lb/ft ³	140.9 lb/ft ³	1.9 lb/ft ³	0.2	0.04
3	143.1 lb/ft ³	140.7 lb/ft ³	2.4 lb/ft ³	-0.3	0.09
4	140.7 lb/ft ³	138.9 lb/ft ³	1.8 lb/ft ³	0.3	0.09
5	145.1 lb/ft ³	143.6 lb/ft ³	1.5 lb/ft ³	0.6	0.36
6	144.2 lb/ft ³	142.4 lb/ft ³	1.8 lb/ft ³	0.3	0.09
7	143.8 lb/ft ³	141.3 lb/ft ³	2.5 lb/ft ³	-0.4	0.16
8	142.8 lb/ft ³	139.8 lb/ft ³	3.0 lb/ft ³	0.9	0.81
9	144.8 lb/ft ³	143.3 lb/ft ³	1.5 lb/ft ³	-0.6	0.36
10	143.0 lb/ft ³	141.0 lb/ft ³	2.0 lb/ft ³	-0.1	<u>0.01</u>
Average Difference:			+2.1 lb/ft ³	$\Sigma x^2 = 2.5$	

Number of data sets

$$n - 1 = 10 - 1 = 9$$

Standard deviation

$$\text{standard deviation} = \sqrt{\frac{2.5}{9}} = 0.53$$

Given:

$$\text{Sum of } x^2 = 2.5$$

$$\text{Number of data sets} = 9$$

The standard deviation of 0.53 is less than 2.5 therefore no cores are eliminated. The average difference from all ten cores is used.



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November 30, 2020

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 47**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Procedure, Mechanical Splitter Type B (Riffle) Method is not allowed.**
- **Under Procedure, Incremental Method, is not allowed, use the Quartering Method or a combination of the Full Quarter and the Apex Method may be utilized.**

REDUCING SAMPLES OF ASPHALT MIXTURES TO TESTING SIZE FOP FOR AASHTO R 47

Scope

This procedure covers sample reduction of asphalt mixtures to testing size in accordance with AASHTO R 47-19. The reduced portion is to be representative of the original sample.

Apparatus

- Thermostatically controlled oven capable of maintaining a temperature of at least 110°C (230°F) or high enough to heat the material to a pliable condition for splitting.
- Non-contact temperature measuring device.
- Metal spatulas, trowels, metal straightedges, or drywall taping knives, or a combination thereof; for removing asphalt mixture samples from the quartering device, cleaning surfaces used for splitting, etc.
- Square-tipped, flat-bottom scoop, shovel or trowel for mixing asphalt mixture before quartering.
- Miscellaneous equipment including hot plate, non-asbestos heat-resistant gloves or mittens, pans, buckets, and cans.
- Sheeting: Non-stick heavy paper or other material as approved by the agency.
- Agency-approved release agent, free of solvent or petroleum-based material that could affect asphalt binder.
- Mechanical Splitter Type B (Riffle): having a minimum of eight equal-width chutes discharging alternately to each side with a minimum chute width of at least 50 percent larger than the largest particle size. A hopper or straight-edged pan with a width equal to or slightly smaller than the assembly of chutes in the riffle splitter to permit uniform discharge of the asphalt mixture through the chutes without segregation or loss of material. Sample receptacles of sufficient width and capacity to receive the reduced portions of asphalt mixture from the splitter without loss of material.
- Quartering Template: formed in the shape of a cross with equal length sides at right angles to each other. Template shall be manufactured of metal that will withstand heat and use without deforming. The sides of the quartering template should be sized so that the length exceeds the diameter of the flattened cone of asphalt mixture by an amount allowing complete separation of the quartered sample. Height of the sides must exceed the thickness of the flattened cone of asphalt mixture.
- Non-stick mixing surface that is hard, heat-resistant, clean, level, and large enough to permit asphalt mixture samples to be mixed without contamination or loss of material.

Sampling

Obtain samples according to the FOP for AASHTO R 97.

Sample Preparation

The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily. Do not exceed either the temperature or time limits specified in the test method(s) to be performed.

Selection of Procedure (Method)

Refer to agency requirements when determining the appropriate method(s) of sample reduction. In general, the selection of a particular method to reduce a sample depends on the initial size of the sample vs. the size of the sample needed for the specific test to be performed. It is recommended that, for large amounts of material, the initial reduction be performed using a mechanical splitter. This decreases the time needed for reduction and minimizes temperature loss. Further reduction of the remaining asphalt mixture may be performed by a combination of the following methods, as approved by the agency. The methods for reduction are:

- Mechanical Splitter Type B (Riffle) Method
- Quartering Method
 - Full Quartering
 - By Apex
- Incremental Method

Procedure

When heating of the equipment is desired, it shall be heated to a temperature not to exceed the maximum mixing temperature of the job mix formula (JMF).

Mechanical Splitter Type B (Riffle) Method

1. Clean the splitter and apply a light coating of approved release agent to the surfaces that will come in contact with asphalt mixture (hopper or straight-edged pan, chutes, receptacles).
2. Place two empty receptacles under the splitter.
3. Carefully empty the asphalt mixture from the agency-approved container(s) into the hopper or straight-edged pan without loss of material. Uniformly distribute from side to side of the hopper or pan.
4. Discharge the asphalt mixture at a uniform rate, allowing it to flow freely through the chutes.
5. Any asphalt mixture that is retained on the surface of the splitter shall be removed and placed into the appropriate receptacle.
6. Reduce the remaining asphalt mixture as needed by this method or a combination of the following methods as approved by the agency.

7. Using one of the two receptacles containing asphalt mixture, repeat the reduction process until the asphalt mixture contained in one of the two receptacles is the appropriate size for the required test.
8. After each split, remember to clean the splitter hopper and chute surfaces if needed.
9. Retain and properly identify the remaining unused asphalt mixture sample for further testing if required by the agency.

Quartering Method

1. If needed, apply a light coating of release agent to quartering template.
2. Dump the sample from the agency approved container(s) into a conical pile on a hard, “non-stick,” clean, level surface where there will be neither a loss of material nor the accidental addition of foreign material. The surface can be made non-stick by the application of an approved asphalt release agent, or sheeting.
3. Mix the material thoroughly by turning the entire sample over a minimum of four times with a flat-bottom scoop; or by alternately lifting each corner of the sheeting and pulling it over the sample diagonally toward the opposite corner, causing the material to be rolled. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one or lifting both opposite corners.
4. Flatten the conical pile to a uniform diameter and thickness where the diameter is four to eight times the thickness. Make a visual observation to ensure that the material is homogeneous.
5. Divide the flattened cone into four equal quarters using the quartering template or straightedges assuring complete separation.
6. Reduce to appropriate sample mass by full quartering or by apex.

Full Quartering

- a. Remove diagonally opposite quarters, including all of the fine material, and place in a container to be retained.
- b. Remove the quartering template, if used.
- c. Combine the remaining quarters.
- d. If further reduction is necessary, repeat Quartering Method Steps 3 through 6.
- e. Repeat until appropriate sample mass is obtained. The final sample must consist of the two remaining diagonally opposite quarters.
- f. Retain and properly identify the remaining unused portion of the asphalt mixture sample for further testing if required by the agency.

Reducing by Apex

- a. Using a straightedge, slice through a quarter of the asphalt mixture from the center point to the outer edge of the quarter.
- b. Pull or drag the material from the quarter with two straight edges or hold one edge of the straightedge in contact with quartering device.
- c. Remove an equal portion from the diagonally opposite quarter and combine these increments to create the appropriate sample mass.
- d. Continue using the apex method with the unused portion of the asphalt mixture until samples have been obtained for all required tests.
- e. Retain and properly identify the remaining unused portion of the asphalt mixture sample for further testing if required by the agency.

Incremental Method

1. Cover a hard, clean, level surface with sheeting. This surface shall be large enough that there will be neither a loss of material nor the accidental addition of foreign material.
2. Place the sample from the agency approved container(s) into a conical pile on that surface.
3. Mix the material thoroughly by turning the entire sample over a minimum of four times:
 - a. Use a flat-bottom scoop; or
 - b. Alternately lift each corner of the sheeting and pull it over the sample diagonally toward the opposite corner, causing the material to be rolled.
4. Create a conical pile by either depositing each scoop or shovelful of the last turning on top of the preceding one or lifting both opposite corners.
5. Grasp the sheeting and roll the conical pile into a cylinder (loaf), then flatten the top. Make a visual observation to determine that the material is homogenous.
6. Remove one quarter of the length of the loaf and place in a container to be saved; by either:
 - a. Pull sheeting over edge of counter and drop material into container.
 - b. Use a straightedge at least as wide as the full loaf to slice off material and place into container.
7. Obtain an appropriate sample mass for the test to be performed; by either:
 - a. Pull sheeting over edge of counter and drop cross sections of the material into container until proper sample mass has been obtained.
 - b. Use a straightedge at least as wide as the full loaf to slice off cross sections of the material until proper sample mass has been obtained and place into container.

Note 1: When reducing the sample to test size it is advisable to take several small increments, determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size, use the sample as reduced for the test.

8. Repeat Step 7 until all the samples for testing have been obtained or until final quarter of the original loaf is reached.
9. Retain and properly identify the remaining unused portion of the asphalt mixture sample for further testing if required by the agency.



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November 30, 2015

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 66**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Procedure, step 3 first bullet, delete the following from the sentence: “or from the delivery truck”. Sampling from the oil delivery truck is not allowed.**
- **Sample asphalt binder at the plant using an in-line sampling device or samples may be obtained from the storage tank, according to AASHTO R 66-15 procedure, section 7.1.1 and 7.2, when mechanical or other circumstances temporarily prohibit the use of the in-line device. Sampling from the storage tank is only permitted to complete the production shift.**

SAMPLING ASPHALT MATERIALS FOP FOR AASHTO R 66

Scope

This procedure covers obtaining samples of liquid asphalt materials in accordance with AASHTO R 66-16. Sampling of solid and semi-solid asphalt materials – included in AASHTO R 66 – is not covered here.

Agencies may be more specific on exactly who samples, where to sample, and what type of sampling device to use.

Warning: Always use appropriate safety equipment and precautions for hot liquids.

Terminology

- Asphalt binder: Asphalt cement or modified asphalt cement that binds the aggregate particles into a dense mass.
- Asphalt emulsion: A mixture of asphalt binder and water.
- Cutback asphalt: Asphalt binder that has been modified by blending with a chemical solvent.

Containers

Sample containers must be new, and the inside may not be washed or rinsed. The outside may be wiped with a clean, dry cloth.

All samples shall be put in 1 L (1 qt) containers and properly identified on the outside of the container with contract number, date sampled, data sheet number, brand and grade of material, and sample number. Include lot and subplot numbers when appropriate.

- Emulsified asphalt: Use wide-mouth plastic jars with screw caps. Protect the samples from freezing since water is a part of the emulsion. The sample container should be completely filled to minimize a skin formation on the sample.
- Asphalt binder and cutbacks: Use metal cans.

Note: The sample container shall not be submerged in solvent, nor shall it be wiped with a solvent saturated cloth. If cleaning is necessary, use a clean dry cloth.

Procedure

1. Coordinate sampling with contractor or supplier.
2. Allow a minimum of 4 L (1 gal) to flow before obtaining a sample(s).
3. Obtain samples of:
 - Asphalt binder from the line between the storage tank and the mixing plant while the plant is in operation, or from the delivery truck.
 - Cutback and emulsified asphalt from distributor spray bar or application device; or from the delivery truck before it is pumped into the distributor. Sample emulsified asphalt at delivery or before dilution.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented



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November 30, 2020

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 67**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

Under the Apparatus Section 4, change or modify as follows:

- **Section 4.2, Core Drill Bit, the core barrel shall have an inside diameter of (6 ± 0.25 in.).**

- **Section 4.3, Separation Equipment, delete and replace with the following:**

Cores lift shall be separated with a saw that provides a clean smooth plane representing the layer to be measured.

- **Section 4.4, Retrieval Device – Removal with a screw driver(s) or similar device shall not be allowed.**

Under Procedure, Step 5.8, delete and replace with the following:

The Hole created from the coring operation shall be filled with fast setting non-shrink grout from the QPL (Qualified Products List). Set time shall be less than 20 minutes. Ensure the final surface is flush with the surrounding surface.

Under the Layer Separation Section 7, delete 7.1 and replace with the following:

Separate the layer of HMAC to be tested from the remainder of each core with a saw. If a clean separation of the desired layer thickness occurs during core removal, sawing of specimen is not necessary. During separation the layer to be tested may be damaged, so use caution during this process.

Standard Practice for

**Sampling Asphalt Mixtures after
Compaction (Obtaining Cores)**

AASHTO Designation: R 67-20¹

Technical Subcommittee: 2c, Asphalt–Aggregate Mixtures

Release: Group 3 (July)



**American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, D.C. 20004**

Standard Practice for

Sampling Asphalt Mixtures after Compaction (Obtaining Cores)

AASHTO Designation: R 67-20¹



Technical Subcommittee: 2c, Asphalt–Aggregate
Mixtures

Release: Group 3 (July)

1. SCOPE

- 1.1. This method describes the process for removal of a core sample of compacted asphalt mixture from a pavement for laboratory testing. Cores may range in diameter from 2 in. to 12 in.
- 1.2. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. REFERENCED DOCUMENT

- 2.1. *ASTM Standard:*
- D3549, Standard Test Method for Thickness or Height of Compacted Asphalt Mixture Specimen

3. SIGNIFICANCE

- 3.1. Samples obtained in accordance with the procedure may be used for measuring asphalt mixture thickness, density, and other testing.

4. APPARATUS

- 4.1. *Core Drilling Machine*—A power-driven core drilling machine shall be used to obtain the sample. The device shall be capable of obtaining a core to the full depth of the asphalt mixture sampled and shall consist of a rigid frame or platform such that the core barrel can be maintained perpendicular to the pavement surface during the drilling process. The core drilling machine must be of sufficient horsepower and have the ability to reach a sufficient depth to minimize distortion of the compacted cores of asphalt mixture.
- 4.2. *Core Drill Bit*—The cutting edge of the core drill bit shall be made of hardened steel or other suitable material with diamond chips embedded in the metal or as recommended by the core drill bit manufacturer in order to drill through the compacted asphalt mixture cleanly. The inside diameter of the core barrel shall be as specified.

- 4.3. *Separation Equipment*—A saw or other method(s) that provides a clean, smooth plane representing the layer to be tested without damaging the specimen.
- 4.4. *Retrieval Device*—A device for removing core samples that will preserve the integrity of the core.
Note 1—Suitable devices have been made from steel rods, wire, or banding material.
- 4.5. *Cooling Agent*—Such as water, ice, dry ice, or liquid nitrogen.
- 4.6. *Sample Marking Tool*—A lumber crayon, paint stick, pen, or other suitable marking tool to mark the core sample for labeling, identifying the separation layers, identifying the layer to test, or as otherwise necessary.
- 4.7. *Package Containers*—Suitable packaging containers for securing and transporting the core samples.

5. PROCEDURE

- 5.1. Freshly compacted asphalt mixtures shall be allowed sufficient time to cool prior to coring in order to prevent damage to the core.
Note 2—To accelerate the coring process, compacted asphalt mixtures may be cooled to expedite the removal of the core by the following methods: water, ice, dry ice, or liquid nitrogen.
- 5.2. Provide a means such as water or air to aid in the removal of cuttings and to minimize the generation of heat caused by friction.
- 5.3. Position the coring machine above the selected location. Engage the power and water or air source to the coring machine. Slowly advance the core drill bit until it contacts the compacted asphalt mixture surface.
- 5.4. Keep the core bit perpendicular to the compacted asphalt mixture surface, applying constant pressure during the process.
Note 3—If any portion of the coring machine shifts during the operation, the core may break or distort. Failure to apply constant pressure or applying too much pressure may cause the core drill bit to bind or distort the core.
- 5.5. Continue the core drilling to the bottom or slightly below the bottom of the asphalt mixture intended to be sampled to allow separation of the core sample at the desired depth from the underlying pavement layers.
- 5.6. After drilling, separate the core sample from the underlying pavement layers using the retrieval device or other suitable means, without damaging or distorting the sample. Obtain the core sample using the retrieval device. Carefully brush off, or use water to wash off, any loose particles adhering to the field cores. For field cores taken immediately over a granular base, carefully remove any embedded granular material.
Note 4—If the core is damaged to a point that it cannot be used for its intended purpose, a new core shall be obtained within 6 in. of the original location.
- 5.7. Clearly label the core with a sample marking tool.
- 5.8. Fill the hole made from the coring operation with asphalt mixture, non-shrink grout, or other suitable material. Consolidate or compact the material in the hole in multiple lifts if necessary. Ensure that the final surface is level with the surrounding surface.

6. PACKAGING AND TRANSPORTING SAMPLES

- 6.1. Package core samples in suitable protective containers. If multiple core samples are packaged in one container, separate the samples from one another using a suitable separation material.
Note 5—Concrete cylinder molds and PVC or HDPE pipe have been found to be suitable containers for protecting and transporting core samples. Crumpled newspaper has been found to be a suitable separation material when packaging multiple core samples in one container.
- 6.2. Transport cores in a manner that prevents damage from jarring, rolling, or impact with any object.
- 6.3. Prevent cores from freezing or from excessive heat during transport to prevent breaking or deforming.
Note 6—In extreme ambient temperature conditions, an insulated container should be used during transport.
- 6.4. If the core is damaged in transport to a point it cannot be utilized for its intended purpose, the core will not be used.

7. LAYER SEPARATION

- 7.1. Using appropriate separation equipment, separate two or more pavement courses, lifts, or layers along the designated lift line.
Note 7—Lift lines are often more visible by rolling a wetted core on a flat surface.

8. REPORT

- 8.1. *The report shall include the following:*
- 8.1.1. Date the cores were obtained.
 - 8.1.2. Paving date.
 - 8.1.3. Coring location.
 - 8.1.4. The lift/layer being evaluated.
 - 8.1.5. Average thickness if required.
 - 8.1.6. If known, provide the core identification information, such as the nominal-maximum aggregate size of the mixture, asphalt mixture design identification, performance grade of the asphalt binder, etc.

9. KEYWORDS

- 9.1. Asphalt mixture; core drilling; core sample.

APPENDIXES

(Nonmandatory Information)

X1. THICKNESS DETERMINATION

- X1.1. Measure the thickness of the designated lift according to ASTM D3549/D3549M-11 to the nearest 0.01 ft, $\frac{1}{8}$ in., or 3 mm. Calculate an average of three or more measurements taken around the lift.

X2. PROCEDURE TO REMOVE CUT AGGREGATES FROM ASPHALT PAVEMENT CORES FOR LABORATORY TESTING

X2.1. *Scope*

- X2.1.1. This procedure is used to remove aggregates that have been cut in the core drilling process. This procedure is only necessary in cases where the asphalt pavement core was obtained for the purpose of determining a mixture property that will be affected by the presence of aggregate cut by the coring drill.

X2.2. *Procedure*

- X2.2.1. Place the core(s) in an oven at 230°F for a period between 30 and 60 min. Remove the core(s) when the material is sufficiently softened to easily remove cut aggregate particles according to Section X2.2.2. Cores shall be placed in the vertical position to prevent premature breakdown of the cores. See Figure X1 for an example of vertical versus horizontal placement.



(a) 30 min after oven storage at 230°F

(b) 60 min after oven storage at 230°F

Figure X1—Photographs of Cores Placed in Oven at 230°F

- X2.2.2. Separate cut aggregate particles by any of the following methods: hand, chisel, spatula, trowel, or by pressing a cylindrical tube (with an internal diameter approximately 1 in. less than the diameter of the core) through the core. Dispose of the removed portion of the core.

X2.2.3. The remainder of the core is ready to proceed with the desired testing. Cores consisting of the same pavement layer and obtained from the same roadway section may be combined to meet the requirements of the minimum sample size according to the applicable test method as needed.

X3. REFERENCE

X3.1. D3549/D3549M-11, Standard Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens

¹ This full standard was first published in 2015.



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November 30, 2016

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 75**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- Supplemental information for Family of Curves Development, Appendix A, is located at the end of R 75.

DEVELOPING A FAMILY OF CURVES FOP FOR AASHTO R 75

Scope

This procedure provides a method to develop a family of curves in accordance with AASHTO R 75-16 using multiple moisture density relationships developed using the same method, A, B, C, or D, from the FOP for AASHTO T 99/T 180.

All curves used in a family must be developed using a single Method: A, B, C, or D of a procedure for AASHTO T 99 or T 180. See the FOP for AASHTO T 99/T 180.

Terminology

family of curves — a group of soil moisture-density relationships (curves) determined using AASHTO T 99 or T 180, which reveal certain similarities and trends characteristic of the soil type and source.

spine — smooth line extending through the point of maximum density/optimum moisture content of a family of moisture-density curves.

Procedure

1. Sort the curves by Method (A, B, C, or D of the FOP for T 99/T 180). At least three curves are required to develop a family.
2. Select the highest and lowest maximum dry densities from those selected to assist in determining the desired scale of the subsequent graph.
3. Plot the maximum density and optimum moisture points of the selected curves on the graph.
4. Draw a smooth, “best fit,” curved line through the points creating the spine of the family of curves.
5. Remove maximum density and optimum moisture points that were not used to establish the spine.
6. Add the moisture/density curves associated with the points that were used to establish the spine. It is not necessary to include the portion of the curves over optimum moisture.

Note 1—Intermediate template curves using slopes similar to those of the original moisture-density curves may be included when maximum density points are more than 2.0 lb/ft³ apart. Template curves are indicated by a dashed line.

7. Plot the 80 percent of optimum moisture range when desired:
 - a. Using the optimum moisture of an existing curve, calculate 80 percent of optimum moisture and plot this value on the curve. Repeat for each curve in the family.
 - b. Draw a smooth, “best fit,” curved line connecting the 80 percent of optimum moisture points plotted on the curves that parallel the spine.

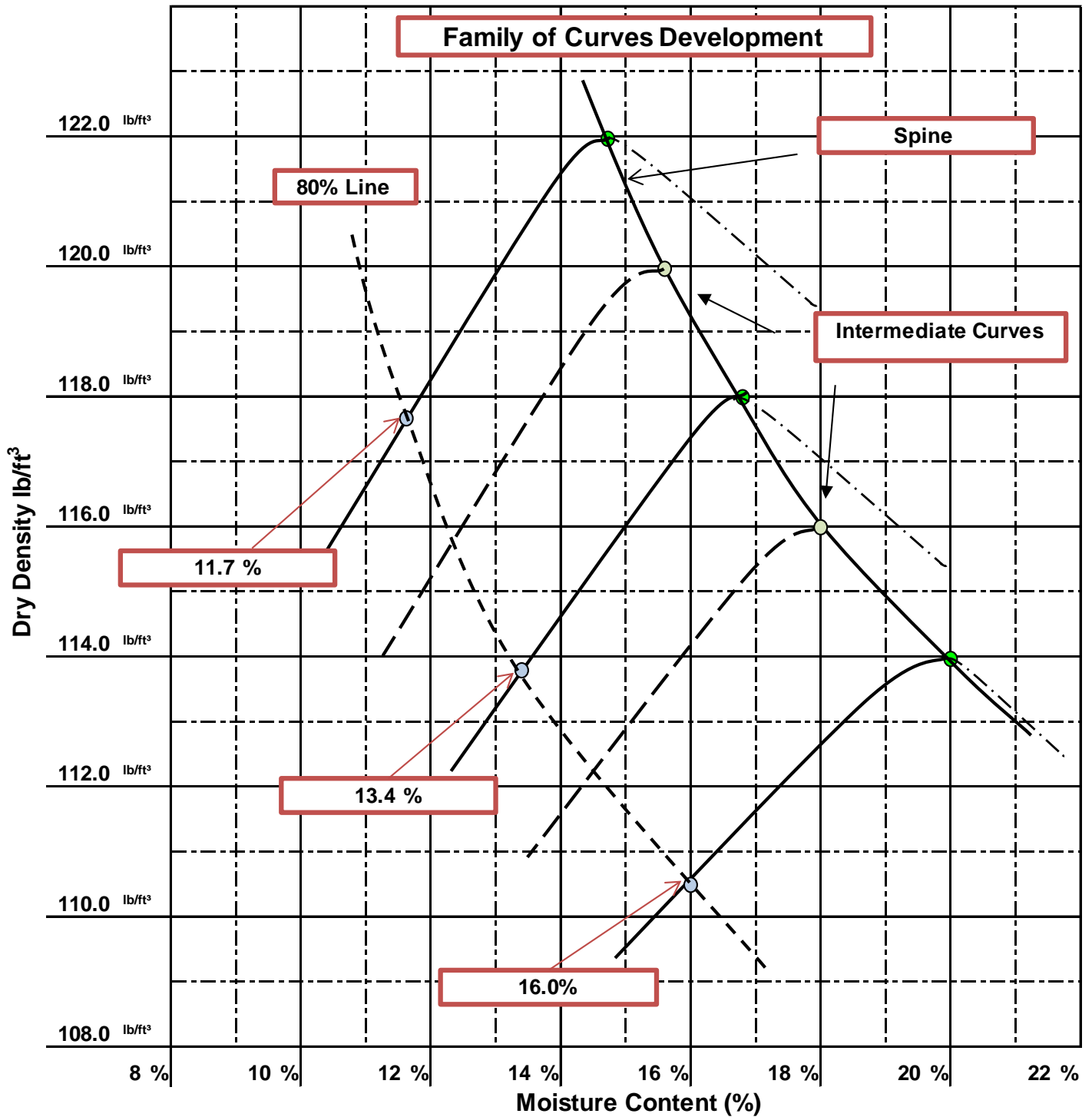
Calculations

Calculate 80 percent of optimum moisture of each curve:

Example:

Optimum moisture of the highest density curve = 14.6%

$$80\% \text{ point} = \frac{80}{100} \times 14.6\% = 11.7\%$$



FAMILY OF CURVES – DEVELOPMENT APPENDIX "A" FOP FOR AASHTO R 75

Significance

The purpose of the family of curves is to represent the average moisture-density characteristics of soils with similar geologic makeup. The family should be based on moisture-density relationships which represent the widest possible range of soils which may be encountered on a project. If the soil types have moisture-density relationships that differ considerably and can not be represented on one general family of curves; then multiple families may be developed. Also, moisture-density relationships for material of widely varying geologic origins should be carefully examined to determine if separate families are required.

Soils sampled from one source will have many different moisture-density relationships. If a group of these curves are plotted together, it reveals similarities of the material in relation to the soil type and source. Developing a family of curves has the potential advantage of spanning a large number of different soil types with a minimal amount of laboratory work.

Scope

This procedure provides a process for developing a family of curves using multiple individual curves as the source of data. The individual curves are sorted according to type and plotted on a single sheet of paper. The individual curves are connected by a common line drawn through their maximum density/optimum moisture points forming a family of curves. A series of individual curves or a combination of curves are utilized as appropriate to create one or more families. This procedure is related to AASHTO T 99, and AASHTO T 180. The family of curves must match the method utilized during the single curve development. A minimum of 3 individual curves is required to form a single family.

Apparatus

See the FOP for AASHTO T 99 and T 180.

Sample

See the FOP for AASHTO T 99 and T 180.

Procedure

See the FOP for AASHTO T 99 and T 180.

Calculations

See the FOP for AASHTO T 99 and T 180.

Overview

- Sort the individual curves into groups based on method of development.
- Plot the point representing the maximum density and optimum moisture for each individual curve on a single sheet of graph paper. At least 3 curves are required to develop a family.
- Draw a "best fit" smooth curve which closely connects all points.
- At 2.0 lbs/ft³ increments draw complete moisture-density relationships using slopes closely matching those of the original moisture-density relationships.
- When a large number of similar single curves exists, the average values may be used, if the difference between curves is less than 2.0 lbs/ft³.

Developing a Family of Curves Relationship

1. Initially sort candidate curves by test method and use only those developed using the same procedure.
2. Review the curves and select the highest and lowest maximum dry densities. Select a vertical density scale that places the highest value in the top 1" portion of the graph. Select a dry density increment that places the lowest value approximately 3" from the bottom portion of the graph. Label the incremental areas between the highest and lowest maximum density values.

Note 1: An increment of 2.0 lbs/ft³ per vertical inch is a recommended scale, but any increment can be used to accommodate the data plotting. It is preferable to use a scale that places whole numbers at the bold one-inch gridlines on the graph.

3. Review the corresponding optimum moisture data for the upper and lower points used to establish the vertical dry density scale described in step 2. Select a horizontal moisture scale that places the high point about 3" from the left edge and the low point about 1" from the right edge of the graph. Label the incremental grids between the highest and lowest optimum moisture values.

Note 2: An increment of 2.0% per horizontal inch is a recommended scale, but any increment can be used to accommodate the data plotting. It is preferable to use a scale that places the whole numbers at the bold one-inch gridlines on the graph.

4. Plot the maximum density and optimum moisture for each candidate curve to determine if they fit the desired pattern of a smooth curve that is slightly concave up and to the left. Eliminate points which do not fit this pattern. A minimum of three points is required to establish a family.
5. Draw a smooth "best fit" curve through the points, creating a curve that is slightly concave, up and to the left.

Note 3: The "best fit" curve (or spine) now defines the maximum density and optimum moisture content of the soils represented by this family of curves. A dry density or dry side, reference needs to be established for each individual curve and is created by replicating the original curve shape. Each individual curve has a unique shape towards the maximum density/optimum moisture point and needs to be plotted. This can be accomplished with tracing paper, a French curve or other objects that can mimic the shape. The only useable area on a family of curves is on the "dry" side of optimum moisture, therefore, we only need to apply one half of the moisture-density curve shape configuration to the family of curves spine.

6. Mark each maximum density/optimum moisture point with a dry side arc of sufficient length to meet the dry side leg. This is accomplished by centering the template directly below and touching the maximum density/optimum moisture point. Initially mark lightly in pencil. The exact length of the arc will be determined when the dry side leg is drawn in tangent to this arc. This process is repeated for each original curve.

Note 4: To establish the "dry side" slope a single point near the bottom of the original curve is required. This point, when plotted, will be connected with the tangent on the arc using a straight line. This will complete the original individual curve or the dry half of the original curve. If the scale of the original curve is the same as the family then you should be able to overlay the family with the original curve and when held to the light, the "dry sides" should match. The point selected on the dry side must accurately reflect the slope of the original curve if another scale is utilized. The point selected may be a data point from the original curve or it may be a point scaled off of the graph of the original curve. This process is repeated for each original curve.

7. Establish the 80% of Optimum Moisture Line at the bottom of the "dry side" legs. This provides a graphical guide for the Density Technician when using the family of curves in the field. Compute 80% of optimum moisture for each curve by multiplying the optimum moisture by 0.8. Lay a ruler vertically on the graph and at the 80% of optimum moisture calculated, make a tick mark where the ruler intercepts the "dry side" leg of that curve. This process is repeated for each original curve. Draw a smooth best-fit curve through the tick marks and label each end of the line with 80%.
8. At 2.0 lbs/ft³ increments draw moisture-density relationships using slopes similar to those of the original moisture-density relationships.

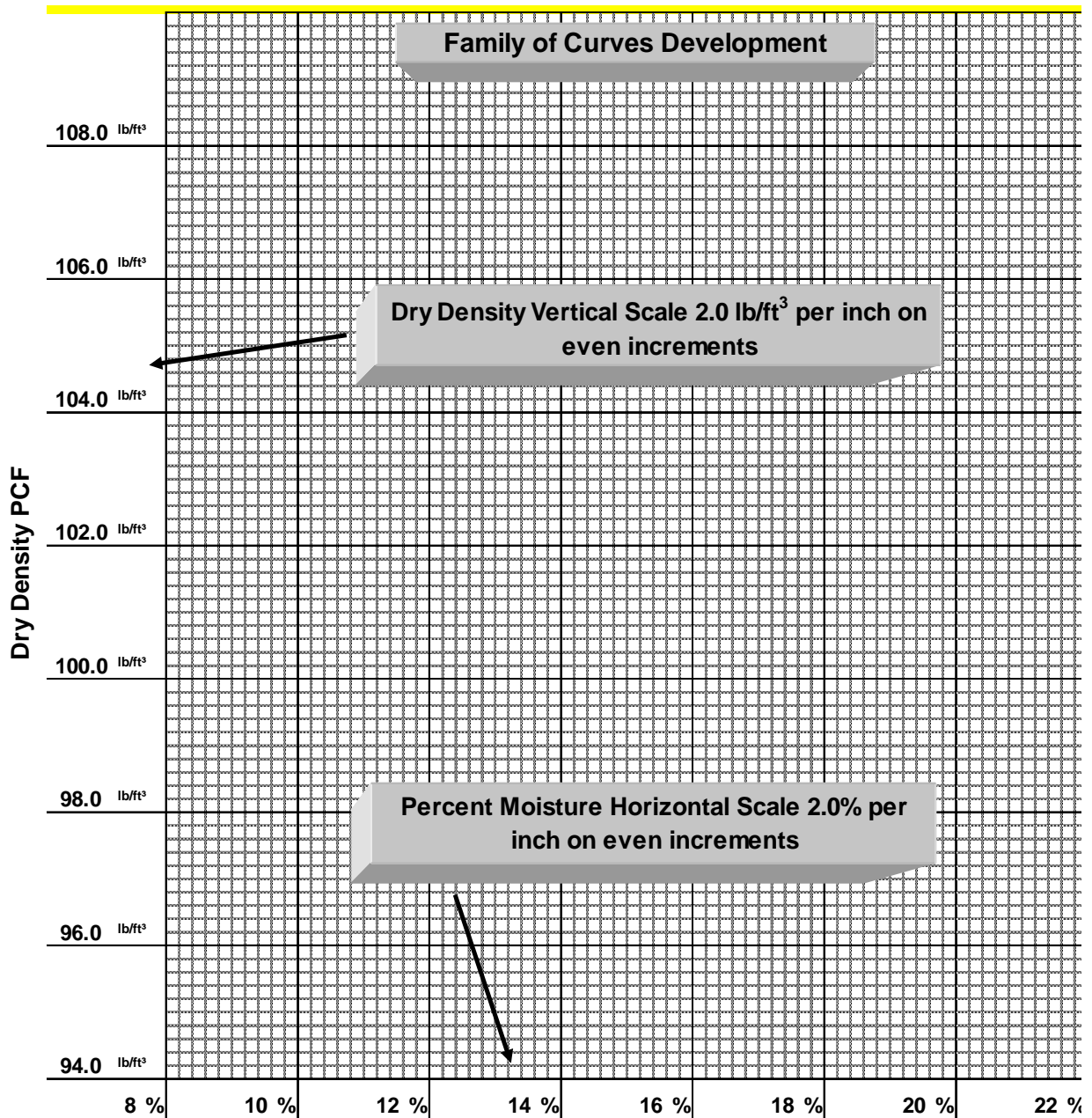
EXAMPLE OF FAMILY DEVELOPMENT:

STEP 1:

- Sort and only retain curves developed by the same procedure (e.g. T 99 method A).

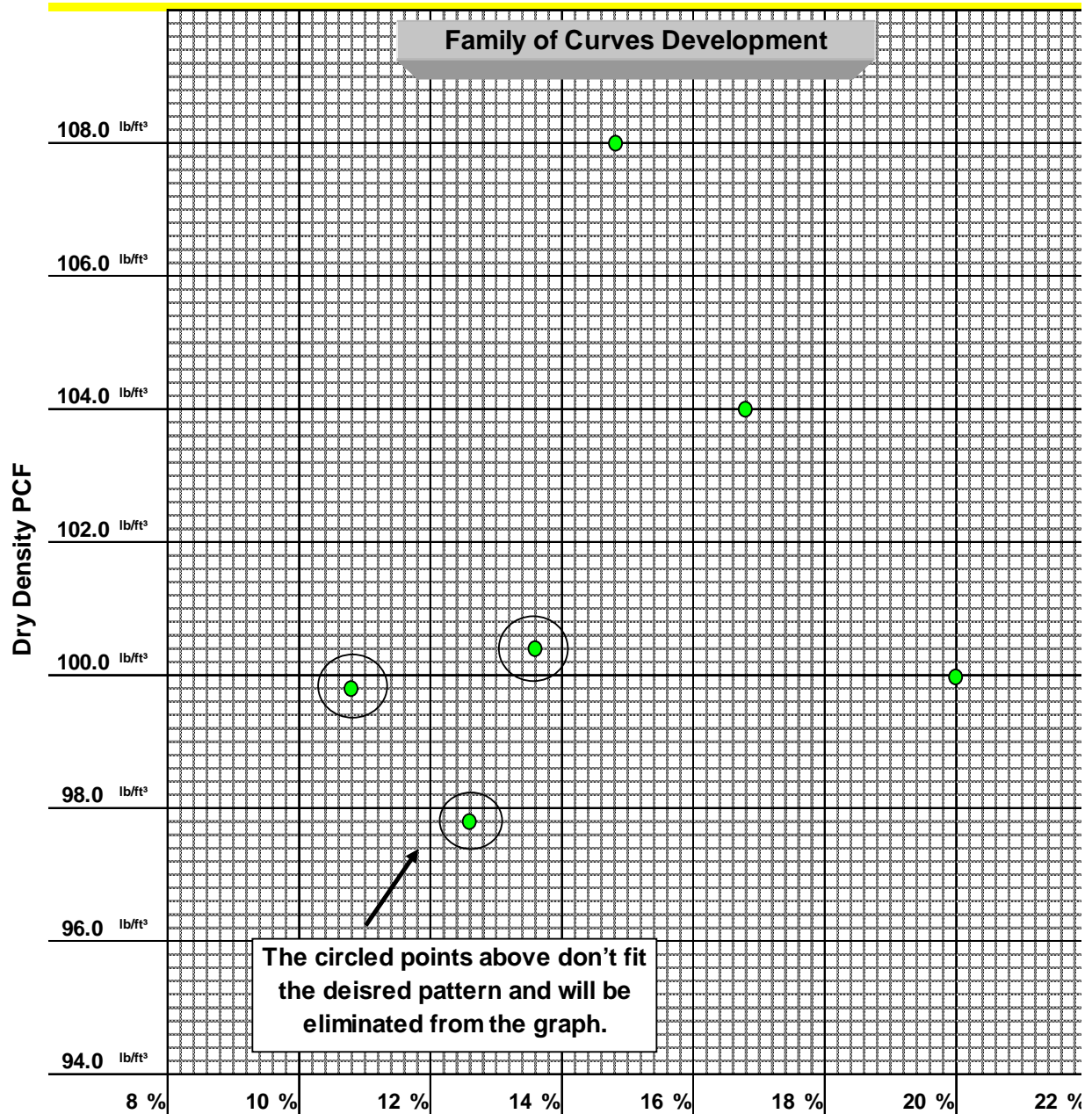
STEP 2 & 3:

- Establish and label an appropriate dry density scale on the vertical axis and a percent moisture scale on the horizontal axis.

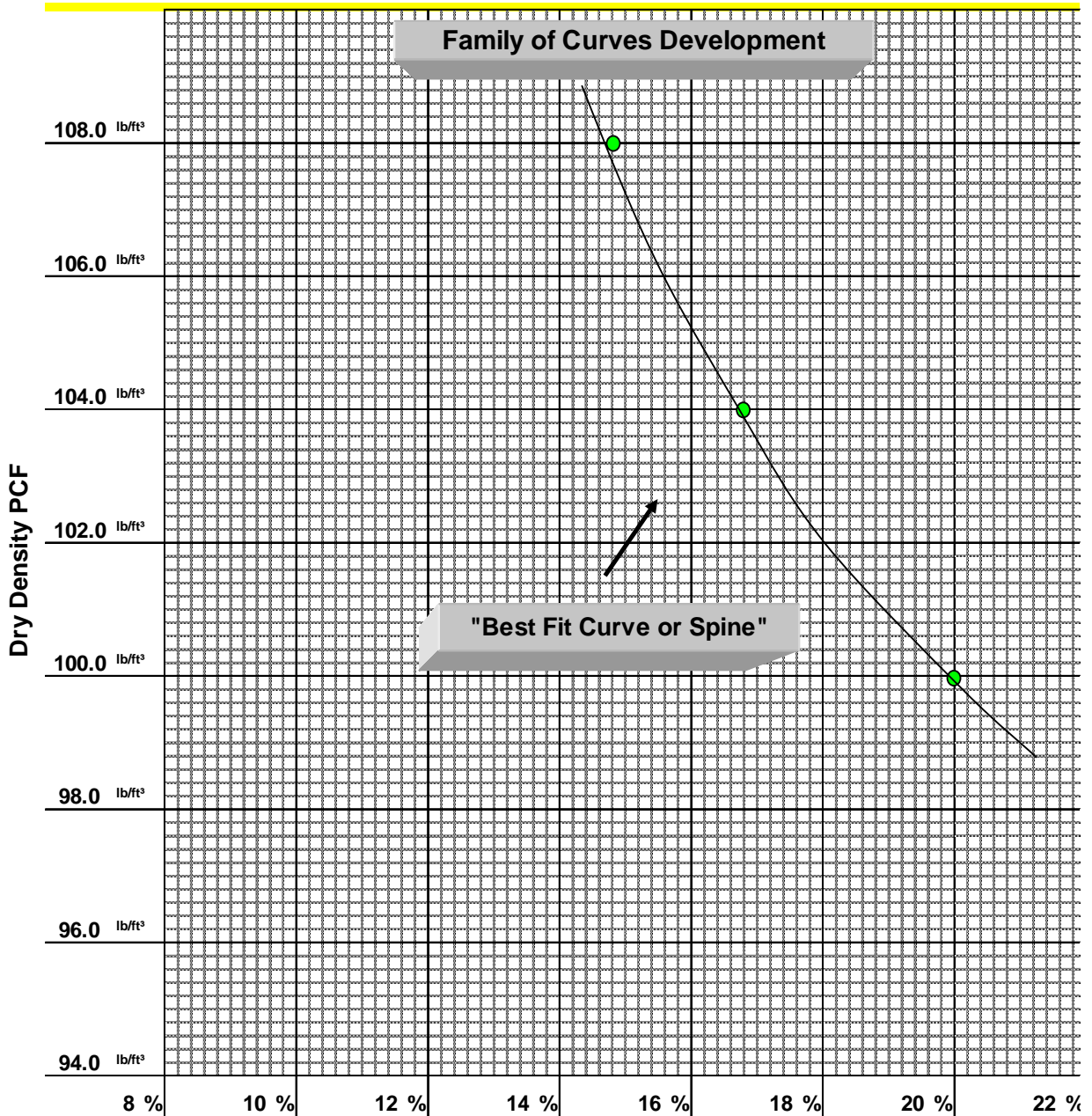


Step 4:

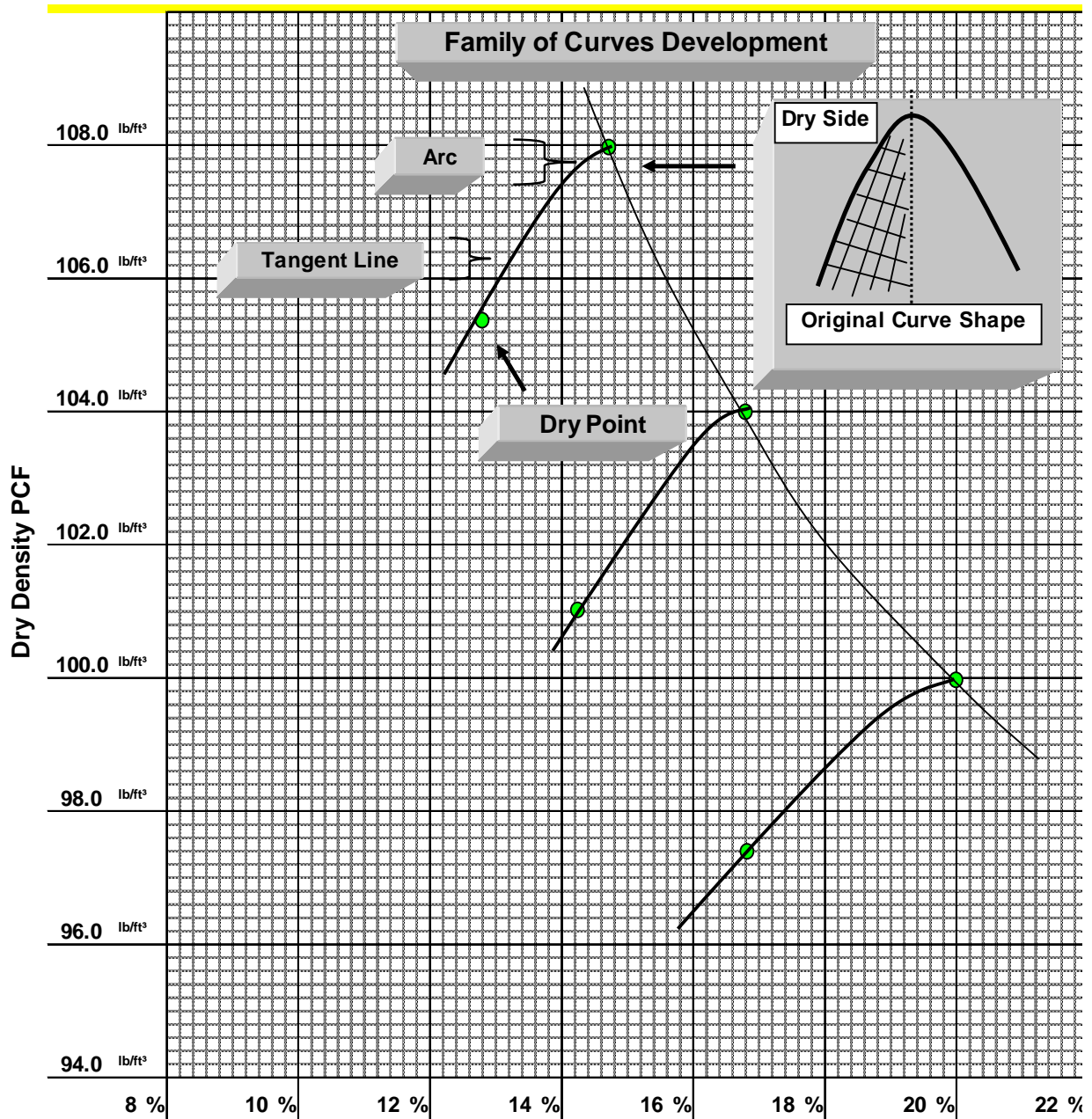
- Plot only the points representing the maximum dry density and optimum moisture from the candidate curves.



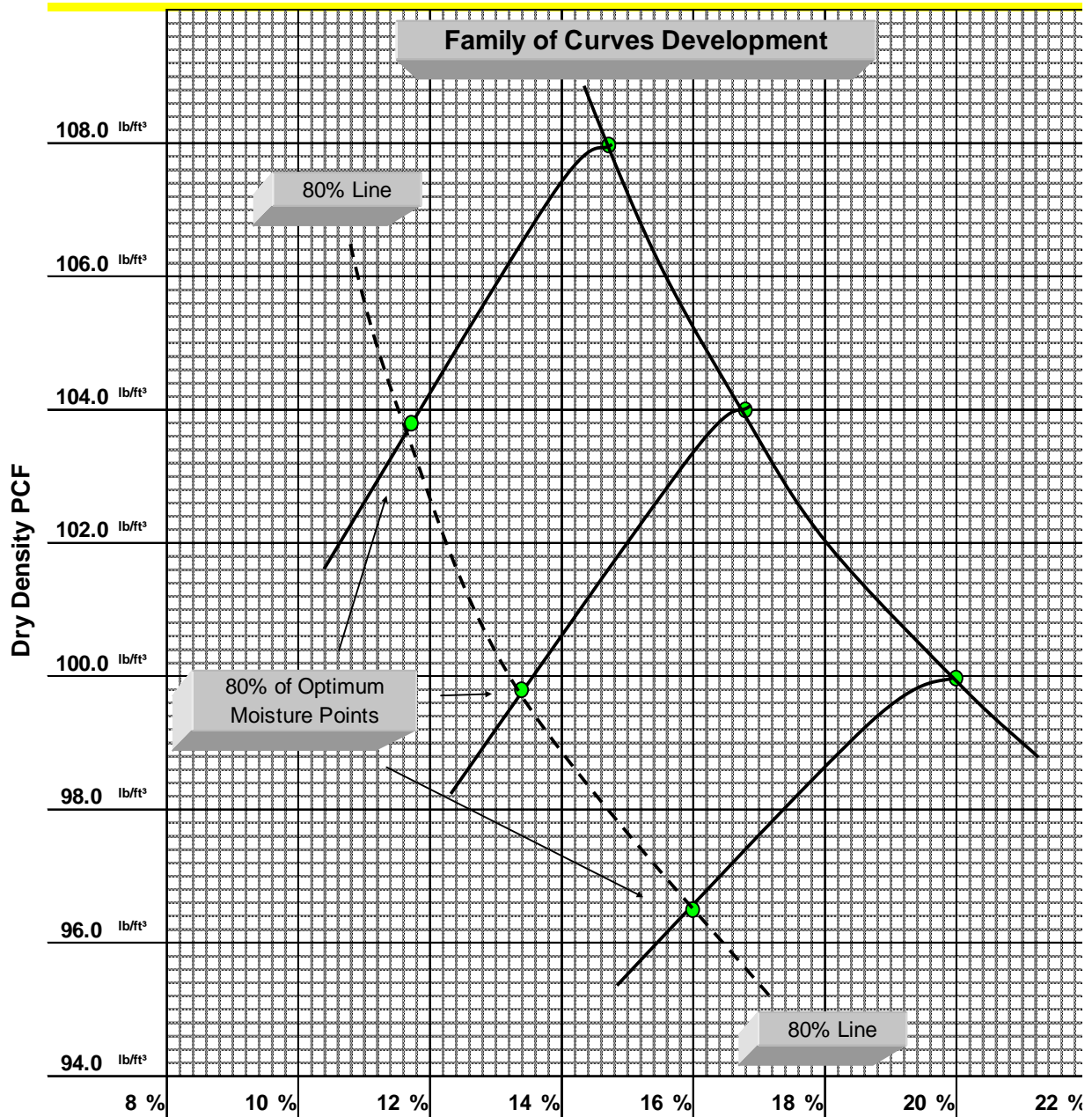
Step 5: Draw a smooth "best fit" curve through the points creating a curve that is slightly concave up and to the left.



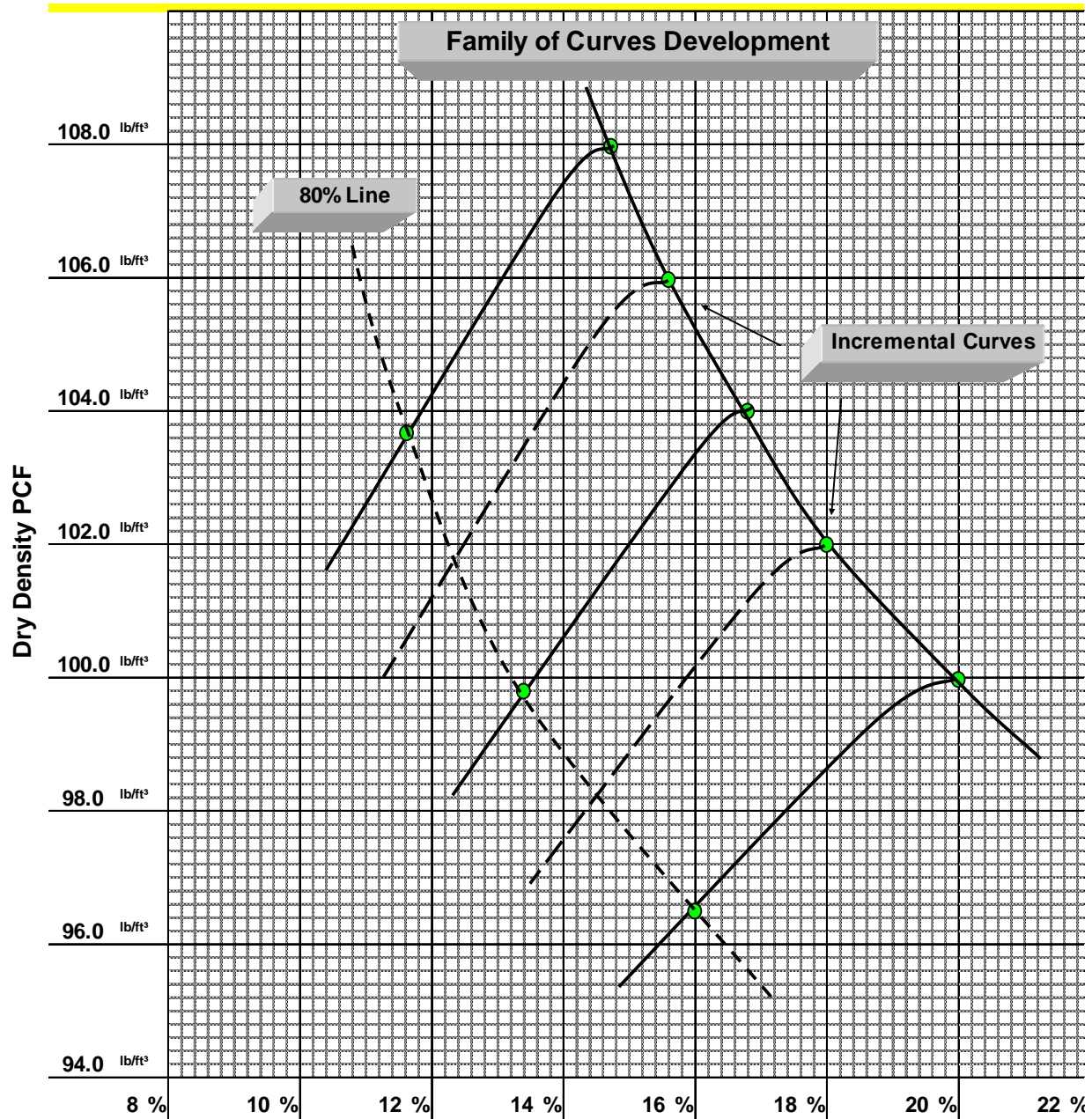
Step 6: Mark each maximum density-optimum moisture point with a dry side arc of sufficient length to meet the dry side leg. Plot a point on the "dry side" and connect the arc with the point using a tangent line.



Step 7: Establish the 80% of Optimum Moisture Line at the bottom of the "dry side" legs.



Step 8: At 2.0 lbs/ft³ increments draw moisture-density relationships using slopes similar to those of the original moisture-density relationships.



Report

- Include original curve data with family.
- Include Gsb & Absorption information of retained material, if available.



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November 30, 2016

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 76**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Delete the Method Selection section and replace with the following**

Samples of FA which are drier than the saturated surface dry (SSD) condition shall be reduced by a mechanical splitter according to Method A. As a quick determination, if the fine aggregate will retain its shape when molded with the hand, it is wetter than SSD.

Samples of FA that are at SSD or wetter than SSD shall be reduced by Method B, or the entire sample may be dried to the SSD condition – using temperatures that do not exceed those specified for any of the tests contemplated – and then reduced to test sample size using Method A.

Samples of CA or mixtures of FA and CA may be reduced by either method. Method A is not recommended for FA / CA mixtures that adhere to the apparatus.

REDUCING SAMPLES OF AGGREGATE TO TESTING SIZE FOP FOR AASHTO R 76

Scope

This procedure covers the reduction of samples to the appropriate size for testing in accordance with AASHTO R 76-16. Techniques are used that minimize variations in characteristics between test samples and field samples. Method A (Mechanical Splitter) and Method B (Quartering) are covered.

This FOP applies to fine aggregate (FA), coarse aggregate (CA), and mixes of the two (FA / CA) and may also be used on soils.

Apparatus

Method A – Mechanical Splitter

Splitter chutes:

- Even number of equal width chutes
- Discharge alternately to each side
- Minimum of 8 chutes total for CA and FA / CA, 12 chutes total for FA
- Width:
 - Minimum 50 percent larger than largest particle
 - Maximum chute width of 19 mm (3/4 in.) for fine aggregate passing the 9.5 mm (3/8 in.) sieve

Feed control:

- Hopper or straightedge pan with a width equal to or slightly less than the overall width of the assembly of chutes
- Capable of feeding the splitter at a controlled rate

Splitter receptacles / pans:

- Capable of holding two halves of the sample following splitting

The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material.

Method B – Quartering

- Straightedge scoop, shovel, or trowel
- Broom or brush
- Tarp: A square canvas or plastic sheet, appropriate for the amount and size of the material being reduced

Method Selection

Samples of CA may be reduced by either Method A or Method B.

Samples of FA which are drier than the saturated surface dry (SSD) condition, as described in AASHTO T 84, shall be reduced by a mechanical splitter according to Method A. As a quick approximation, if the fine aggregate will retain its shape when molded with the hand, it is wetter than SSD.

Samples of FA / CA which are drier than SSD may be reduced by Method A or Method B.

Samples of FA and FA / CA that are at SSD or wetter than SSD shall be reduced by Method B, or the entire sample may be dried – using temperatures that do not exceed those specified for any of the tests contemplated – and then reduced to test sample size using Method A.

Table 1

	Drier than SSD	Wetter than SSD
Fine Aggregate (FA)	Method A (Mechanical)	Method B (Quartering)
Mixture of FA/CA	Either Method	Method B (Quartering)
Coarse Aggregate (CA)	Either Method	Either Method

Procedure

Method A – Mechanical Splitter

1. Place two clean empty receptacles under the splitter.
2. Empty the sample into the hopper or pan without loss of material.
3. Uniformly distribute the material in the hopper or pan from edge to edge so that approximately equal amounts flow through each chute.
4. Discharge the material at a uniform rate, allowing it to flow freely through the chutes.
5. Remove any material retained on the surface of the splitter and place into the appropriate receptacle.
6. Using one of the two receptacles containing material, repeat Steps 1 through 6 until the material in one of the two receptacles is the appropriate sample size for the required test.
7. Retain and properly identify the remaining unused sample for further testing if required.

Mechanical Splitter Check

- Determine the mass of each reduced portion. If the percent difference of the two masses is greater than 5 percent, corrective action must be taken.

Calculation

$$\frac{\text{Smaller Mass}}{\text{Larger Mass}} = \text{Ratio} \quad (1 - \text{ratio}) \times 100 = \% \text{ Difference}$$

Splitter check: 5127 g total sample mass

Splitter pan #1: 2583 g

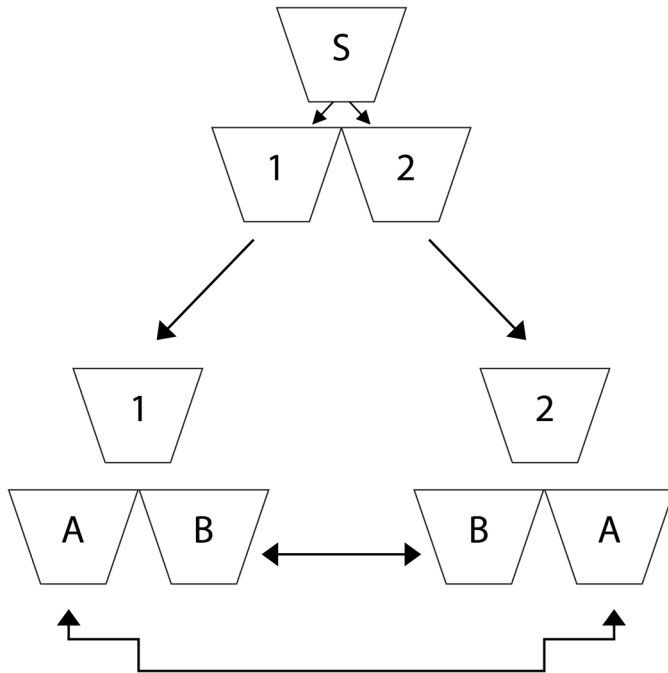
Splitter pan #2: 2544 g

$$\frac{2544 \text{ g}}{2583 \text{ g}} = 0.985 \quad (1 - 0.985) \times 100 = 1.5\%$$

Alternative to Mechanical Splitter Check

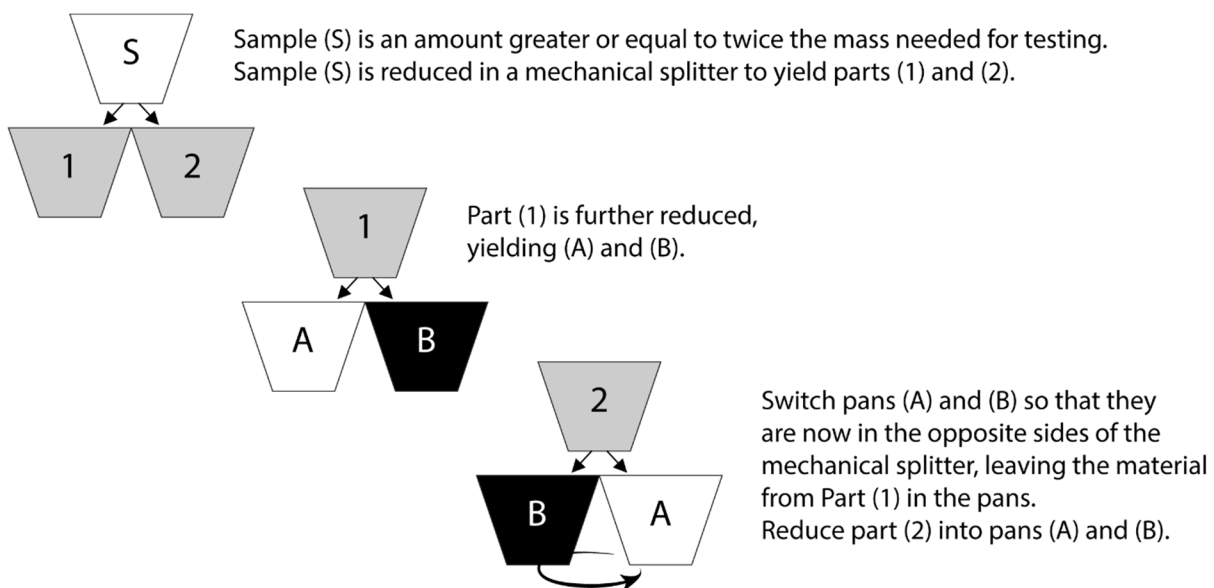
- In lieu of determining the mass of each reduced portion, use the method illustrated in Figure 1 or 2 during reduction.

Figure 1



- Sample (S) is an amount greater than or equal to twice the mass needed for testing. Sample (S) is reduced in a mechanical splitter to yield parts (1) and (2).
- Part (1) is further reduced yielding (A) and (B) while part (2) is reduced to yield (B) and (A).
- Final testing sample is produced by combining alternate pans, i.e. A/A or B/B only.

Figure 2



Method B – Quartering

Use either of the following two procedures or a combination of both.

Procedure 1: Quartering on a clean, hard, level surface:

1. Place the sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material.
2. Mix the material thoroughly by turning the entire sample over a minimum of four times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one.
3. Flatten the conical pile to a uniform thickness and diameter by pressing down with a shovel. The diameter should be four to eight times the thickness.
4. Divide the flattened pile into four approximately equal quarters with a shovel or trowel.
5. Remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean.
6. Successively mix and quarter the remaining material until the sample is reduced to the desired size.
7. The final test sample consists of two diagonally opposite quarters.

Procedure 2: Quartering on a tarp:

1. Place the sample on the tarp.
2. Mix the material thoroughly a minimum of four times by pulling each corner of the tarp horizontally over the sample toward the opposite corner. After the last turn, form a conical pile.
3. Flatten the conical pile to a uniform thickness and diameter by pressing down with a shovel. The diameter should be four to eight times the thickness.
4. Divide the flattened pile into four approximately equal quarters with a shovel or trowel or insert a stick or pipe beneath the tarp and under the center of the pile, then lift both ends of the stick, dividing the sample into two roughly equal parts. Remove the stick leaving a fold of the tarp between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four roughly equal quarters.
5. Remove two diagonally opposite quarters, being careful to clean the fines from the tarp.

6. Successively mix and quarter the remaining material until the sample size is reduced to the desired size.
7. The final test sample consists of two diagonally opposite quarters.



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November 30, 2020

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 90**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

For all produced aggregates the definition of “Nominal Maximum Size” shall be as follows:

“One sieve larger than the first sieve that retains more than 10% of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size.”

SAMPLING AGGREGATE PRODUCTS FOP FOR AASHTO R 90

Scope

This procedure covers sampling of coarse, fine, or a combination of coarse and fine aggregates (CA and FA) in accordance with AASHTO R 90-18. Sampling from conveyor belts, transport units, roadways, and stockpiles is covered.

Apparatus

- Shovels or scoops, or both
- Brooms, brushes, and scraping tools
- Sampling tubes of acceptable dimensions
- Mechanical sampling systems: normally a permanently attached device that allows a sample container to pass perpendicularly through the entire stream of material or diverts the entire stream of material into the container by manual, hydraulic, or pneumatic operation
- Belt template
- Sampling containers

Procedure – General

Sampling is as important as testing. The technician shall use every precaution to obtain samples that are representative of the material. Determine the time or location for sampling in a random manner.

1. Wherever samples are taken, obtain multiple increments of approximately equal size.
2. Mix the increments thoroughly to form a field sample that meets or exceeds the minimum mass recommended in Table 1.

TABLE 1
Recommended Sample Sizes

Nominal Maximum Size*		Minimum Mass	
mm (in.)		g (lb)	
90	(3 1/2)	175,000	(385)
75	(3)	150,000	(330)
63	(2 1/2)	125,000	(275)
50	(2)	100,000	(220)
37.5	(1 1/2)	75,000	(165)
25.0	(1)	50,000	(110)
19.0	(3/4)	25,000	(55)
12.5	(1/2)	15,000	(35)
9.5	(3/8)	10,000	(25)
4.75	(No. 4)	10,000	(25)
2.36	(No. 8)	10,000	(25)

* One sieve larger than the first sieve to retain more than 10 percent of the material using an agency specified set of sieves based on cumulative percent retained. Where large gaps in specification sieves exist, intermediate sieve(s) may be inserted to determine nominal maximum size. Maximum size is one size larger than nominal maximum size.

Note 1: Sample size is based upon the test(s) required. As a general rule, the field sample size should be such that, when split twice will provide a testing sample of proper size. For example, the sample size may be four times that shown in Table 1 of the FOP for AASHTO T 27/T 11, if that mass is more appropriate.

Procedure – Specific Situations

Conveyor Belts

Avoid sampling at the beginning or end of the aggregate run due to the potential for segregation. Be careful when sampling in the rain. Make sure to capture fines that may stick to the belt or that the rain tends to wash away.

Method A (From the Belt)

1. Stop the belt.
2. Set the sampling template in place on the belt, avoiding intrusion by adjacent material.
3. Remove the material from inside the template, including all fines.
4. Obtain at least three approximately equal increments.
5. Combine the increments and mix thoroughly to form a single sample.

Method B (From the Belt Discharge)

1. Pass a sampling device through the full stream of the material as it runs off the end of the conveyor belt. The sampling device may be manually, semi-automatic or automatically powered.
2. The sampling device shall pass through the stream at least twice, once in each direction, without overfilling while maintaining a constant speed during the sampling process.
3. When emptying the sampling device into the container, include all fines.
4. Combine the increments and mix thoroughly to form a single sample.

Transport Units

1. Visually divide the unit into four quadrants.
2. Identify one sampling location in each quadrant.
3. Dig down and remove approximately 0.3 m (1 ft.) of material to avoid surface segregation. Obtain each increment from below this level.
4. Combine the increments and mix thoroughly to form a single sample.

Roadways**Method A (Berm or Windrow)**

1. Obtain sample before spreading.
2. Take the increments from at least three random locations along the fully formed windrow or berm. Do not take the increments from the beginning or the end of the windrow or berm.
3. Obtain full cross-section samples of approximately equal size at each location. Take care to exclude the underlying material.
4. Combine the increments and mix thoroughly to form a single sample.

Note 2: Obtaining samples from berms or windrows may yield extra-large samples and may not be the preferred sampling location.

Method B (In-Place)

1. Obtain sample after spreading and before compaction.
2. Take the increments from at least three random locations.
3. Obtain full-depth increments of approximately equal size from each location. Take care to exclude the underlying material.
4. Combine the increments and mix thoroughly to form a single sample.

Stockpiles

Method A – Loader Sampling

1. Direct the loader operator to enter the stockpile with the bucket at least 150 mm (6 in.) above ground level without contaminating the stockpile.
2. Discard the first bucketful.
3. Have the loader re-enter the stockpile and obtain a full loader bucket of the material, tilt the bucket back and up.
4. Form a small sampling pile at the base of the stockpile by gently rolling the material out of the bucket with the bucket just high enough to permit free flow of the material. (Repeat as necessary.)
5. Create a flat surface by having the loader back drag the small pile.
6. Visually divide the flat surface into four quadrants.
7. Collect an increment from each quadrant by fully inserting the shovel into the flat pile as vertically as possible, take care to exclude the underlying material, roll back the shovel and lift the material slowly out of the pile to avoid material rolling off the shovel.
8. Combine the increments and mix thoroughly to form a single sample.

Method B – Stockpile Face Sampling

1. Create horizontal surfaces with vertical faces in the top, middle, and bottom third of the stockpile with a shovel or loader.
2. Prevent continued sloughing by shoving a flat board against the vertical face. Sloughed material will be discarded to create the horizontal surface.
3. Obtain sample from the horizontal surface as close to the intersection as possible of the horizontal and vertical faces.
4. Obtain at least one increment of equal size from each of the top, middle, and bottom thirds of the pile.
5. Combine the increments to and mix thoroughly form a single sample.

Method C – Alternate Tube Method (Fine Aggregate)

1. Remove the outer layer that may have become segregated.
2. Using a sampling tube, obtain one increment of equal size from a minimum of five random locations on the pile.
3. Combine the increments to and mix thoroughly form a single sample.

Identification and Shipping

- Identify samples according to agency standards.
- Include sample report (below).
- Ship samples in containers that will prevent loss, contamination, or damage of material.

Report

- On forms approved by the agency
- Date
- Time
- Sample ID
- Sampling method
- Location
- Quantity represented
- Material type
- Supplier



Oregon

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November 30, 2019

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 97**

The Oregon Department of Transportation has specified method(s) for this Test Procedure.

Please observe the following for our projects:

The following sampling locations are not permitted:

- **Conveyor Belts**
- **Stockpiles, Method 1 and 2**

SAMPLING ASPHALT MIXTURES FOP FOR AASHTO R 97

Scope

This procedure covers the sampling of asphalt mixtures from plants, haul units, and roadways in accordance with AASHTO R 97-19. Sampling is as important as testing, use care to obtain a representative sample and to avoid segregation and contamination of the material during sampling.

This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Apparatus

- Shovel or Metal Scoops, or Other Equipment: square-head metal shovels at least 125 mm (5.5 in.) wide.
- Sample containers: such as cardboard boxes, metal cans, stainless steel bowls, or other agency-approved containers
- Sampling plate: thick metal plate, minimum 8 gauge, sized to accommodate sample requirements, with a wire attached to one corner long enough to reach from the center of the paver to the outside of the farthest auger extension. A minimum of one hole 6 mm (0.25 in.) in diameter must be provided in a corner of the plate.
- Cookie cutter sampling device: formed steel angle with two 100 mm by 150 mm by 9 mm (4 in. by 6 in. by 3/8 in.) handles, sized to accommodate sample requirements. Minimum 50 mm (2 in.) smaller than the sampling plate when used together.

Example: Sampling plate 380 mm (15 in.) square and a cookie cutter sampling device 330 mm (13 in.) square.

- Mechanical sampling device: a permanently attached device that allows a sample receptacle to pass perpendicularly through the entire stream of material or diverts the entire stream of material into the container by manual, hydraulic, or pneumatic operation.
- Release agent: a non-stick product that prevents the asphalt mixture from sticking to the apparatus and does not contain solvents or petroleum-based products that could affect asphalt binder properties.

Sample Size

Sample size depends on the test methods specified by the agency for acceptance. Check agency requirement for the size required.

Procedure

General

- Select sample locations using a random or stratified random sampling procedure, as specified by the agency. The material shall be tested to determine variations. The supplier/contractor shall provide equipment for safe and appropriate sampling, including sampling devices on plants when required.
- Ensure the container(s) and sampling equipment are clean and dry before sampling.
- For dense graded mixture samples use cardboard boxes, stainless steel bowls or other agency-approved containers.
- For hot open graded mixture samples use stainless steel bowls. Do not put open graded mixture samples in boxes until they have cooled to the point that asphalt binder will not migrate from the aggregate.

Attached Sampling Devices

These are normally permanently attached devices that allow a sample container to pass perpendicularly through the entire stream of material. Operation may be hydraulic, pneumatic, or manual and allows the sample container to pass through the stream twice, once in each direction, without overfilling. A sampling device may also divert the entire stream into a sampling receptacle.

1. Lightly coat the container attached to the sampling device with an agency-approved release agent or preheat it, or both, to approximately the same discharge temperature of the mix.
2. Pass the container twice through the material perpendicularly without overfilling the container.
3. Transfer the asphalt mixture to an agency-approved container without loss of material.
4. Repeat until proper sample size has been obtained.
5. Combine the increments to form a single sample.

Conveyor Belts

1. Avoid sampling at the beginning or end of an asphalt mixture production run due to the potential for segregation.
2. Stop the belt containing asphalt mixture.
3. Set the sampling template into the asphalt mixture on the belt, avoiding intrusion by adjacent material.
4. Remove the asphalt mixture from inside the template, including all fines, and place in a sample container.
5. Repeat, obtaining equal size increments, until proper sample size has been obtained.
6. Combine the increments to form a single sample.

Haul Units

1. Visually divide the haul unit into approximately four equal quadrants.
2. Identify one sampling location in each quadrant.
3. Dig down and remove approximately 0.3 m (1 ft.) of material to avoid surface segregation. Obtain each increment from below this level.
4. Combine the increments to form a sample of the required size.

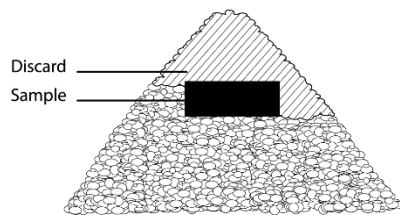
Paver Auger

1. Obtain samples from the end of the auger using a square head shovel.
2. Place the shovel in front of the auger extension, with the shovel blade flat upon the surface to be paved over.
3. Allow the front face of the auger stream to cover the shovel with asphalt mixture, remove the shovel before the auger reaches it by lifting as vertically as possible.
4. Place asphalt mixture in a sample container.
5. Repeat until proper sample size has been obtained.
6. Combine the increments to form a sample of the required size.

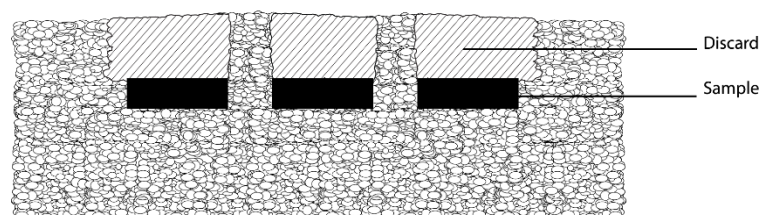
Note 1: First full shovel of material may be discarded to preheat and ‘butter’ the shovel.

Windrow

1. Obtain samples from the windrow of a transport unit. Avoid the beginning or the end of the windrow section.
2. Visually divide the windrow into approximately three equal sections.
3. Remove approximately 0.3 m (1 ft) from the top of each section.
4. Fully insert the shovel into the flat surface as vertically as possible, exclude the underlying material, roll back the shovel and lift the material slowly out of the windrow to avoid material rolling off the shovel.
5. Place in a sample container.
6. Repeat, obtaining equal size increments, in each of the remaining thirds.
7. Combine the increments to form a sample of the required size.



Windrow cross section



Windrow side view

Roadway before Compaction

There are two conditions that will be encountered when sampling asphalt mixtures from the roadway before compaction. The two conditions are:

- Laying asphalt mixture on grade or untreated base material requires Method 1.
- Laying asphalt mixture on existing asphalt or laying a second lift of asphalt mixture requires Method 2.

SAFETY:

Sampling is performed behind the paving machine and in front of the breakdown roller. For safety, the roller must remain at least 3 m (10 ft.) behind the sampling operation until the sample has been taken and the hole filled with loose asphalt mixture.

Method 1 requires a plate to be placed in the roadway in front of the paving operation and therefore there is always concern with moving, operating equipment. It is safest to stop the paving train while a plate is installed in front of the paver. When this is not possible the following safety rules must be followed.

1. The plate placing operation must be at least 3 m (10 ft.) in front of the paver or pickup device. The technician placing the plate must have eye contact and communication with the paving machine operator. If eye contact cannot be maintained at all time, a third person must be present to provide communication between the operator and the technician.
2. No technician is to be between the asphalt supply trucks and the paving machine. The exception to this rule is if the supply truck is moving forward creating a windrow, in which case the technician must be at least 3 m (10 ft.) behind the truck.

If at any time the Engineer feels that the sampling technique is creating an unsafe condition, the operation is to be halted until it is made safe or the paving operation will be stopped while the plate is being placed.

Method 1 - Obtaining a Sample on Grade or Untreated Base (Plate Method)

1. Following the safety rules detailed above, the technician is to:
 - a. Smooth out a location in front of the paver at least 0.5 m (2 ft.) inside the edge of the mat.
 - b. Lay the plate down diagonally with the direction of travel, keeping it flat and tight to the base with the lead corner facing the paving machine.

Note 2: The plate may be secured by driving a nail through the hole in the lead corner of the plate.

2. Pull the wire, attached to the outside corner of the plate, taut past the edge of the asphalt mixture mat and secure it. Let the paving operation pass over the plate and wire.
3. Using the exposed end of the wire, pull the wire up through the fresh asphalt mixture to locate the corner of the plate.

- a. Plate only:
 - i. Using a small square head shovel or scoop, or both, remove the full depth of the asphalt mixture from the plate. Take care to prevent sloughing of adjacent material.
 - ii. Place asphalt mixture, including any material adhering to the plate and scoop or shovel in a sample container.
- b. "Cookie Cutter":
 - i. Place the "cookie cutter" sample device, just inside the end of the wire; align the cutter over the plate. Press "cookie cutter" device down through the asphalt mixture to the plate.
 - ii. Using a small square tipped shovel or scoop, or both, carefully remove all the asphalt mixture from inside of the cutter and place in a sample container.
 - iii. Remove the sample cutter and the plate from the roadway. The hole made from the sampling must be filled by the contractor with loose asphalt mixture.

Method 2 - Obtaining a Sample on Asphalt Surface (Non-plate Method)

1. After the paving machine has passed the sampling point, immediately place the "cookie cutter" sampling device on the location to be sampled.
2. Push the cutter down through the asphalt mixture until it is flat against the underlying asphalt mat.
3. Using a small square tipped shovel or scoop, or both, carefully remove all the asphalt mixture from inside of the cutter and place in a sample container.
4. Remove the cutter from the roadway. The hole made from the sampling must be filled by the contractor with loose asphalt mixture.

Stockpiles

Remove at least 0.1 m (4 in.) from the surface before sampling; mixtures in a stockpile may develop an oxidized crust.

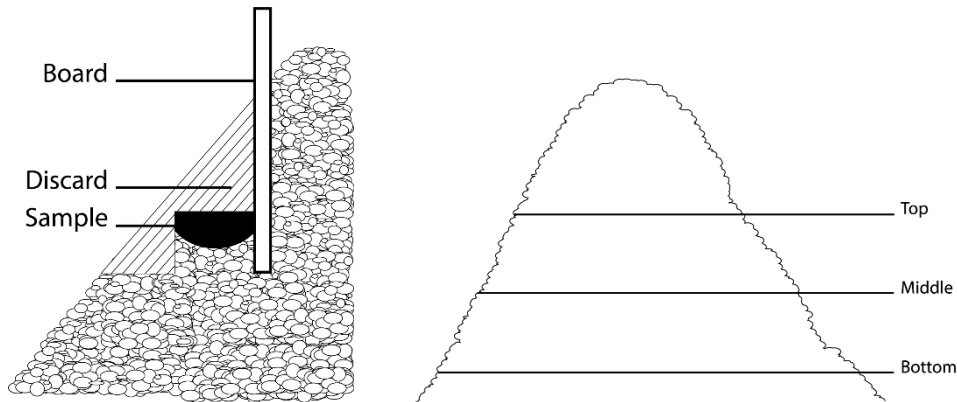
Method 1 – Loader

1. Direct the loader operator to enter the stockpile with the bucket at least 0.3 m (1 ft) above ground level without contaminating the stockpile.
2. Obtain a full loader bucket of the asphalt mixture; tilt the bucket back and up.
3. Form a small sampling pile at the base of the stockpile by gently rolling the asphalt mixture out of the bucket with the bucket just high enough to permit free-flow of the mixture. Repeat as necessary.
4. Create a flat surface by having the loader "back-drag" the small pile.

5. Obtain approximately equal increments from at least three randomly selected locations on the flat surface at least 0.3 m (1 ft) from the edge.
6. Fully insert the shovel, exclude the underlying material, roll back the shovel and lift the asphalt mixture slowly out of the pile to avoid mixture rolling off the shovel.
7. Combine the increments to form a sample.

Method 2 – Stockpile Face

1. Create horizontal surfaces with vertical faces in the top, middle, and bottom third of the stockpile with a shovel or a loader if one is available.
2. Shove a flat board against the vertical face behind the sampling location to prevent sloughing of asphalt mixture. Discard the sloughed mixture to create the horizontal surface.
3. Obtain the sample from the horizontal surface as close as possible to the intersection of the horizontal and vertical faces.
4. Obtain at least one sample increment of equal size from each of the top, middle, and bottom thirds of the pile.
5. Combine the increments to form a single sample.



Identification and Shipping

1. Identify sample containers as required by the agency.
2. Ship samples in containers that will prevent loss, contamination, or damage.

Report

- On forms approved by the agency
- Sample ID
- Date
- Time
- Location
- Quantity represented



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October 31, 2022

To: All Holders of the Manual of Field Test Procedures

Section: **Test Procedure AASHTO R 100**

The Oregon Department of Transportation has specified method(s) for this Test Procedure. Please observe the following for our projects:

- **Under Procedure - Initial Curing, Use Method 1, cure in a cooler with controlled water temperature. See test procedure for temperature requirements.**
- **Use a high/low temperature-recording device to monitor the water temperature during curing process. Record the high/low temperature range during the cure process on agency approved form.**
- **Under Procedure - Transporting Specimens, Delete Bullet 4 and replace with the following:**
 - **For concrete cylinders that are not able to be placed in final cure at the site where the compression testing will be performed, within 48 hours, a “temporary final cure” environment will be provided and maintained. Cylinders placed into this “temporary final cure” environment will then be transported to the final cure location within 12 days of casting. Temporary final cure is defined as;**
 - **Temporary final cure –An environment that meets the temperature and moisture requirements of bullet 2 under “Final Curing” of AASHTO T23. Curing may be accomplished in a moist room or water tank conforming to AASHTO M201. Molds do not have to be removed for Cylinders in Temporary final cure**
- **Under Procedure for Making Cylinders—Rodding step 3, the use of a mallet meeting the requirements under apparatus may be used for single-use plastic molds conforming to AASHTO M-205.**

METHOD OF MAKING AND CURING CONCRETE TEST SPECIMENS IN THE FIELD FOP FOR AASHTO R 100

Scope

This practice covers the method for making, initially curing, and transporting concrete test specimens in the field in accordance with AASHTO R 100-22.

Warning—Fresh Hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.

Apparatus

- Concrete cylinder molds: Conforming to AASHTO M 205 with a length equal to twice the diameter. Standard specimens shall be 150 mm (6 in.) by 300 mm (12 in.) cylinders. Mold diameter must be at least three times the maximum aggregate size unless wet sieving is conducted according to the FOP for WAQTC TM 2. Agency specifications may allow cylinder molds of 100 mm (4 in.) by 200 mm (8 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.).
- Beam molds: Rectangular in shape with ends and sides at right angles to each other. Must be sufficiently rigid to resist warpage. Surfaces must be smooth. Molds shall produce length no more than 1.6 mm (1/16 in.) shorter than that required (greater length is allowed). Maximum variation from nominal cross section shall not exceed 3.2 mm (1/8 in.). Ratio of width to depth may not exceed 1:5; the smaller dimension must be at least 3 times the maximum aggregate size. Standard beam molds shall result in specimens having width and depth of not less than 150 mm (6 in.). Agency specifications may allow beam molds of 100 mm (4 in.) by 100 mm (4 in.) when the nominal maximum aggregate size does not exceed 25 mm (1 in.). Specimens shall be cast and hardened with the long axes horizontal.
- Standard tamping rod: 16 mm (5/8 in.) in diameter and 400 mm (16 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 150 mm (6 in.) x 300 mm (12 in.) cylinders.
- Small tamping rod: 10 mm (3/8 in.) diameter and 305 mm (12 in.) to 600 mm (24 in.) long, having a hemispherical tip of the same diameter as the rod for preparing 100 mm (4 in.) x 200 mm (8 in.) cylinders.
- Vibrator: At least 9000 vibrations per minute, with a diameter no more than 1/4 the diameter or width of the mold and at least 75 mm (3 in.) longer than the section being vibrated.
- Scoop: a receptacle of appropriate size so that each representative increment of the concrete sample can be placed in the container without spillage.
- Trowel or float

- Mallet: With a rubber or rawhide head having a mass of 0.57 ± 0.23 kg (1.25 ± 0.5 lb.).
- Rigid base plates and cover plates: may be metal, glass, or plywood.
- Initial curing facilities: Temperature-controlled curing box or enclosure capable of maintaining the required range of 16 to 27°C (60 to 80°F) during the entire initial curing period (for concrete with compressive strength of 40 Mpa (6000 psi) or more, the temperature shall be 20 to 26°C (68 to 78°F). As an alternative, sand or earth for initial cylinder protection may be used provided that the required temperature range is maintained, and the specimens are not damaged.
- Thermometer: Capable of registering both maximum and minimum temperatures during the initial cure meeting the requirements for FOP for AASHTO T 309.

Procedure – Making Specimens – General

1. Obtain the sample according to the FOP for WAQTC TM 2.
2. Wet Sieving per the FOP for WAQTC TM 2 is required for 150 mm (6 in.) diameter specimens containing aggregate with a nominal maximum size greater than 50 mm (2 in.); screen the sample over the 50 mm (2 in.) sieve.
3. Remix the sample after transporting to testing location.
4. Begin making specimens within 15 minutes of obtaining the sample.
5. Set molds upright on a level, rigid base in a location free from vibration and relatively close to where they will be stored.
6. Fill molds in the required number of layers, attempting to slightly overfill the mold on the final layer. Add or remove concrete before completion of consolidation to avoid a deficiency or excess of concrete.
7. There are two methods of consolidating the concrete – rodding and internal vibration. If the slump is greater than 25 mm (1 in.), consolidation may be by rodding or vibration. When the slump is 25 mm (1 in.) or less, consolidate the sample by internal vibration. Agency specifications may dictate when rodding or vibration will be used.

Procedure – Making Cylinders –Self-Consolidating Concrete

1. Use the scoop to slightly overfill the mold. Evenly distribute the concrete in a circular motion around the inner perimeter of the mold.
2. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
3. Immediately begin initial curing.

Procedure – Making Cylinders – Rodding

1. For the standard 150 mm (6 in.) by 300 mm (12 in.) specimen, fill each mold in three approximately equal layers, moving the scoop or trowel around the perimeter of the mold to evenly distribute the concrete. For the 100 mm (4 in.) by 200 mm (8 in.) specimen, fill the mold in two layers. When filling the final layer, slightly overfill the mold.
2. Consolidate each layer with 25 strokes of the appropriate tamping rod, using the rounded end. Distribute strokes evenly over the cross section of the concrete. Rod the first layer throughout its depth without forcibly hitting the bottom. For subsequent layers, rod the layer throughout its depth penetrating approximately 25 mm (1 in.) into the underlying layer.
3. After rodding each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Making Cylinders – Internal Vibration

1. Fill the mold in two layers.
2. Insert the vibrator at the required number of different points for each layer (two points for 150 mm (6 in.) diameter cylinders; one point for 100 mm (4 in.) diameter cylinders). When vibrating the bottom layer, do not let the vibrator touch the bottom or sides of the mold. When vibrating the top layer, the vibrator shall penetrate into the underlying layer approximately 25 mm (1 in.)
3. Remove the vibrator slowly, so that no large air pockets are left in the material.

Note 1: Continue vibration only long enough to achieve proper consolidation of the concrete. Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

4. After vibrating each layer, tap the sides of each mold 10 to 15 times with the mallet (reusable steel molds) or lightly with the open hand (single-use light-gauge molds).
5. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
6. Immediately begin initial curing.

Procedure – Making Flexural Beams – Rodding

1. Fill the mold in two approximately equal layers with the second layer slightly overfilling the mold.
2. Consolidate each layer with the tamping rod once for every 1300 mm² (2 in²) using the rounded end. Rod each layer throughout its depth, taking care to not forcibly strike the bottom of the mold when compacting the first layer. Rod the second layer throughout its depth, penetrating approximately 25 mm (1 in.) into the lower layer.

3. After rodding each layer, strike the mold 10 to 15 times with the mallet and spade along the sides and end using a trowel.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Making Flexural Beams – Vibration

1. Fill the mold to overflowing in one layer.
2. Consolidate the concrete by inserting the vibrator vertically along the centerline at intervals not exceeding 150 mm (6 in.). Take care to not over-vibrate and withdraw the vibrator slowly to avoid large voids. Do not contact the bottom or sides of the mold with the vibrator.
3. After vibrating, strike the mold 10 to 15 times with the mallet.
4. Strike off the surface of the molds with tamping rod, straightedge, float, or trowel.
5. Immediately begin initial curing.

Procedure – Initial Curing

- When moving cylinder specimens made with single use molds support the bottom of the mold with trowel, hand, or other device.
- For initial curing of cylinders, there are two methods, use of which depends on the agency. In both methods, the curing place must be firm, within $\frac{1}{4}$ in. of a level surface, and free from vibrations or other disturbances.
- Maintain initial curing temperature:
 - 16 to 27°C (60 to 80°F) for concrete with design strength up to 40 Mpa (6000 psi).
 - 20 to 26°C (68 to 78°F) for concrete with design strength of 40 Mpa (6000 psi) or more.
- Prevent loss of moisture.

Method 1 – Initial cure in a temperature-controlled chest-type curing box

1. Finish the cylinder using the tamping rod, straightedge, float, or trowel. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).
2. Place the mold in the curing box. When lifting light-gauge molds be careful to avoid distortion (support the bottom, avoid squeezing the sides).
3. Place the lid on the mold to prevent moisture loss.
4. Mark the necessary identification data on the cylinder mold and lid.

Method 2 – Initial cure by burying in earth or by using a curing box over the cylinder

Note 2: This procedure may not be the preferred method of initial curing due to problems in maintaining the required range of temperature.

1. Move the cylinder with excess concrete to the initial curing location.
2. Mark the necessary identification data on the cylinder mold and lid.
3. Place the cylinder on level sand or earth, or on a board, and pile sand or earth around the cylinder to within 50 mm (2 in.) of the top.
4. Finish the cylinder using the tamping rod, straightedge, float, or trowel. Use a sawing motion across the top of the mold. The finished surface shall be flat with no projections or depressions greater than 3.2 mm (1/8 in.).
5. If required by the agency, place a cover plate on top of the cylinder and leave it in place for the duration of the curing period, or place the lid on the mold to prevent moisture loss.

Procedure – Transporting Specimens

- Initially cure the specimens for 24 to 48 hours. Transport specimens to the laboratory for final cure. Specimen identity will be noted along with the date and time the specimen was made and the maximum and minimum temperatures registered during the initial cure.
- Protect specimens from jarring, extreme changes in temperature, freezing, or moisture loss during transport.
- Secure cylinders so that the axis is vertical.
- Do not exceed 4 hours transportation time.

Final Curing

- Upon receiving cylinders at the laboratory, remove the cylinder from the mold and apply the appropriate identification.
- For all specimens (cylinders or beams), final curing must be started within 30 minutes of mold removal. Temperature shall be maintained at $23^{\circ} \pm 2^{\circ}\text{C}$ ($73 \pm 3^{\circ}\text{F}$). Free moisture must be present on the surfaces of the specimens during the entire curing period. Curing may be accomplished in a moist room or water tank conforming to AASHTO M 201.
- For cylinders, during the final 3 hours before testing the temperature requirement may be waived, but free moisture must be maintained on specimen surfaces at all times until tested and ambient temperature is between 20 to 30°C (68 to 80°F).
- Final curing of beams must include immersion in lime-saturated water for at least 20 hours before testing.

Report

- On forms approved by the agency
- Pertinent placement information for identification of project, element(s) represented, etc.
- Sample ID
- Date and time molded.
- Test ages.
- Slump, air content, and density.
- Temperature (concrete, initial cure max. and min., and ambient).
- Method of initial curing.
- Other information as required by agency, such as: concrete supplier, truck number, invoice number, water added, etc.